



ISD2014 Croatia

Vjeran Strahonja, Neven Vrček, Dijana Plantak Vukovac,
Chris Barry, Michael Lang, Henry Linger, Christoph Schneider
Editors

Information Systems Development: Transforming Organisations and Society through Information Systems

Proceedings of the 23rd International Conference
on Information Systems Development
(ISD2014 Croatia)

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Preface

This publication is the outcome of the 23rd International Conference on Information Systems Development (ISD2014 Croatia) that was hosted by the University of Zagreb, Faculty of Organization and Informatics (FOI), in Varaždin, Croatia, during September 2-4, 2014.

It was a great honour for us to organise the ISD conference, held for the first time in Croatia. We approached the organisation with a lot of enthusiasm and new ideas how to maintain the high quality standards of the conference set by the previous ISD organisers and the International Steering Committee. In spite of recession that took place in the last few years in Europe and especially in Croatia, we are proud that some improvements in marketing and careful planning of the conference have attracted 198 authors from 31 countries to submit 91 papers, representing an increase over the number of submissions received by previous conferences in the ISD series in recent years.

The theme of the conference was "Transforming Organisations and Society through Information Systems", in order to emphasize the changing nature of real-life environments where information systems play a significant role. The conference promoted research of theoretical and methodological issues as well as ways in which IS designers and developers are transforming organisations and society through information systems.

All papers submitted to the ISD2014 conference have been rigorously double-blind, peer reviewed by 2 or 3 reviewers (a total of 263 review reports were submitted, corresponding to an average of 2.9 reviews per paper), resulting in 50 papers that were accepted to be prepared for camera-ready version. After the second part of review process (meta-reviews done by the conference track chairs), 46 papers were accepted for presentation and publication, giving the conference acceptance rate of 50.5%.

In total, 82 delegates from 21 different countries registered for the conference, making it a truly international event. Over the course of 3 days, 15 sessions were held, covering a range of areas such as information systems for reshaping information society and organisations, information systems development for education and education for information systems development, ubiquitous computing, web-based systems development, mobile systems and applications development, model-driven development and concepts, information systems development in enterprise content management and general concepts related to ISD methodologies, project management and other topics.

This proceedings volume contains all papers scheduled for presentation at ISD2014 conference including one keynote address. Papers are grouped by conference tracks and organised by the order of the conference sessions. While all the accepted papers were of high quality, we have selected two of them to share the *Best Paper Award*. The first one is "Supporting Organizational Agility in a Software Company through Boundary Spanning and Knowledge Brokering" by Christoph Rosenkranz and Karlheinz Kautz. The second one is "The Mindfulness and Mindlessness in Mobile Business Intelligence Adoption" by Olgerta Tona and Sven Carlsson.

While we acknowledge the quality of aforementioned papers, our gratitude is extended firstly to all those who attended and authored work for the conference. Furthermore, a big thanks goes to the International Program Committee whose extensive and constructive

feedback on the papers was invaluable. Track chairs have demonstrated a great commitment to the conference while doing vital work to select the best papers for presentation and publishing, for which we are deeply grateful. Our sincere thanks are also extended to Prof. Marite Kirkova from Riga Technical University, Latvia, and Prof. Ivica Crnković from Mälardalen University, Sweden, who delivered the keynote addresses.

Last but not least, a special thanks goes to all people directly included in the organisation of the conference: to our local Organising Committee for volunteering, suggesting improvements and doing all behind-the-scene work; to International Steering Committee for guidance and helpful insights; to our sponsors for their financial support and other aid. However, without institutional support it would be impossible to organise this conference, so we extend our gratitude to the University of Zagreb and all FOI's services, staff and students included in preparation of this event.

We hope that all of you will find the scientific programme of ISD2014 Croatia to be interesting and beneficial to your research.

Varaždin, September 2014

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Conference Organisation

The 23th International Conference on Information Systems Development was hosted by the Faculty of Organization and Informatics (FOI), Varaždin, University of Zagreb, Croatia, from 2 to 4 September 2014. The organisation and management of such a major international conference requires the collaboration and dedication of very many people. We are especially grateful to our international programme committee who voluntarily gave their time to review the submissions. The excellent standard of papers contained within this publication bears testimony to the diligence and rigour of the peer review process. We are also very appreciative of the efforts of all the committee and the tremendous support provided by the local organising committee.

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From Variability to Viability

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Abstract

Socially and industrially globalized environment generates the need for flexibility of enterprises acting, cooperating and preserving their identity in various value and supply chains and socio-technical ecosystems. Achieving required flexibility, ability to cooperate, and ability to care for enterprise identity is possible via use of information systems that can provide a high level of variability of systemically organized information services. The points of variation may reside in types of information provided, in information, data, software, hardware, and network architectures, systems development methods, and in types of chosen information sources in enterprises and their environment. Vigorous models are needed to handle the variability in enterprises in general and in information systems in particular. St. Beer's Viable Systems Model known in organizational cybernetics is one of the candidates for handling and utilizing the variability to achieve enterprise viability via viable information systems.

Keywords: Variability, Enterprise, Information System, Viable Systems Model.

1. Introduction

Socially and industrially globalized environment generates the need for flexibility of enterprises acting, cooperating, and maintaining their identity in various value and supply chains and socio-technical ecosystems. Achieving required flexibility, ability to cooperate, and ability to care for enterprise identity is possible via use of information systems that can provide a high level of variability of systemically organized information services.

The need for variability of services depends on variation points that may be discovered by looking at the enterprise from different viewpoints at different levels of detail. The following issues can be considered regarding the variation points in [1], [2]:

- enterprise operational contexts or environment
- enterprise and systems development goals
- business or production processes
- information sources and information users
- data, information, software, hardware, and network architectures
- types of systems development methods

The variation points have to be carefully analyzed when changes are introduced due to external and internal factors influencing strategies, goals, and activities of enterprises. Therefore vigorous models are needed to handle the variability in enterprises in general and in information systems in particular.

2. Managing Variability

St. Beer's Viable Systems Model known in organizational cybernetics, if applied from enterprise and information systems perspectives, is one of the candidates for handling and utilizing the variability to achieve enterprise viability via viable information systems [3], [4]. This model has a potential to balance standardization and openness to changes via its fractal organization of subsystems at the level of organizational processes. Viable Systems Model combined with contemporary enterprise architecture analysis methods can be used as a

framework for continuous acquisition of information systems requirements [5] and analyzing their completeness and consistency according to the changes that can be introduced by external or internal organizational factors such as changes in regulations, changes in strategies, changes in human resource policy, changes in technologies and other issues. In Viable Systems Model the ideas for handling variability with respect to external environment are rooted in the law of requisite variety stated by W. R. Ashby [6]. The law states that the larger the variety of actions available to a control system, the larger the variety of perturbations it is able to compensate. Or in other words: the quantity of variety that the model system or controller possesses provides an upper bound for the quantity of variety that can be controlled or modeled [7]. Thus the law implies that the degree of control of a system is proportional to the amount of information available [8]. The application of the Ashby's law has become more realistic with supercomputing, high network throughput, and development of new methods of business intelligence that can monitor physical and social events and provide statistical and predictive data about expected and unexpected changes in the enterprise environment and promote use of larger scope of actions by decision makers.

The Viable Systems Model gives an opportunity to flexibly change the borders of enterprises and see them as individual entities, the members of supply and value chains as well as parts of organizational ecosystems [9]. When using powerful models of enterprises, the information systems models should be capable to represent information demands and flows at different levels of detail and for different combinations of data and information providers and consumers. Specific enterprise architecture patterns [10] can be utilized to model and analyze information flows between physical and virtual information processing nodes in the enterprise. These enterprise architecture patterns can reflect active enterprise architecture elements such as roles and actors, software systems, and hardware; as well as passive enterprise elements such as business objects, data objects, and artifacts at the technology level; as well as behavioral elements of the enterprise such as process or functions.

3. Conclusion

Using the architecture patterns, Viable Systems Model, and specific models for representation of variety it is possible to take into consideration whether the information processing is to be done manually, automatically, or semi automatically and support, configure, or orchestrate information processes and services at different levels of abstraction and detail and from different viewpoints or perspectives. Both predictive and adaptive approaches of information systems development can be utilized when handling variability via use of principles prescribed by Viable Systems Model. These principles enable the use of well known and innovative systems analysis and design methods at a higher capacity by considering different variation points relevant in enterprises and their information systems as well as by imposing needed variability in the process of information system and service development through supporting different levels of rigidity of artifacts and different frequency and length of information systems development cycles performed by internal or outsourced information systems development teams.

References

1. Berger, Th, Pfeiffer, R-H, Tartler, R, Dienst, St., Czarneck Krz, Wąsowski A, She St.: Variability mechanisms in software ecosystems, Original Research Article Information and Software Technology, In Press (2014)
2. Thorn, Ch. and Sandkuhl, K: Feature Modeling: Managing variability in complex systems. In: Tolk, A., Jain L.C. (eds.): Comp. Sys. in Knowledge-based Environments, SCI 168, pp. 129-161, Springer (2009)
3. Espejo, R., Reyes A.: Organizational Systems. Managing Complexity with the Viable System Model, Springer (2011)

4. Rios, J. P.: Design and Diagnosis for Sustainable Organization, Springer, (2012)
5. Kirikova, M.: Viable Systems Model based requirements engineering. In: Penzenstadler, B., Persson, A, Herrmann, A., Daneva, M., Doerr J., Hoffmann, A., Schneider, K., Kalenborn, A. Trapp, M. Wieringa R., Berry, D. M., Franch, X., Ralyté, J., Wnuk, Krz., Gervasi, V. (eds.) Proceedings of REFSQ-2014 Workshops, Doctoral Symposium, Empirical Track, and Posters, co-located with the 20th International Conference on Requirements Engineering: Foundation for Software Quality (REFSQ 2014), Essen, Germany, April 7-10, Vol. 1138, pp. 143-144 CEUR-WS.org (2014)
6. Ashby, W.R.: Requisite variety and its implications for the control of complex systems, *Cybernetica* 1:2, pp. 83-99 (1958)
7. Principa Cybernetica Web, available at <http://pespmc1.vub.ac.be/REQVAR.html>
8. Requisite Variety, available at <http://firstlaw.wordpress.com/2011/10/18/ashbys-law>
9. Kirikova, M., Pudane, M.: Viable Systems Model based information flows. In: Catania, B., Cerquitelli, T., Chiusano, S., Guerrini, G., Kämpf, M., Kemper, A., Novikov, B., Palpanas, T., Pokorný, J., Vakali A. (eds.) ADBIS 2013 - 17th East-European Conference on Advances in Databases and Information System. Genoa, Italy, September 1-4, 2013. Springer, New Trends in Databases and Information Systems. Advances in Intelligent Systems and Computing, Volume 241, Part 1, pp. 97-104, Springer (2014)
10. Rudzajs, P., Kirikova, M.: Service functioning mode in variability model, In: Salinesi, C., Pastor, O. (eds.) Advanced Information Systems Engineering Workshops, Lecture Notes in Business Information Processing Vol. 178, pp. 124-135, Springer (2014)

Challenges in Education in Global Software Engineering: What Are the Problems in Communication Mismatches, and How to Ensure Information Consistency?

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Abstract

This talk presents needs, challenges and experience of education of Global Software engineering. In Global Software Development the developers and other stakeholders are acting in a distributed environment, with different contexts and with different assumptions. This usually causes different understanding of the same information and different reactions of the stakeholders which may lead to different problems during the development process. What can be done to avoid these problems? This talk addresses these questions through an analysis of education for distributed development, performed in a distributed environment. In particular, experiences from a course "Distributed Software Development" (DSD) will be discussed. DSD course was organized and performed between the School for Innovation, Design and Engineering at Mälardalen University (MDH), Sweden, the University of Zagreb, Faculty of Electrical Engineering and Computing (FER), Croatia, and partially joined by the Politecnico di Milano, Italy. The talk will discuss the challenges in creating and performing a joint DSD course due to misunderstanding of information and the solutions implemented at DSD, lessons learned, and success stories.

Keywords: Education in Global Software Engineering, Distributed Environment.

Extended Abstract

A strong trend of globalization is in particular visible in ICT. ICT is the main enabler of all activities that spread all over the world. This also has consequences on education – young people should not only be prepared for technical & professional tasks but also to perform them in a distributed, geographically dispersed, and culturally diverse environment. Training students to act in a distributed multicultural environment is a new very important initiative, and a form of such education is becoming an obligatory part in ICT curricula. Education in distributed environment suffers however from low experience how to manage interactions between the actors (the students, the teaching staff, administration), laws, legacy issues, and cultural differences.

One of emerging education initiative is Education in Global Software Engineering (GSE). GSE is also emerging trend in software development: Development of software systems and software-intensive systems in a global environment, distributed through all continents. Education in GSE is even more challenging than education in Software Engineering. In addition to "real industrial problems" simulation, where sufficiently complex problems (still solvable with a reasonable amount of efforts) should be given, GSE education also requires appropriate simulation of a distributed environment. Experience in GSE shows that the successful performance in GSE context requires specific skills beyond the technical expertise. In GSE the developers and other stakeholders are acting in a distributed environment, with different contexts and with different assumptions. This usually causes different understanding of the same information and different reactions of the stakeholders which may lead to different problems during the development process. What can be done to avoid these problems? These challenges than should be addressed in education. The best way is to perform the training in a real distributed environment, having geographically separated students, as well as teaching

staff, performing a development project that student experience directly the challenges , they are supposed to trained to.

This talk presents needs, challenges and experience of Education of Global Software engineering. This talk addresses these questions through an analysis of education for distributed development, performed in a distributed environment. In particular, experiences from a course "Distributed Software Development" (DSD) will be discussed. DSD course was organized and performed during more than 10 years between the School for Innovation, Design and Engineering at Mälardalen University (MDH), Sweden, the University of Zagreb, Faculty of Electrical Engineering and Computing (FER), Croatia, and partially joined by the Politecnico di Milano, Italy. The talk will discuss the challenges in creating and performing a joint DSD course due to misunderstanding of information and the solutions implemented at DSD, lessons learned, and success stories. The talk will cover the following topics: a) providing and understanding information in a distributed environment: the challenges are two folded – first the information is limited both contents-wise and amount-wise, second the semantics of the information can be quite different; b) managing communication: both technical and cultural aspects are of crucial importance, and c) organizational aspects: the project organization and development models used in a distributed environment play a crucial role for a successful implementation.

Towards a Business Process Quality Culture: From High-Level Guidelines to Grassroots Actions

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Abstract

We present an information systems development (ISD) approach to integrate quality culture in business processes. Action research is our mode of inquiry and a company from the food industry provides the setting. Food production involves auditing throughout the supply chain and a demanding information system, with numerous goals and rules grounded on the organizational policies and values. However, there is a lack of holistic process-oriented approaches to leverage a quality culture. This paper provides a contribution, with the ISO₂ approach, offering a set of artifacts to support the ISD lifecycle. An audit from a food retail group confirmed the positive outcome of its use, internalizing quality principles while developing the IS, and it is planning to suggest its adoption by their network of food suppliers.

Keywords: Business Process Quality Culture, Information Systems, Quality, Synergies.

1. Introduction

Information systems (IS) development (ISD) takes place in regulated environments, influenced by organizational culture [6, 9]. In turn, ISD has an increasing influence on work practices and their underlying business processes [20]. When the processes are critical, a complex range of policies defines the regulatory space [5]. That is the case of the food sector, one of the most important in the world economy. Moreover, the trust that consumers put in this industry depends on the quality of the processes and on the principles they embrace. One of the most popular standards for quality management is ISO 9001 [15], which is structured in eight principles that shape a quality culture [15, 19]: Customer focus; Leadership; Involvement of people; Process approach; System approach; Continual improvement; Factual approach to decision-making; and Mutually beneficial supplier relationships.

ISD must consider the context and the characteristics of the organization, namely its policies and procedures [9, 20]. Additionally, the IS has a significant impact on quality management and performance [22]. Yet, there are difficulties in the articulated development of the IS and of the quality management system (QMS), since organizations do not usually leverage the synergistic potential in combining their efforts [4]. Grounded on narrow perspectives, quality experts view the IS as mere support, while the IS experts view the QMS as a mere matter of compliance issues. For these reasons, the principles to implement a quality culture in the organization [19] are frequently underestimated in the design and run-time of the IS, when compared with operational requirements and rules of business processes.

This raises the question: “*How to create a business process quality culture?*” According to [6], organizational culture is a set of shared values that define the way in which a firm conducts its business. Therefore, a quality culture requires the combination of organizational culture and quality principles [6, 19]. The IS and the QMS require similar organizational cultures and may be combined for a cultural change [23]. Recent research points to the importance of combining culture and process management [25]. However, the literature does not provide approaches that

organizations can use to integrate quality culture with their processes, information, people, and IT. We argue that an approach named ISO₂ [4] can contribute to this purpose, while simultaneously addressing known difficulties with process management in quality systems [13]. Our work presents an action research cycle that extends the ISO₂ approach. The remainder of the paper is organized as follows. Section 2 establishes the background, describing the food industry context and the challenges for ISD. Next, we present our research approach. Section 4 details the action research project. The case reports to the joint development of the IS and QMS for the maintenance process of the organization, integrating quality principles from standards and policies. Finally, Section 5 presents the conclusions, the study limitations, and future work.

2. Background

2.1. Food Industry Setting: Regulatory Space and Quality Culture

According to [28], the regulatory space is a social space “*in which different regulatory schemes operate simultaneously [and] the state must compete for control of regulation with other regulatory entities*”. Therefore, private regulators, interest groups, customers, and distinct business experts also influence the regulatory space. Law may impose regulations, or they may be voluntary, when standards, policies, and norms are adopted.

There are popular standards in use in the food sector, for example, ISO 9001 [15], ISO 22000, International Food Standard (IFS), and British Retail Consortium Food Global Standard (BRC). ISO 9001 aims at the continuous improvement of business processes and implies a set of principles that shape the quality culture [6, 19]. ISO 22000 for food safety combines the key components of interactive communication, system management, prerequisite programs, and the principles of Hazard Analysis Critical Control Point. BRC was created in 1998 for UK retailers and manufacturers, while German, French, and Italian counterparts developed IFS. In a situation of multiple standards, some authors [17] outline three levels of integration: (1) “*compatibility with cross-references between parallel systems*”; (2) “*coordination of business processes*”; and (3) “*an organizational culture of learning, continuous improvements of performance and stakeholder involvement related to internal and external challenges*”. Quality requires transparency towards government entities, business partners, and the consumer society in general [30]. The food industry must provide information about “*what*” is done to achieve compliance, “*how*” they achieve it, and which values (“*why*”) are followed [21]. There is a need to create a quality culture in the entire organization [19], and the IS is critical to this effort [30], as explained in the next section.

2.2. Synergies of Information Systems and Quality Management Systems

Quality and regulatory compliance are well-known subjects in IS research. The literature addresses topics such as the compliance of business processes and services [24], requirements engineering [27], and auditing IS [18]. There are also contributions that provide automated approach for goal-modeling and reasoning [12], normative compliance [14], goal-process integration [8], and value modeling [26]. However, the majority of studies focus on the perspective of modeling and checking compliance, lacking the human behavior and the guidance to allow cooperation between different experts, technology independent.

Several authors have suggested synergies between the IS and the QMS. The IS and the QMS can be combined into an integrated approach that should leverage synergies from early stages of design [7], for example, by simultaneously developing the quality and IS plans [16]. The benefits of combining the systems are mutual, and must consider different phases of the development, as presented by [4] and [11]. Nevertheless, there are also problems: the need of an approach that is simple enough to be used simultaneously by IS and quality experts; the diversity of the legislation and standards; the pressure that continuous improvement represents to the IS in design and run-time; the need to translate the external requirements into internal practices; and the difficulty in evidencing regulatory compliance in audits, and statutory

reporting [1, 4]. ISD must deal with the issues of diversity, knowledge, and structure at distinct behavior levels; for example, the business, company, project, team, and the individual [9, 20]. Therefore, methodologies are vital for ISD and can be adapted or combined into specific situations [3]. The IS in the context of the food industry is a current concern. For example, [31] consider both the organizational and technical aspects for process management in food sector. Still, existing studies do not include a cultural quality perspective in business processes [19, 25], applicable for the entire ISD lifecycle.

3. Research Approach

We selected action research (AR) to study ISD and quality culture, since we were simultaneously aiming at improving the body of knowledge and solve a practical problem [10]. We have followed a canonical form of AR, characterized by five phases of *Diagnosing, Action planning, Action taking, Evaluating, and Specifying learning* [29]. To ensure rigor and validity, we have relied on the principles proposed by [10]. One of those principles is a frame of reference, for which we elected the ISO₂ approach. ISO₂ was originally proposed for the joint development of IS and QMS, in the context of ISO 9001. Table 1 describes the major steps of the approach.

Table 1. Summary of ISO₂ steps [4]

Step	Description
1	<i>Prepare the mindset:</i> Both systems must be entwined from the start. This step may contribute for the team coordination, management commitment and an awareness campaign;
2	<i>Diagnosis (as-is):</i> Identify current quality and IS practices, ISO 9001, and other contextual requirements. Define and assess the current processes from the users perspective;
3	<i>Define a Vision (ought-to-be):</i> Define quality and IS policies. Create the desired process map;
4	<i>Design (to-be):</i> Detail each process and indicators. Establish the plan and ISD objectives;
5	<i>Code the systems:</i> Develop the IT artifacts and the QMS documents;
6	<i>Deploy:</i> Implement the systems, train, internalize, transfer to daily practice;
7	<i>Evaluate:</i> Audit, test, validate, and perform user acceptance. Restart to improve.

Previous work with ISO₂ has focused on the artifacts to support the design stage. The result is a high-level blueprint of the five main ISD components: context; people; process; IT; and information/data. There are three core artifacts: the O₂ matrix; the O₂ artifact; and the O₂ map. The matrix identifies the information requirements for each process. Those requirements are then grouped in O₂ artifacts, which are IT artifacts. A layered map of the IS is obtained by connecting all the O₂ artifacts with the processes, regulations, and organizational functions. The work presented in Section 4 extends the ISO₂ approach, fostering a quality culture.

4. ISD Action: Towards a Business Process Quality Culture

4.1. Client-System Infrastructure

Our case reports to an agro-food organization with five lines of sauces and olive production. They export to pizza restaurant chains and supermarkets around the globe. Audits by customers, government bodies (e.g. FDA - Food and Drug Administration), and certification authorities are quite regular, at four times on average each month. The company adopted ISO 9001, IFS, BRC, and ISO 22000 standards. One of their major problems was managing the maintenance process of their industrial equipment. Records were scarce and the process should conform to the standards, laws, and their principles. To address this problem, a team of consultants was assisting the organization with the standards and another one was responsible for the ISD.

4.2. Diagnosing

According to the company's quality manager, "there is a gap between policies and processes (...) top level quality principles are translated into standards requirements that, in turn, direct our process information requirements. Ok, processes comply with requirements, but they should conform to the principles". She presents an example: "We comply with the complaints management requirement in commercial process, which is the 'rule' (...) [although] that does not mean that we are fully integrating customer focus principle in the process. A traditional process matrix links the requirements with clauses, not with the higher principles that truly matters". As stated by the quality manager, "people issues are our problem, not the technological ones (...) they know 'what' to do and 'how', but we want them to incorporate our values. People must understand the importance of the 'why', being aware that, across the globe, a child may be eating our product and laughing with their parents. Our work contributes to that moment success (...)". In this background, we understood that our action plan could not simply be a matter of compliance, or whether the IS and the QMS "violates or not a set of obligations". The ISD challenge was socio-technical, researching the *why!*

4.3. Action Planning

We outlined a plan with the steps of ISO₂, described in Table 1. The initial meetings aimed to present the approach to the managers and identify the IS and the QMS requirements. The steps 1 to 3 of ISO₂ were refined in previous action research cycles. Figure 1 presents an extract of the O₂ map for the maintenance process.

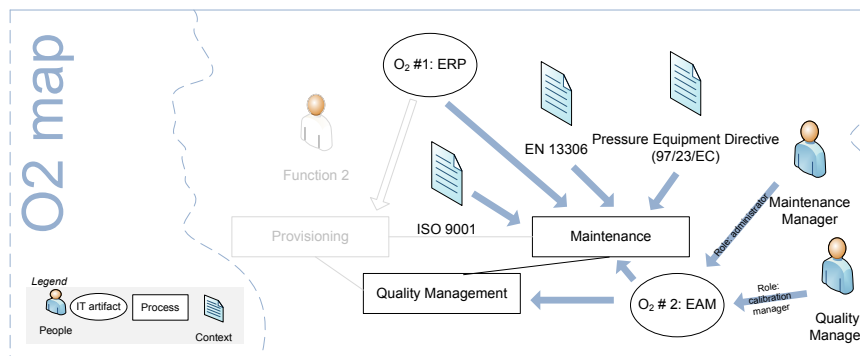


Fig. 1. O₂ map extract for the maintenance process at a high-level of abstraction.

The O₂ map can provide a simple portrait of which regulations affect the process, their users, and the IT artifacts that support them. In our case, there are two main IT systems to support the maintenance process – the Enterprise Resource Planning (ERP) and a new Enterprise Asset Management (EAM) system. Additional spreadsheets and desktop databases, specific laws and procedures were omitted to simplify the figure at the highest abstraction level. The map can be drilled-down by sub-levels of analysis; for example, the standard can be "zoomed" into goals and rules to comply, the process expanded into its sub-processes, and the O₂ artifacts detailed by their services, forms, or fields. After creating the map, the requirements for the maintenance process IS were obtained by the O₂ matrices [4]. ISO₂ required changes to fit our scenario, as we present in the next section.

4.4. Action Taking

This section summarizes the extension we made to ISO₂, by creating three additional artifacts to use in the ISD lifecycle, while solving the organizational problem. Figure 2 presents an extract of the first new artifact that is the *O₂ principles evaluation*.

Main Principle	General Description	Business Process Quality Culture
Customer focus	Organizations depend on their customers and therefore must understand their present and future needs, satisfy their requirements and make an effort to exceed their expectations.	Consider external and internal customers. External customer interest includes the safety of materials used in maintenance, avoiding food contamination. They may ask for maintenance evidences in case of product traceability. Maintenance must ensure that (...)
Factual approach to decision-making	Effective decisions are based on data analysis and information.	Maintenance IS quality must be measured and continuously improved. Records must ensure traceability and proper identification (...)
(...)	(...)	(...)
Ethics (company policies)	Our stakeholders must ensure transparency and a code of conduct that respect our tradition.	Materials and services acquisition must be decided after requesting proposals from at least three suppliers (...)
Sustainability (company policies)	Our activity must respect the environment and ensure energy optimization.	Maintenance must ensure the minimum waste in equipments. Suppliers must be identified for dangerous materials and their disposal (...)

Fig. 2. The *O₂ principles evaluation* for the maintenance process (excerpt).

The organization selected eight principles drawn from ISO 9001, and added other three, namely: safety, ethics, and sustainability. These are core values for their future, so they decided to evaluate them specifically (column 1). By creating the *O₂ principles evaluation*, the users perceive the process by the lens of the principles that they defend, as described in column 3. The second artifact, the *O₂ principles matrix*, is presented in Figure 3.

Maintenance Process		Outside-in	Within	Inside-out	
Customer focus	Current	✓Complaints that can have maintenance causes	✓Materials used in equipment maintenance	✓Provide information to the customer regarding the equipment safety (customer audits)	ISD goals and rules
	Planned	✓Regulatory product process and product constraints; ✓Universities and R&D institutes communication	✓Risk management;	✓Maintenance plan must be timely given to the production sector – integration with production plan ✓Integration with ERP stock management	
Sustainability	Current	✓ -	✓Reduce water consumption in cleaning tasks	✓Energy consumption report	
	Planned	✓Monitor energy consumption in all critical equipments	✓Increase the use of recycled materials in maintenance execution	✓Water consumption ✓Supply waste management reports to government entities	

Fig. 3. *O₂ principles matrix* (excerpt)

The *O₂ principles matrix* aims to identify the outside-in, within, and inside-out IS requirements (columns 3 to 4) related with quality principles (on the left). This matrix complements the original *O₂* matrix proposed in [4], which focused on operational requirements for the process. By combining the matrix cells into a new matrix, new goals and rules of the IS are added, and others that are redundant can be eliminated. Next, we generated the improvement plan with the *O₂ principles development checklist*. The purpose is to establish actions to implement the planned requirements of the *O₂ principles matrix*, to evaluate them and to improve. Figure 4 presents an example regarding the goal established in the second line of Figure 3, third column (inside-out).

Quality Principle	Goal/Rule Checklist	Process Owner *	Auditor*	Action	Action Stage
Customer focus	Maintenance plan must be timely given to the production sector	3	2	(A1) Integration between maintenance plan and ERP purchase plans	
				(A2) Develop a decision support system to simulate plan changes	

*evaluate from 1 (inexistent), 2 (weak), 3 (satisfactory), 4 (good), and 5 (very good)

Fig. 4. *O₂ principles development checklist* (excerpt)

The first column identifies the quality principle; the second describes the goal/rule for that principle. One principle may have several goals/rules. Since our purpose was also to perform an evaluation, we added two columns to compare the perspective of the process owner and that of the quality auditor (internal or external). The last two columns identify the improvement actions established for the IS and its development stage. Actions must be planned for each line that does not reach a grade of five. Each action is monitored considering the P-Plan, D-Do, C-Check, A-Act (PDCA) cycle [15]. The approach described above is now being applied to other processes in the company, besides the original maintenance process. The artifacts are created according to the following steps, for each business process:

1. Identify quality principles adoption to the process (*O₂ principles evaluation*);
2. Define outside-in, within, and inside-out information [4] required to develop the quality principle in the process (*O₂ principles matrix*);
3. Establish an improvement plan (*O₂ principles development checklist*);
4. Continuously revise the O₂ matrices and propose improvement actions.

4.5. Evaluating

The original ISO₂ approach could provide some support for user training, since part of the documents were software manuals and quality procedures. However, we did not have a quality culture perspective with the initial tools, justifying the new artifacts presented in Section 4.4. Interestingly, the use of the *O₂ principles matrix* allowed the identification of new ISD requirements that were missed when using the original O₂ matrix. There were two team meetings: first to apply the principles to the process and an initial draft of the *O₂ principles matrix*. A week later, the team refined the O₂ information. If we combine the information of the same lines of all process matrices, we can identify how the organization globally internalizes each principle. There is the potential of identifying processes that do not adhere to the policies and principles, as they should, or principles that are not addressed by the processes. This cannot be achieved with traditional matrices that are common to ISO 9001, mixing processes with standard clauses. The maintenance manager confirmed that the ISD meetings were effective for learning-by-doing, increasing process knowledge by process users, sensing their motivation, and perceiving effort/value to follow the process principles [2]. The evaluation made possible by the *O₂ principles development checklist* was used to produce different charts and indicators for the IS and the QMS. According to a major customer of the organization: “*the approach puts forward the company interest in improvement and their commitment with the policies they defend*”.

4.6. Specifying Learning

It is time to bring quality principles and values to development efforts. Although several standards and laws are built according to high-level principles that shape a quality culture, there is a risk of seeing those principles forgotten in daily practice. By including cultural aspects in a process-oriented approach, the findings suggest that we can increase the internalization of quality principles. The matrices provide auditing support, with the potential of diffusing the approach to other suppliers of the food chain. A customer of the firm suggested using the average evaluation of the *O₂ principles development checklist* to measure the quality principle internalization, comparing distinct processes. The crosscheck evaluation by process owners and auditors is an opportunity to contrast perspectives of improvement. It is difficult to connect generic principles such as “customer focus” and IS requirements, with specific goals/rules. With the proposed approach, we defy the process participants to think *why* their work is important, for them, for stakeholders, and ultimately for the society. Note that the extension that we introduced to ISO₂ is not specific to the food industry; however, this sector provides an example that can benefit from the approach due to its increasing need for transparency and quality culture in business processes.

5. Conclusions, Limitations, and Future Work

We challenged and extended the ISO₂ approach to bridge the gap between overall quality principles and business processes, within the ISD lifecycle. With the support of the O₂ artifacts, process users can collaborate in the joint design of the goals and rules of the IS and the QMS. At run-time, there is guidance to internalize quality culture in daily practice. Moreover, we gathered evidence during our research that ISO₂ approach presented benefits for interactive communication throughout the supply chain. The case company in the food industry asked us to create an “ISO₂ kit” that they could distribute to their partners and suppliers, representing a distinctive image of their process quality culture.

This study has limitations. First, the scope is restricted to specific standards, namely those used by this particular company in the food sector. Second, our contribution only addresses the quality culture dimension, according to a set of predefined principles selected by the organization. Cultural studies are complex and we did not consider individual or national culture aspects. Finally, in spite of the positive results that we observed for integrating cultural aspects in ISD, the approach still lacks a tool to support its expedite use by practitioners. Future work can also involve distinct sectors and larger scale scenarios, for example the aerospace, for which we already have planned interventions. It would be useful to extend our study with additional standards and models that have a great impact on the business processes and ISD; for example, the ones related with IT service management, IT governance, business continuity management, and human resource management. Moreover, it would be interesting to create a metamodel or ontology to formally define the cultural integration. The approach can be further tested by ISD and quality efforts of supply chains, in quest for trust and trustworthiness [21].

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References

1. Abdullah, N.S., Sadiq, S., Indulska, M.: Information systems research: Aligning to industry challenges in management of regulatory compliance. In: Proceedings of the 14th Pacific Asia Conference on Information Systems (PACIS 2010), Taipei. (2010)
2. Antunes, A., Cunha, P.R., Barata, J.: MUVE IT: Reduce the Friction in Business Processes. *Bus. Process Manag. J.* 20 (4), 571–597 (2014)
3. Avison, D., Fitzgerald, G.: Where now for development methodologies? *Commun. ACM.* 46 (1), 78–82 (2003)
4. Barata, J., Cunha, P.R.: ISO2: A New Breath for the Joint Development of IS and ISO 9001 Management Systems. In: Proceedings of the 22nd International Conference on Information Systems Development (ISD 2013), Seville. (2013)
5. Barata, J., Cunha, P.R.: Modeling the Organizational Regulatory Space: A Joint Design Approach. In: Grabis, J., Kirikova, M., Zdravkovic, J., and Stirna, J. (eds.) 6th IFIP WG 8.1, The Practice of Enterprise Modeling (PoEM 2013), LNBIP 165. pp. 206–220. Springer, Heidelberg (2013)
6. Barney, J.: Organizational culture: can it be a source of sustained competitive advantage? *Acad. Manag. Rev.* 11 (3), 656–665 (1986)
7. Bonazzi, R., Hussami, L., Pigneur, Y.: Compliance management is becoming a major issue in IS design. In: D’Atri, A. and Saccà, D. (eds.) Information Systems: People, Organizations, Institutions, and Technologies. pp. 391–398. Springer, Heidelberg (2010)
8. Cardoso, E., Jr, P.S.: Semantic integration of goal and business process modeling. In: IFIP International Conference on Research and Practical Issues of Enterprise Information Systems (CONFENIS 2010), Natal. (2010)
9. Curtis, B., Krasner, H., Iscoe, N.: A field study of the software design process for large systems. *Commun. ACM.* 31 (11), 1268–1287 (1988)

10. Davison, R., Martinsons, M.G., Kock, N.: Principles of canonical action research. *Inf. Syst. J.* 14 (1), 65–86 (2004)
11. Domínguez-Mayo, F.J., Escalona, M.J., Mejías, M., Ross, M., Staples, G.: A quality management based on the Quality Model life cycle. *Comput. Stand. Interfaces.* 34 (4), 396–412 (2012)
12. Giorgini, P., Mylopoulos, J.: Formal reasoning techniques for goal models. In: Spaccapietra, S., March, S., and Aberer, K. (eds.) *Journal on Data Semantics I*, LNCS 2800. pp. 1–20. Springer, Heidelberg (2003)
13. Iden, J.: Investigating process management in firms with quality systems: a multi-case study. *Bus. Process Manag. J.* 18 (1), 104–121 (2012)
14. Ingolfo, S., Siena, A., Susi, A., Perini, A., Mylopoulos, J.: Modeling laws with nomos 2. In: *Proceedings of the 6th International Workshop on Requirements Engineering and Law (RELAW 2013)*, Rio de Janeiro. pp. 69–71. IEEE (2013)
15. ISO: ISO 9001 Quality management system – Requirements. International Organization for Standardization, Geneva (2008)
16. Jabnoun, N., Sahraoui, S.: Enabling a TQM structure through Information Technology. *Compet. Rev. An Int. Bus. J. Inc. J. Glob. Compet.* 14 (1/2), 72–81 (2004)
17. Jørgensen, T.H., Remmen, A., Mellado, M.D.: Integrated management systems – three different levels of integration. *J. Clean. Prod.* 14 (8), 713–722 (2006)
18. Julisch, K., Suter, C., Woitalla, T., Zimmermann, O.: Compliance by design – Bridging the chasm between auditors and IT architects. *Comput. Secur.* 30 (6-7), 410–426 (2011)
19. Kanji, G.K., Yui, H.: Total quality culture. *Total Qual. Manag.* 8 (6), 417–428 (1997)
20. Kautz, K., Madsen, S., Nørbjerg, J.: Persistent problems and practices in information systems development. *Inf. Syst. J.* 17 (3), 217–239 (2007)
21. Meijboom, F., Visak, T., Brom, F.: From Trust to Trustworthiness: Why Information is not Enough in the Food Sector. *J. Agric. Environ. Ethics.* 19 (5), 427–442 (2006)
22. Perez-Arostegui, M.N., Benitez-Amado, J., Tamayo-Torres, J.: Information technology-enabled quality performance: an exploratory study. *Ind. Manag. Data Syst.* 112 (3), 502–518 (2012)
23. Philip, G., McKeown, I.: Business Transformation and Organizational Culture: The Role of Competency, IS and TQM. *Eur. Manag. J.* 22 (6), 624–636 (2004)
24. Sadiq, S., Governatori, G.: Managing Regulatory Compliance in Business Processes. In: Vom Brocke, J. and Rosemann, M. (eds.) *Handbook of Business Process Management 2*. pp. 157–173. Springer, Heidelberg (2010)
25. Schmiedel, T., vom Brocke, J., Recker, J.: Development and validation of an instrument to measure organizational cultures’ support of Business Process Management. *Inf. Manag.* 51 (1), 43–56 (2014)
26. Schuster, R., Motal, T.: From e3-value to REA: Modeling Multi-party E-business Collaborations. In: *Proceedings of the IEEE Conference on Commerce and Enterprise Computing (CEC 2009)*, Vienna. pp. 202 – 208. IEEE (2009)
27. Sepideh Ghanavati, Amyot, D., Peyton, L., Siena, A., Perini, A., Susi, A.: Integrating business strategies with requirement models of legal compliance. *Int. J. Electron. Bus.* 8 (3), 260–280 (2010)
28. Shearing, C.: A Constitutive Conception of Regulation. In: Grabosky, P. and Braithwaite, J. (eds.) *Business Regulation and Australia’s Future*. pp. 67–79. A. Inst. Criminology (1993)
29. Susman, G.I., Evered, R.D.: An Assessment of the Scientific Merits of Action Research. *Adm. Sci. Q.* 23 (4), 582–603 (1978)
30. Trienekens, J.H., Wognum, P.M., Beulens, A.J.M., van der Vorst, J.G.A.J.: Transparency in complex dynamic food supply chains. *Adv. Eng. Informatics.* 26 (1), 55–65 (2012)
31. Wolfert, J., Verdouw, C.N., Verloop, C.M., Beulens, A.J.M.: Organizing information integration in agri-food—A method based on a service-oriented architecture and living lab approach. *Comput. Electron. Agric.* 70 (2), 389–405 (2010)

Mining Competences of Expert Estimators

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Abstract

This paper reports on a study conducted with intention to identify competences of employees engaged on software development projects that are responsible for reliable effort estimation. Execution of assigned project tasks engages different human characteristics and effort estimation is integral part of development process. Competences are defined as knowledge, skills and abilities required to perform job assignments. As input data we used company internal classification and collection of employee competences together with data sets of task effort estimates from ten projects executed in a department of the company specialized for development of IT solutions in telecom domain. Techniques used for modeling are proven data mining methods, the neural network and decision tree algorithms. Results provided mapping of competences to effort estimates and represent valuable knowledge discovery that can be used in practice for selection and evaluation of expert effort estimators.

Keywords: Effort Estimation, Competences, Data Mining, Neural Networks, Decision Trees.

1. Introduction

Knowledge about the skills and competences of employees is of supreme importance for company success [22]. It enables efficient employee selection and staffing during project initialization as well as support during offer preparation and project planning [4]. Efficient competence management across organization ensures competitive position and a way to increase workforce productivity. Likewise structured competence framework provides transparency over available competences within organization and targeted development of those that are important through trainings and certifications [7].

Effort estimation is important part of software project management. The reliable effort estimates ensure planned project execution and compliance with the set time and budget constraints. Despite the long term efforts to produce accurate estimates based on formal and analogy based estimation methods expert estimation remains the most widely used technique of effort estimation [11]. Several reasons have contributed to this: studies consistently report that formal methods in comparison to expert estimation fail to produce more accurate estimates [9], expert estimation is easy to implement and finally expert estimation is more flexible regarding the type and format of the information used to produce estimates [19].

In this study we investigate the relationship between experts competences and accuracy of their effort estimates. To figure out the relation between ones competences and success in effort estimation we have to apply methods of knowledge discovery. Data mining algorithms are such an example and as studies report software engineering can benefit from use of this approach [15], [23]. Data mining in terms of software engineering consists of collecting software engineering data, extracting knowledge and when possible using this knowledge to improve the software engineering process. In this study we use two data mining approaches: neural networks and decision trees.

The remaining part of this paper is organized as follows: section 2 quotes the related research in this area. Section 3 introduces the model of competences used in the study. Section 4 describes the design of study. Section 5 explains the experiment setup and modeling performed in study. In section 6 survey results and their implications are discussed. Section 7 gives the conclusion and directions for the future research.

2. Related Research

Organizations have always been concerned about the competences of their employees. Today in a knowledge-based economy the success of organization mostly depends on workforce competences and competent employees are their main resource [2]. Competences are the best predictors of job performance [18]. In the same way estimating effort and therefore time and costs in different phases of a project is particularly important as these form a base on which decisions are made. The problem is when these estimates are not prepared by competent estimators. The present knowledge of how experts competences affect estimation accuracy arouses research interests [6].

Competence is a combination of knowledge, skills and process abilities that are causally linked and provide a base for job performance [16]. In certain form they represent a company's resource that could be exploited to gain competitive advantage [20]. While human resource development literature is mostly concerned with development of highly transferable generic competences that are required for most jobs or roles, particular company management is often emphasizing competences that are unique and company specific.

There are different competence models, usually in a form of a hierarchical catalogue that describes those that are desirable for organization and particular role [14]. Models depend on approach used to classify competences and can be one-dimensional or multi-dimensional which today are de facto standard [16]. Organizations use specialized IT-based systems to support the strategic competence management process [8]. Our previous study confirmed employees experience and role on a project give a high level notion of one's ability to successfully perform effort estimation tasks [12]. When it comes to competences required to perform estimation tasks questions are still incompletely answered.

This study was conducted with the aim to identify competences of professional software engineers engaged on projects within the company and occupying different positions that are important in determining one's ability to produce accurate estimates of efforts required to perform certain project tasks. Insights gained through application of various advanced knowledge discovery techniques help software engineers improve their everyday work practice.

3. Competences

Competency models are used to align individual capabilities with the competence of organization. These models are viewed as descriptive tools to identify the skills, knowledge, personal characteristics and behaviors that are required to efficiently perform a job in the organization [17]. The relation between competences and performance is shown on Figure 1.

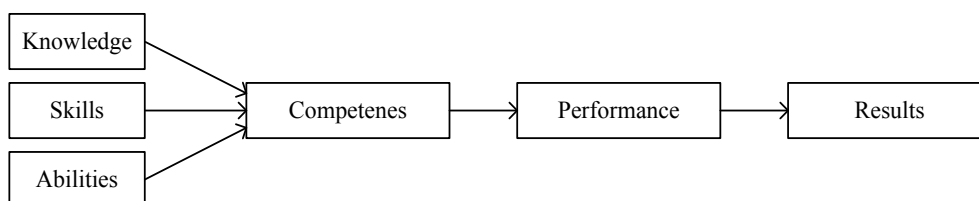


Fig. 1. Relation between competences and professional results.

A company competence model establishes a common language which allows better communication between project managers and employees as it defines job expectations. It can

also assist recruiting process where it can be used as some form of a guideline [13]. Knowing the skills, knowledge and abilities of employees allows better mapping of personnel to the company functions. For practical purposes of our study we are concerned with competences that a person working in a given occupational area should be able to do and demonstrate. Model of competences used by the company where study was performed covers tree segments: technical, professional and products and solutions competences. Each segment is further partitioned into sub-segments as it is shown in Table 1.

Table 1. Model of competences used in the study.

Segment	Competence	Description
Technical Competences	Operating Systems	Competence in use of operating systems
	Programming Languages	Competence in use of programming languages
	Development Environments	Competence in use of integrated development environments
	Database Systems	Competence in use of database management systems
	ALM Tools	Competence in use of application lifecycle management tools
	Project Process	Competence in application of different organization processes
Professional Competences	Development	Competence in different phases of software development process
	Operation and Maintenance	Competence in different operation and maintenance roles
	Project Types	Competence in various type of projects, current and past
	Role and Responsibility	Competence in relevant roles and responsibilities on projects, current and past
	Certifications	Level of certifications
Products and Solutions Competences	In-house Products and Solutions	Competence in development and use of in-house products and solutions
	Third Party Products and Solutions	Competence in development and use of third party products and solutions

It is important to note that in structured competence questionnaire used by the company to collect and store data each sub-segment represents an area that is further divided. For instance Programming Languages area specifically quotes languages in which skills are expected (C, C++, C#, Java, etc.) or Project Types area quotes current and past types of projects that employee possibly participated in (Maintenance, R&D, Product development, etc.).

The process of creating of competencies collection is organized the following way: initially the structured competencies questionnaire is created and distributed to all employees in the department. All employees have to fill the questionnaire and return it to responsible person. The method of estimation is therefore a self-assessment and competency in each specific area can be marked with levels noted in Table 2. Once all questionnaires are collected they are imported to central department competence database.

Table 2. Competence levels.

Level	Description
1 Initial	Performs routine tasks with supervision and guidance
2 Basic	Performs range of tasks, supervision is required for more complex tasks
3 Intermediate	Performs some complex and non-routine tasks, able to manage the subject without constant guidance, can oversee the work of others
4 Advanced	Performs a wide range of complex and non-routine tasks, can train others in this subject
5 Expert	Performs all tasks, applies a significant range of fundamental principles and techniques, has strategic view and can train others in this subject

4. Study Design

As it is mentioned the study was conducted in the Croatian branch of international company specialized for development of IT solutions used by a number of different telecom companies. This department has more than 50 employees occupying different positions of whom majority are software engineers responsible for software development and maintenance tasks on different projects. The solutions are developed using Microsoft technology stack (Team Foundation Server, Visual Studio, SQL Server, C#, etc.). In total 32 experts from 10 projects participated in study forming a set of 2090 items used for training and testing purposes. Details of projects included in study are displayed in Table 3.

Table 3. Details of projects included in study.

Project	Duration (months)	Development method	Team size	LOC ¹	Size ²	Precedentedness ³
1	20,40	Sequential	6	92.091	Small	True
2	26,66	Sequential	6	123.693	Small	True
3	34,15	Sequential	9	46.668	Small	False
4	31,90	Sequential	9	249.732	Medium	True
5	61,02	Sequential	12	457.745	Large	False
6	7,80	Sequential	12	167.644	Medium	True
7	27,11	Sequential	8	148.409	Small	True
8	17,01	Iterative	23	261.781	Large	False
9	34,94	Sequential	6	263.485	Large	True
10	66,37	Sequential	6	125.967	Small	True

¹ Size expressed in number of physical Lines of Code, calculated using LocMetrics tool (www.locmetrics.com)

² Company internal classification of project size (determined by financial indicators)

³ Parameter that indicated presence of similar projects already executed in department

The work is organized in teams consisting of a project manager, software developers and testers. Solution architects, quality and configuration managers are department functions and engage in projects at different phases. From selected projects profile competences of in total 32 employees were randomly selected for later analysis. Characteristics of this competence data set are the following: a) out of 32 profiles 29 were males and 3 were females, b) roles occupied by employees in data set are: 4 project managers, 3 solution architects, 18 developers, 3 testers, 3 quality managers and 1 configuration manager and c) regarding the position level there were 16 seniors, 14 advanced and 2 junior engineers.

4.1. Data Sources

From the above listed projects development task and employee competence data required for the research were collected using following sources:

- Application lifecycle management tool implemented on projects that support development process. In this case it primarily served as a central place for collection of work item data. For this purpose on all considered projects Microsoft Team Foundation Server was used. Advantage that this and similar tools offer is the capability of various forms of data presentation, manipulation and export.
- The estimators competence data were gathered during company internal assessment procedure performed by dedicated department functions. The data collection was organized in form of a structured questionnaire that each employee received, had to fill and return to department. The questionnaire covered different aspects of employee profile of which major part was concerned with professional competences that are required to perform every day engineering tasks.

For employees involved on projects, collected competence data were structured in appropriate form, this made the total of 32 estimator profiles that entered the analysis. Input variables that are used to represent estimators competence characteristics are logically

organized into segments as defined in Table 1. Data exported from tracking system contain both reference to an item owner (employee) and assigned efforts. This allowed two things: first, linking of an item to estimators competence profile and second, calculation of estimation error. As a measure of estimation error i.e. accuracy the magnitude of relative error is used, MRE [3]:

$$MRE = \frac{abs(actual\ effort - estimated\ effort)}{actual\ effort} \quad (1)$$

The MRE (1) is the most widely used measure of effort estimation accuracy [1], [5], [21], it is basically a degree of estimation error in an individual estimate.

4.2. Data Mining Approach

Building of the data mining model considered in this research required the definition of business objectives. In this case it is the identification of the expert estimators competences and their relative importance in producing reliable effort estimates. This business objective was mapped to data mining objective with intention to create such a model that could later be implemented in practice. Methodological framework consists of following phases:

- Data collection: during which both work item and employee competence data were collected. This stage therefore included export of project tasks, identification of involved team members and structuring of their competence data.
- Data preparation: at this stage data was processed according to specific needs of model building process. The end product is data set that contains efforts data of each item and related employee (item was assigned to). This way single resulting data set from all ten analysed projects was generated. At this stage outliers, extremes and missing data are handled.
- Data partitioning: input data is randomly divided into two segments, training and test sets. From the initial data set the ratio of 2/3 of the data is used for the training (building of a model) and 1/3 for the testing phase (assessing of model performance).
- Model building: during this phase the predictive models are built using a MLP neural network and C&R decision tree algorithms and evaluated for predictive performance.

5. Experiment Setup

In accordance with the data mining practice data was prepared to produce input set comprising the total of 2090 records corresponding to projects being analyzed. Variables considered in the input data sets are listed in Table 4:

Table 4. Predictors and target in input data set.

Segment	Variables	
	Name (Code)	Type
Technical Competences	Operating Systems (OPS), Programming Languages (PRO), Development Environments (IDE), Database Systems (DBM), ALM Tools (ALM), Project Process (MET)	Predictor
Professional Competences	Development (DEV), Operation and Maintenance (OPR), Project Types (TYP), Role and Responsibility (ROL), Certifications (CER)	
Products and Solutions Competences	In-house Products and Solutions (IPS), Third Party Products and Solutions (TPS)	
	Magnitude of Relative Error (MRE)	Target

From the input set of variables 13 are used as predictors and single variable (MRE) as a target. Experiment was conducted using IBM SPSS Modeler 14.2. For analyzed data a stream representing data flow was developed to perform experiment. The experiments followed the

sequence in which data is initially fed into the stream after which it passed steps of preparation, transformation and partitioning before it entered the modeling element. The modeling elements used in this study implement following data mining algorithms:

- Neural network model uses MPL (multilayer perceptron) with the back propagation. Perceptron's architecture is organized into layers: input layer that receives information, hidden layer(s) and the output layer. During formation the model determines how the network connects the predictors to the target. This is done by hidden layer(s) that uses input values and modifies them using some weight. The activation function defines the output signal from the neuron. New value is then sent to the output layer where it is modified by some weight from connection between hidden and output layer. The back-propagation looks for the minimum of the error function. The combination of weights which minimize the error function is considered to be a solution of the learning problem.
- Decision tree model uses C&R (classification and regression) algorithm. Decision tree algorithm performs the procedure of examining the fields in dataset to find the ones that give the best classification or prediction by splitting data into subgroups. The process is applied recursively, splitting subgroups into smaller and smaller units until the tree is formed. The C&R algorithm minimizes the impurity at each step, where the node in the tree is considered "pure" if 100% cases in the node fall into a specific category of the target field. The output from a decision trees is a tree like structure that can be easily interpreted as a set of IF-THEN rules.

Application of data mining methods is well suited for our problem for several reasons. First of all they can operate on large data sets that are typical for research in field of software engineering. Next, they are used to extract knowledge from data and represent it in a form of rules for separation i.e. classification of input variable sets. This enables us to interpret and understand results of modeling. Finally, results from data mining process afterwards can be implemented in daily practice on projects, which can be a beneficial for business in multiple ways. In terms of our study these findings can enhance effort estimation process and thus result in more optimal utilization of project resources.

6. Survey Results

The outputs resulting from the models report the relative importance of the top predictors. The importance of each predictor is relative to the model and it identifies the input variables that matter the most during prediction process. Results of modeling process for both neural network and decision tree are displayed on Figure 2.

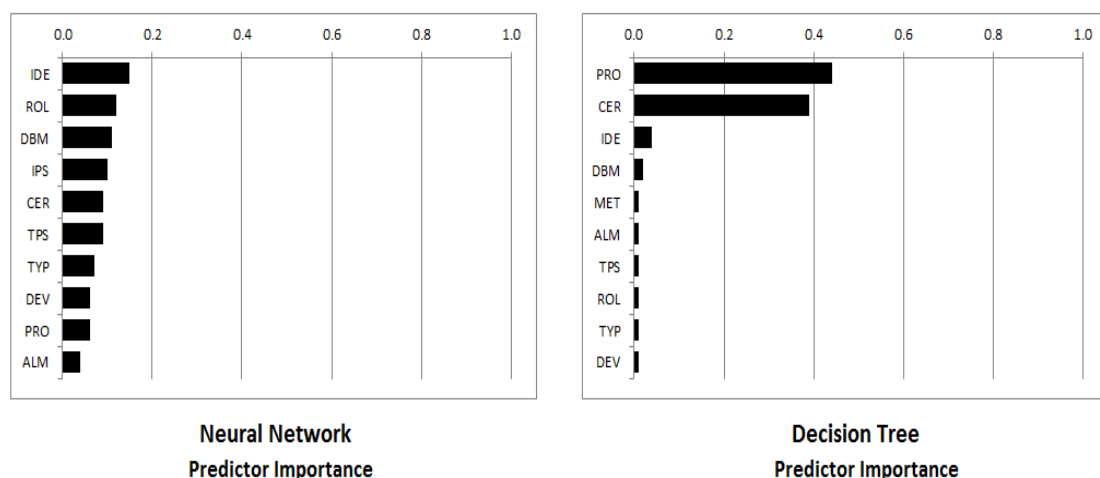


Fig. 2. Relative importance of predictors used in models.

The Multilayer Perceptron (MLP) neural network model returns the group of predictors with descending predictive power: IDE=0,15; ROL=0,12; DBM=0,11; IPS=0,10; CER=0,09; TPS=0,09; TYP=0,07; DEV=0,06; PRO=0,06; ALM=0,04. Resulting model has a single hidden layer with 10 neurons. Overall accuracy of resulting model is 57,9%. Although top predictors of estimation accuracy are competences i.e. know-how and skills in segments of development environment used on a project, current and previous roles and responsibilities, database management systems, in-house products and solutions know-how, certifications etc. from this model it is hard to designate typical predictors that could be used as classifiers.

On the other hand resulting model from the C&R decision tree clearly indicates predictors credible for the accurate effort estimates. This is obvious from distinctive values of their predictive importance: PRO=0,44; CER=0,39; IDE=0,04; DBM=0,02; MET=ALM=TPS=ROL=TYP=DEV=0,01. Model accuracy is similar to that of neural network. The resulting decision tree has depth = 3 and can be expressed as:

```

CER in [ "Basic" ]
    DBM in [ "Advanced" "Basic" ]
    DBM in [ "Intermediate" ]
CER in [ "Advanced" "Expert" "Initial" "Intermediate" ]
    PRO in [ "Advanced" "Basic" "Expert" ]
    PRO in [ "Intermediate" ]
        IDE in [ "Advanced" ]
        IDE in [ "Intermediate" ]

```

The decision tree can be interpreted the following way: the most important predictor of one's effort estimation accuracy is the competence CER. This competence belongs to professional segment and indicates the level of employees certification in areas important for assigned job position. In resulting model this predictor is rated with second greatest predictive importance. CER divides the initial set into two subsets, those with basic level of certification and the rest that belong to group with levels initial, intermediate, advanced and expert. First subset is further divided by DBM criteria based on its corresponding levels. The important segment of second subset is further divided by PRO, competence that indicates experts level of competence in programming languages, this is predictor with greatest importance in resulting model. Those with PRO level intermediate are later divided into subsets by IDE. To conclude, the decision tree gives us simple and readable form of results.

Results of modeling indicate competences that can be used as predictors of experts effort estimation accuracy. In terms of neural network model they are relatively closely grouped by predictor importance what made it hard to derive conclusions. On the other hand decision tree model gives comprehensive model from which a set of rules can be derived. Those rules, in terms of prediction of expert estimators accuracy can be expressed the following way: use level of certifications (CER) in areas relevant for the project context together with programming languages (PRO) competences as most relevant predictors. Only then consider group of predictors that is formed of IDE, DBM, IPS competences. Other predictors can be ignored due to their predictive power.

7. Conclusions and Future Directions

This paper reports a detailed description of the methodology used to develop predictive models in software engineering filed of effort estimation. Motivation comes from the need of introducing modeled approach of assessing expert competences used in effort estimation. The methodology was applied on the real data extracted from the tracking system used on projects and data collected in structured competence questionnaire. The study identified predictors that can be used to assess reliability of experts efforts estimates.

Results of this and future studies support the development of a model for enhanced expert effort estimation. Based on better understanding of effects that estimators competences have on reliability of effort estimates it would allow the application of corrective measures at early

stage of estimation process. Such a model is intended to enhance reliability of effort estimates and could be applied to everyday practice of software engineers.

References

1. Basha, S., Ponnuram, D.: Analysis of Empirical Software Effort Estimation Models. *International Journal of Computer Science and Information Security*, 7 (3), (2010)
2. Chouhan V. S., Srivastava, S.: Understanding Competencies and Competency Modeling – A Literature Survey. *International Organization of Scientific Research Journal of Business and Management*, 16 (1), 14-22 (2014)
3. Conte, S. D., Dunsmore, H. E., Shen, V. Y.: *Software Engineering Metrics and Models*. Benjamin-Cummings, Menlo Park, CA (1986)
4. Dorn, J., Pichlmair, M., Schimper, K., Tellioglu, H.: Supporting Competence Management in Software Projects. *Proceedings of International Conference on Concurrent Enterprising*, 451-458 (2008)
5. Ferrucci, F. et al.: Genetic Programming for Effort Estimation an Analysis of the Impact of Different Fitness Functions. *2nd International Symposium on Search Based Software Engineering*, Benevento, Italy, 89-98 (2010)
6. Giammalvo, P.: Creating a Competency Assessment for Cost Estimators. *Project Management World Journal*, 1 (2), (2012)
7. Hale, J.: *Performance-Based Certification: How to Design a Valid, Defensible, Cost-Effective Program*. Pfeiffer (2012)
8. Hustad, E., Munkvold, B., Moll, B.: Using IT for Strategic Competence Management - Potential Benefits and Challenges. *Proceedings of European Conference on Information Systems*, (2004)
9. Jørgensen, M.: A review of studies on expert estimation of software development effort. *The Journal of Systems and Software*, 70 (1-2), 37-60 (2004)
10. Jørgensen, M., Sjøberg, D. I. K.: Impact of experience on maintenance skills. *The Journal of Software Maintenance and Evolution*, 14, 1-24 (2002)
11. Jørgensen, M., Boehm, B. and Rifkin, S.: Software Development Effort Estimation: Formal Models or Expert Judgment?. *IEEE Software*, 26 (2), 14-19 (2009)
12. Karna, H., Gotovac, S.: Estimators Characteristics and Effort Estimation of Software Projects. *9th International Conference of Software Engineering and Applications*, Vienna, Austria, (2014)
13. Kenexa Corporation an IBM Company: *How Competencies Enhance Performance Management*. Available at: <http://www.kenexa.com>, (2012)
14. Klendauer, R. et al.: Towards a competency model for requirements analysts. *Information Systems Journal*, 22 (6), 475-503 (2012)
15. Layman, L. et al.: Mining Software Effort Data: Preliminary Analysis of Visual Studio Team System Data. *Proceedings of the 2008 International Working Conference on Mining Software Repositories*, 43-46 (2008)
16. Le Deist, D. F., Winterton J.: What is competence?. *Human Resource Development International*, 8 (1), 27-46 (2005)
17. Lucia, A.D.: Lepsinger, R., *The Art and Science of Competency Models: Pinpointing Critical Success Factors in an Organization*. Pfeiffer, San Francisco, CA (1999)
18. McClelland D.C.: Testing for Competence Rather Than for Intelligence. *American Psychologist*, 28 (1), 1-14 (1973)
19. Molokken K., Jørgensen, M.: Expert Estimation of Web-Development Projects - Are Software Professionals in Technical Roles More Optimistic Than Those in Non-Technical Roles, *Empirical Software Engineering*, 10, 7-29 (2005)
20. Nader, D. A., Tushman, M.: The Organization of the future: strategic imperatives and core competencies for the 21st century. *Organizational Dynamics*, 27 (1), 45-58 (1999)

21. Stensrud, E. et al.: A Further Empirical Investigation of the Relationship Between MRE and Project Size. *Empirical Software Engineering*, 8 (2), 139-161 (2003)
22. Winterton, J., Le Deist, F., Stringfellow, E.: *Typology of knowledge, skills and competences: Clarification of the concept and prototype*. Luxembourg (2006)
23. Xie, T., Thummalapenta, S., Lo, D., Chao Liu, C.: *Data Mining for Software Engineering*. *IEEE Computer*, 42 (8), 35-42 (2009)

The Mindfulness and Mindlessness in Mobile Business Intelligence Adoption

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Abstract

Mobile business intelligence (m-BI) is a hot topic attracting the attention of many companies. Little is known about the main motivations that drive a company to adopt an innovation in general and specifically that kind of study is lacking within the mobile BI field, whose research is still in its early stages. This paper has two main contributions: first, the motivations which drive an organization to adopt mobile BI are explored based on the organizing vision concept and second the adoption rationales which the companies develop are discussed in terms of mindfulness and mindlessness. This study revealed that both mobile BI organizing vision (external factor) and the enthusiasm of the executives and users (internal factor) are affecting the decision of the companies to adopt mobile BI.

Keywords: Mobile Business Intelligence, Decision to Adopt, Organizing Vision.

1. Introduction

Business Intelligence (BI) systems provide information to users to support their decision-making process based on data analysis [14]. From the software perspective, BI has always been in continuous improvements in order to meet users' expectations and market changes. Today's business is requesting updated, real time information to be available anywhere, any time. BI vendors are working hard to align their products with the demanding business requirements and the advancements of the BI market.

Recently, a new technology, mobile BI, is being promoted as an extension of BI. The term mobile BI adopted in this paper refers to "a data-driven decision support applications on mobile devices like smartphones and tablet computers" [6, p.6]. The emergence of mobile BI is due to two main factors: (1) the need to make decisions 'on the move' and (2) the generation of new mobile devices.

Mobile BI has attracted a lot of attention and enthusiasm regarding its potential benefits, which makes it a hot topic [13]. Although people started to talk about mobile BI as early as 2000s, its recognized growth is only after 2010—the same year iPad was released [12]. According to Tona and Carlsson [12], there has been a continuous discussion among different stakeholders such as vendors, consultants, early adopters, analysts and journalists. The discourse results in the creation of a mobile BI organizing vision, which is a "focal community idea for the application of information technology in organizations" [10, p.460]. The organizing vision provides information and knowledge through its interpretation, legitimation and mobility as well as influences the potential adopters. According to this organizing vision, mobile BI is expected to have benefits in terms of efficiency and effectiveness such as enhanced communication among decision-makers, decision making on spot, reduction of decision time especially in critical situation like in emergencies, better customer services and new flexible ways of working. [12].

When a new technology is introduced, the organizations often face a dilemma if it is going to be widely adopted in such a way that it transforms the business practices or if it is going to be just another passing fashion [13]. Organizations engage with the organizing vision to help them evaluate whether they should adopt mobile BI or not. However, from a prescriptive point of view organizations are expected to be mindful, where they should pay careful attention to their organization specifics and evaluate the business value of mobile BI by matching their specific needs to it [11]. On the contrary, they may behave mindlessly as well, where they do not pay enough attention to organization specifics. There is a lack of studies which have tried to answer ‘why’ a certain innovation, like mobile BI, is adopted [7]. This kind of study lacks even within the mobile BI field, where there is a call for papers [4] as its academic research is still in its early stages [3]. Consequently, the following research question will be addressed: ‘Why do organizations adopt mobile BI?’ This study has two main contributions: (1) the motivations which drive an organization to adopt mobile BI will be explored based on the organizing vision concept, and (2) the adoption rationales which the companies develop will be discussed in terms of mindfulness and mindlessness.

The remainder of the paper is organized as follows. In Section 2 we describe shortly the mindfulness and mindlessness in innovation adoption. Section 3 presents the research approach. This is followed by a presentation and discussion of the results. Conclusions and future research are presented in the final section.

2. Mindfulness and Mindlessness in Innovation Adoption

According to Swanson and Ramiller [11] the adoption process of a new innovation in an organization starts with comprehension where organizations make efforts to make sense of the new innovation. Based on the knowledge gained during this process, they position themselves as adopters or non-adopters. The comprehension process is tightly related to the organizing vision which influences the potential adopters’ decision making process. The community which consists of vendors, consultants, journalists, academic researchers, early adopters, certain practitioners and executive groups interact in a public discourse which in turn shapes the organizing vision. Each organizing vision is identified by a name by which the community members refer to it and it includes metaphors, scenarios, stories, problems and issues [10]. In order to exploit a new technology, the organizing vision provides interpretation, legitimation and mobilization. Interpretation clarifies the existence and purpose of the technology in order to reduce its uncertainty. Legitimation links the innovation to its benefits and business processes. In mobilization different market forces are coordinated to provide the needed resources to support innovation adoption and fusion.

Although, the organizing vision provides knowledge on the new IT/IS, still the decision on why to adopt the innovation should be related to the specifics of the organization. Therefore, business values and challenges of the innovation shall be evaluated by organizations before taking the decision to adopt. To show the engagement of an organization with a new IT/IS, Swanson and Ramiller [11] have introduced two concepts: mindful and mindless. An organization is considered to be mindful when “it attends to an innovation with reasoning grounded in its own organizational facts and specifics” [11, p.559]. A mindful organization shall pay close attention to its specifics to decide on whether to adopt the new IT. Its engagement shall generate knowledge and learning under the context of its own organizational situation such as the organization’s objectives, structure and processes. Five main attributes of mindfulness, from an IT innovation context, have been identified by Swanson and Ramiller [11]:

- Preoccupation with failure – Companies shall look at the innovation with close attention to the possibilities of failure.
- Reluctance to simplify interpretation – Companies shall resist the simplified interpretation that is represented in the organizing vision. They should try to look beyond it with a critical eye and exert complex and conflicting interpretation.

- Sensitivity to operations – Companies shall be alert towards its operations as it may affect the organization reliability. Usually, enhancing the inefficient operations is the main reason that drives a company to adopt a new IT. They shall involve internal experts to relate the organizing vision to the problems of the firms.
- Commitment to resilience – The companies shall accept that unexpected consequences and new situations may arise with the passing of time. Therefore, they shall embrace a practical and realistic view.
- Deference to expertise – The expertise shall be heterogeneous and involve many organizational members through the whole process of innovation. An on-going learning shall take place among them.

However, in many cases, organizations are mindless which results in “actions [which] betray a lack of attention to organizational specifics” [11, p.563]. The companies can get involved in the enthusiasm surrounding an organizing vision and the success stories told by the early adopters. They believe in the community that takes part in the discourse, therefore they attach themselves to this learning without making a thorough interpretation. However in many situations, mindlessness can be embraced when the benefits outweigh the risks. When a company first faces an innovation, it is hard to be mindful and interpret the validity of other firms’ interpretations. Mindfulness and mindlessness interact through the organization vision and create “an evolving landscape of supposition, hopeful belief, and qualified knowledge” [11, p.570]. Mindfulness will be observed in the case when the organizing vision is less fashionable, and mindlessness will be more present where the organizing vision is more fashionable.

3. Method

Getting access to organizations that have already adopted and implemented mobile BI was rather challenging. Taking advantage of a professional network, LinkedIn, we managed to send research requests to 16 people. Out of 16 requests we got 6 responses from 6 separate companies. The response rate was 37.5% and it is fair enough. In addition, 3 more interviews—recommended by one of the contact persons—were conducted within the same company. This adds up to 9 interviews in total.

The contacted companies are operating in different industries and located in different parts of the world (see Table 1). The persons interviewed are key persons who have been part of the decision-making process in mobile BI adoption in their own organizations. Due to their different locations, the interviews were conducted via Skype. Semi-structured interviews were chosen because they made it possible to adjust questions and alter an interview sequence as the interviews unfolds. The interviews lasted for approximately one hour each and all of them were recorded with the consent of the interviewees. The interviews were transcribed and e-mailed back to the participants for comments or feedback. Once confirmation was obtained, the transcripts were ready to be analysed. In order to maintain the anonymity of the participants—because of the risk to unfold their internal strategies and policies—the cases are named alphabetically.

Table 1. List of cases

Nr.	Cases	Industry	Location
1	Company A	Healthcare	UK
2	Company B	Consulting	Nashville, TN, USA
3	Company C	Aviation	Sydney, Australia
4	Company D	Retail	Netherlands
5	Company E	Non-Profit Organization	Florida, US
6	Company F	Retail	Sweden

Company A is operating in the healthcare industry. They have implemented mobile BI to support their community clinicians, who visit their patients out in the community. Using the same device they could enter the information they were as well able to retrieve different BI reports. Company B is a consulting company and its mobile BI users are most of the time away in different client sites. Company C is operating in the aviation industry and its operational team use mobile BI to get on-time understanding of the airport capacity planning and also on-time departure and performance. Company D and F are operating in the retail industry and have supplied mainly their regional managers with mobile BI who are always on-the-go and paying visits to the different stores in different regions. Company E is a non-profit organization that uses mobile BI to support its community employees to consume information out in the field and be able to answer many questions, which usually emerge during meetings with other stakeholders.

4. Analysis and Discussion

In this section, we analyze the data collected from our cases. Our interviewees have decided to ‘jump the bandwagon’ in adopting mobile BI.

4.1 Making Sense of Mobile BI Innovation

When an organization decides to adopt mobile BI, it makes sure that the facilities and technology needed to support its usage are already in place. Putting the pieces together to understand the circumstances under which organizations decide to adopt mobile BI, we saw that nearly all our cases had already adopted tablets long before they decided to implement mobile BI on them. The adoption of the tablets was not necessarily related to the aim of adopting mobile BI. None of the companies has bought mobile devices with the sole purpose to implement mobile BI. *We became first mobile and then we got mobile BI. It wasn't the other way around... We are already mobile, and we need BI for those people. (Interviewee, Company E).* For most of them it has been a perfect match between BI, which they saw as a ‘big thing’, and the availability of the mobile devices their mobile force possessed. Having the mobile devices already there, knowledge on the power of BI and a mobile force on the road in need of information, created a favorable background for the organization to consider the adoption of mobile BI.

However, the organization’s situation is not sufficient enough to influence the decision of adoption. Other external forces are having an impact on that type of decision. One of the interviewees stated: *But first of all, Gartner also said...they said just do it, just buy such a thing, and play around and see what it can bring and that was actually the approach we have taken... (Interviewee, Company D).* Many analysts conduct different research in the market and publish their results in the forms of reports. We are observing a number of industrial research companies (for example Gartner, Dresner Advisory Services) which are promising to deliver the most objective, reliable and accurate studies to organizations. Generally, these reports are based on a market research studying different perspectives of technology, for instance the identification of the hottest IT issues. The reports are followed by guidelines on how companies shall behave and which specific innovation shall they embrace in order to increase their performance and competitiveness in the market. Our data analysis shows a strong influence and ‘pressure’ from this kind of industrial research. Most of the time, the executives buy a copy of the reports to gain an understanding of the main IT/ IS trends emerging in the market. Executives are attentive to these reports because (1) they want to increase their internal and external legitimacy through innovation [13]; (2) they want to avoid the risk of being left behind; and (3) they do not want to risk their competitive survival [9]. Hence, as one interviewee of company A said: *‘being in the BI industry, you would always be looking at new technologies; new ways to deliver BI’* indicates that the companies are keen in adopting new promising innovation. This is in line with the point made in [13] that those who have adopted a specific innovation and make it to the headlines of the newspapers have a

better reputation. This results in a higher remuneration scheme for executives. Unfortunately, this is not a characteristic of a mindful behavior.

In addition to the industrial analyst reports, the success stories of mobile BI early adopters are attracting the intention of the decision-makers. One of the interviewees in company A describes:

And we saw case studies where, you know, [a certain company]'s sales people, walking into its store, and straight away on their tablet device they would see sales figures related to that [company name] brand etc.... Again you start looking at the benefit of you doing that. What benefits it would be to go down similar road really...

This instance illustrates what and how a company would consider as a success story. Although these companies do not operate in the same industry, a success story like this can have an impact on the decision-makers. Generally, the success stories are related to a higher performance and are characterized by a list of benefits generated from the usage of an innovation. They have the potential to influence other companies' decision to adopt similar innovation and to make the bandwagon start rolling [1]. The more success stories get published, the more companies will join the bandwagon, especially when the already joined companies have a higher reputation. Following the footsteps of another company, which appears to be successful, increases the confidence of the following companies. Besides the published stories, the interviews revealed that there is an informal communication between companies. The discussion in this communication aims to share their experiences and perceptions in mobile BI adoption. However, in both cases, the managers seem to assimilate the knowledge transmitted by success stories exactly as they are told and presented to them. They do not scrutinize further as a mindful manager should do. A mindful manager should be attentive to his own organizational specifics. He also should be able to see mindlessness and/or mindfulness in other cases too [9].

On the vendors' webpages and articles you may see a lot of success stories published. The main aim of this published material is to communicate the success of a company in terms of performance because of the mobile BI adoption. However, when we try to scrutinize one of these companies, we understood that that is not always the case. One of our cases has been published as a success story on one of the vendor's web page. However, during the discussion with a representative of that company, he/she confessed that they had many problems with mobile BI in terms of user adoption as people are refusing to use it. Case in point, if there is no use, how could mobile BI be so beneficial that it could be published as a success story? This study casts a doubt on industrial published success stories. They tend to depict that organizations could have an outstanding performance because of an implementation of a specific innovation. These results are consistent with other studies ([13], [8]).

Concluding, decision-makers are making sense of mobile BI through their external environment. In terms of external environment we identify different stakeholders who are directly influencing the decision to adopt such as the research analysts and other organizations' success stories. This relates to what Swanson and Ramiller [10] referred to as organizing vision. However, we have to stress at this point that the informal communication that takes place between the companies to share their experiences, is not formally part of this organizing vision. The organizing vision does have a considerable impact on the early phase of the decision-making process to adopt mobile BI. Due to the engagement with the mobile BI organizing vision, the organizations gain an insight of its interpretation, legitimation and mobilization [10]. We argue in our discussion that organizations engage with the mobile BI organizing vision mindlessly.

However, the mobile BI organizing vision is an unfinished 'solution', which the potential adopters shall customize and fit in their own organization settings and needs [10].

4.2 Innovating Mindfully or Mindlessly?

In this section we are going to describe the rest of rationales adopted by the organizations in terms of mindfulness and mindlessness.

The adopters who decide to ‘jump the bandwagon’ are in a constant influence of the organizing vision. Therefore it is difficult to adopt reluctance behaviour to simplify mobile BI interpretation. When asked about their understanding and perception of mobile BI the main keywords obtained were: mobility, whenever and wherever, getting the right information and making decisions. Comparing these keywords with the ones provided by the mobile BI organizing vision [12] there is not much difference. So, we can argue that the companies embrace and accept the interpretation provided by the organizing vision without being critical or making it more complicated. This is one instance where they are believed to behave mindlessly [11].

In terms of evaluating their own organizational specifics, nearly all the organizations have found a need, problem or opportunity that mobile BI could meet (see Table 2). The main driver at this point has been mobility.

The organizations had already highlighted their main user groups who most of the times work out in the community; visit store branches, patients and clients; attend different meetings within and outside their respective headquarters. They have customized mobile BI based on the mobile employees who need information when on the go during their everyday work. Through mobile BI, users can access many reports provided to them and have the possibility to drill down in more detailed information. Additionally, based on Table 2 we observe that the organizations have pinpointed their needs to make a case for mobile BI adoption. In order to innovate mindfully, these organizations have tried to identify the needs within their own environment and looked at their specific circumstances before making the final decision to adopt mobile BI. At this point, we observe a mindful behaviour, as they are trying to customize and fit mobile BI within their own processes and users.

Table 2. Summary of the main user groups and organization needs revealed by the data analyses

User Groups	Need/Problem/Opportunity
<ul style="list-style-type: none"> • Executives • Regional managers • Consultants • Social workers • Clinicians 	<ul style="list-style-type: none"> • enhance the efficiency of the community-based staff/clinicians • reduce the paper consumption • eliminate the big time lag between the changes on KPIs and the actions of the regional managers • avoid the Excel usage on iPads, which results in losing the context of the information • support people in the community to consume information out in the field but also be able to share it • improve the operational part of the business in terms of monthly reporting and capacity changing • enhance the collaboration within and outside the company

However, when it comes to sensitivity of operations [11], the interviewees have found difficulties in evaluating the potential benefits of mobile BI:

Actually, everybody believed there was a business case but it is very hard to measure the effects...in the end you can never measure this... (Interview, company D)

It is difficult to quantify the success, like what it is produced, for example what's the value of sharing the information particularly with the community for instance (Interviewee, company E)

The difficulty of evaluating the impacts of mobile BI is related to the class of the systems it belongs to. Mobile BI is emerging within the decision support system (DSS) application

area [6], and over the years, many studies have been conducted in order to evaluate the impacts of these systems. Most of the academic discussion is based upon improving the efficiency and the effectiveness of DSS. To be effective, a DSS shall allow people to be more efficient such as performing the same task in less time and effort [2,5], but it is really difficult to measure it quantitatively.

Different companies have approached this issue differently. Company A, for instance, has conducted some evaluations related to mobility such as travel time and travel cost that mobile BI could have saved. These evaluation studies represent their efforts to understand the potential impacts of mobile BI within their own organizations. However in other cases we observe that although they found it very hard to measure they have decided to ‘jump the bandwagon’ saying that *‘this is the way to go, as it will take us a far too much time measure it’* (interviewee, company D); whereas company C states that *‘it was actually me who came up with the idea ..I thought this was actually a good thing for the business to install and run with...’*

At this point, we can argue that mindful behaviour depends upon how the organizations look at the innovation. There are companies which (1) try and manage to conduct different evaluation studies before the final decision to adopt; (2) have the will to evaluate but find it difficult and time-consuming; and (3) follow the gut feeling that it will be a success. Being in the same line of discussion, some of the reasons that might determine whether a company would evaluate its innovation attempt, like the mobile BI, are: the kind of industry they are operating; the availability of the resources, especially money and time; and the policies and strategies they follow in regards to innovation.

Being an innovation that is *hot* and in *fashion* [13], not surprisingly it creates enthusiasm among the C-level managers-- *..one of the first users to use it was our CEO in the iPhone. He was so happy.. he was so enthusiastic and he went to the investor to show it, so..It was a very cheap and easy way to start with mobile BI(Interviewee, company D)--and as well the users, which influence at this point the final decision to adopt--Once you get a visualization that is interesting and you know it produces a lot of enthusiasms... So, for us, part of our problems has been that we have created so much enthusiasm that has been difficult to keep up and actually written and thrown away 3 versions that were BI application. (Interviewee, company E).* Hence, not only external factors such as the organizing vision influence the decision to adopt, but as well internal factors such as the board of directors and its potential users.

In terms of deference to expertise [11], during the innovation process the main members involved were the BI team and the final users. It’s worth describing that this collaboration took place mainly during the design of the reports, dashboards, and different visualizations (end-products) rather than throughout the whole innovation process. After the design process, there is an ongoing collaboration between these two parties: mobile BI users requesting information related to mobile BI and the BI team catering it to them. However, we can’t really see other organizational members involved in this process.

Going through the rest of the adoption rationales in this subsection we conclude that there is not ‘black and white’ in categorizing a company either mindful or mindless in adopting mobile BI. As we noticed, there is a combination of mindful and mindless behaviour. Through the whole process of decision-making we see companies shift from being mindless such as in mobile BI interpretation, deference to expertise to mindful in case of defining their organizational needs and user groups. However, because of the nature of BI, we encounter different behaviours in trying to evaluate its potential benefits.

5. Conclusions

This paper sheds lights on the motivations that drive organizations to adopt mobile BI through the lens of organizing vision, mindfulness and mindlessness.

We find that organizations engage with mobile BI organizing vision during the early phases of their adoption decision-making process. At the beginning they take part in this engagement passively where they absorb knowledge on mobile BI interpretation, legitimation and mobilization. Afterwards, they move to a more active position in giving their contribution

in terms of experiences and perceptions that on the other hand shapes further mobile BI organizing vision. Informal communication between companies takes place, but unfortunately they do not become public to be officially part of the organizing vision. Besides the influence of the organizing vision, the board of directors and some users (internal influence) who are driven by the innovation enthusiasm may have an impact on the decision to adopt mobile BI.

Being positively influenced by the organizing vision, organizations progress further in their decision-making process. At this point they try to fit mobile BI in their business processes. Although, it is advised that organizations shall innovate mindfully [9], we see a combination of mindfulness and mindlessness behaviour in the decision-making process to adopt. At the beginning they interact with the organizing vision mindlessly as they do not question or have a critical stance towards mobile BI interpretations and different success stories being published. This can sometimes mislead their decision, as the success stories not always are related to high performing companies because of the innovation. In identifying user groups and organizational needs to be met by mobile BI, organizations behave mindfully, however only some of them manage to evaluate the potential benefits of the innovation. This is due to the nature of the mobile BI system; kind of industry they are operating; the availability of the resources, especially money and time; and the policies and strategies they follow in regards to innovation. Therefore during the decision-making process to adopt mobile BI we observe a shift of companies from behaving mindfully in one case to behaving mindlessly in another, creating a swing, which moves back and forth.

References

1. Abrahamson, E.: Managerial Fads and Fashions: The Diffusion and Rejection of Innovations. *Academy of Management Review*. 16 (3), 586-612 (1991)
2. Alter, S.: *Decision support systems: current practice and continuing challenges*, Reading, Mass, Addison-Wesley (1980)
3. Chen, H., Chiang, R. H. and Storey, V. C.: Business Intelligence and Analytics: From Big Data to Big Impact. *MIS Quarterly*. 36 (4), 1165-1188 (2012)
4. Gao, S.: Mobile decision support systems research: a literature analysis. *Journal of Decision Systems*. 22 (1), 10-27 (2013)
5. Pick, R. A.: Benefits of Decision Support Systems. In: Burstein, F., Holsapple, C. (eds.) *Handbook on Decision Support Systems 1*. Berlin: Springer (2008)
6. Power, D. J.: Mobile decision support and business intelligence: an overview. *Journal of Decision Systems*. 22 (1), 4-9 (2013)
7. Rogers, E. M.: *Diffusion of innovations*, New York, Free press (2003)
8. Staw, B. M. and Epstein, L. D.: What bandwagons bring: Effects of popular management techniques on corporate performance, reputation, and CEO pay. *Administrative Science Quarterly*. 45 (3), 523-556 (2000)
9. Swanson, E. B.: The manager's guide to IT innovation waves. *MIT Sloan Management Review*. 53 (2), 75 (2012)
10. Swanson, E. B. and Ramiller, N. C.: The Organizing Vision in Information Systems Innovation. *Organization Science*. 8 (5), 458-474 (1997)
11. Swanson, E. B. and Ramiller, N. C.: Innovating Mindfully with Information Technology. *MIS Quarterly*. 28 (4), 553-583 (2004)
12. Tona, O. and Carlsson, S.: The organizing vision of mobile business intelligence. In: *Proceedings of the 21st European Conference on Information Systems*. (2013)
13. Wang, P.: Chasing the hottest IT: effects of information technology fashion on organizations. *MIS quarterly*. 34 (1), 63-85 (2010)
14. Watson, H. J. and Wixom, B. H.: The Current State of Business Intelligence, *Computer*, 40 (9), 96-99 (2007)

Architecture and Data Flow Model for Consumer-Oriented Smart Meter Design

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Abstract

The power grid needs modernisation to efficiently manage the needs of the ever growing population. Smart metering systems have been the main area of focus in smart grid. Smart meter rollouts have started in many countries, but the majority of them are facing resistance from end-users, particularly residential consumers. Generally, consumers have the scheme imposed on them, they are required to pay for the new device, they have little control over their power usage, and they have no control over the considerable amount of additional personal data that the device collects. In this article we identify means of reducing consumer concerns about the data that is extracted and transmitted. We in particular, propose a Smart Metering System Architecture with controls and choices for the consumer, and an abstract data flow model that identifies the security and privacy requirement at each point in the flow.

Keywords: Smart Meter, Advanced Metering Infrastructure (AMI), Data Flow Model, Smart Metering Architecture, Consumer Concern, Technology Acceptance.

1. Introduction

The traditional power-grid is no longer adequate to cope with increasingly extensive and intensive use of electrical devices, and the generation of power within what was previously a transmission and distribution network. Modernisation of the grid is necessary, through the integration of intelligent sensors, controls, robust communications and other technologies. Of all the components in the smart grid, smart meters have attracted the most attention [9, 10]. The majority of grid modernisation projects appears to be focusing their investment on smart meters and advanced metering infrastructure (AMI).

Smart meters enable the recording of power consumption at short intervals, and access to that data by at least the utility and perhaps other organisations in the supply chain. This provides a basis for the imposition of a time-of-use (TOU) tariff. The idea was projected that this would help in reducing the consumption of electricity during peak periods, and thereby enable the postponement of the construction of new power plants, perhaps even indefinitely [9,10]. This would result in savings in capital expenditure and associated borrowing costs, and contribute to reductions in carbon emissions. Smart meters were also claimed to be an enabler of such smart grid features as real-time power-outage tracking and management of power-exportation from renewable sources such as solar panels [8, 9, 10]. These functionalities offer benefits and possibilities to various stakeholders in the grid. Proponents of these projects expected consumers to accept smart meters as a device that would enable them to manage their own power usage. The assumption was made that, by making consumer usage available to them in real-time, together with information about the cost of that usage, particularly during peak periods, they would change their energy usage patterns [8, 9, 10]. It is unclear to

what extent those propositions were evidence-based, and to what extent they were merely aspirations.

In practice, smart meter projects have faced considerable resistance from consumers [1, 2]. This strongly suggests that project sponsors failed to understand consumers' needs and concerns, and/or failed to communicate the advantages, and/or failed to have suitable answers to the criticisms levelled at the schemes. Consumers view smart meters with distrust. They perceive smart meters to be a means whereby utilities can maximise their benefits at the expense of consumers' costs, choice, privacy, and even health.

For expensive infrastructure like an economy-wide smart meter system, it is important to achieve consumer confidence. Particularly in the face of activism over issues like security, privacy and health effects, a project-sponsor may spend years battling to convince consumers of the benefits of smart meters [1, 2, 16]. Unless a technology is equipped to act as a support to end-user, it will not be welcome even if it could contribute to solving major issues like lowering carbon emissions and climate change.

The purpose of the research reported in this paper was to address the needs of project sponsors, by showing how consumer resistance to smart meters can be overcome, but to do so in such a manner that consumers' needs are actually addressed. The means whereby this is achieved is by outlining a consumer-friendly design. Key characteristics of such a design include firstly recognition of consumer concerns and of the variability of those concerns across various consumer segments, secondly features that directly address those concerns and are seen by consumers to do so, but also technical feasibility, and compatibility with existing technologies.

The research method adopted was as follows:

1. We identified ways to reduce consumer concern about the data that is collected and accessed by organisations.
2. We undertook a consumer segmentation study, based on subjective control over smart meters.
3. We proposed a Smart Metering System Architecture with controls and choices for the consumer.
4. We prepared an abstract Data Flow Model that identifies the security and privacy requirement at each point in the flow.

The work's contribution is to build on the limited prior literature on the specific question of consumer-oriented smart-meter design, and establish a basis for evaluating existing products and devising new products that better meet the needs of consumers and scheme sponsors alike.

2. Consumer Concerns

In many places, smart meter rollouts have been delayed and even stopped. Even mandated schemes have been halted due to the strong involvement of consumer advocacy groups [1, 2]. If customers' first experiences with smart meters are negative, their trust in the smart meter system will be low. And if trust is low, then it will be challenging to motivate customers to use them, and to participate in demand response in the future.

There are significant unresolved consumer concerns about smart meters [1, 2, 6, 16]. Some consumer concerns may be perceptions rather than actual risks. For example, many communications devices generate electric and magnetic fields (EMF), smart meters generate less traffic than many other such devices, and the nature and extent of EMF-related health risks are in any case contentious matters.

A further issue has arisen from the impression conveyed by many proposals that demand response functionality will provide the utility with the capability to unilaterally shut down the consumer's appliances in order to reduce load. This would represent a substantial limitation on consumers' rights to self-determination. This is commonly referred to as a 'choice' issue.

Many media reports depict the smart meter as a spy in the home. Research evidence shows that smart meter data at one-minute intervals are capable of providing insights into a

household's appliances and activities, thereby revealing the residents' living patterns [15]. On the other hand, measurements of lower granularity would appear to make it more difficult to infer such information.

From the consumer's viewpoint, smart meter schemes appear to be demanding that they pay for a new meter, learn new skills, use them frequently, change their usage patterns of their appliances, give up some control over their appliances, and even permit the escape of potentially sensitive personal data. It is unsurprising that consumers are inclined to believe that the real purpose of smart meters is to enable energy suppliers to increase their profits at consumers' expense.

All of these concerns are real, irrespective of the extent to which they are justifiable. They represent impediments to the adoption of smart meters, and barriers to both return on investment and the ultimate objectives of efficient power-production and –delivery, and lower environmental impact.

The focus in the remainder of this article is on privacy and choice issues. A theoretical basis is provided by recognition that negative emotions arise from a subjective loss of control, and that negative emotions greatly reduce a person's preparedness to use a technology [3]. Kranz et al. conducted research to explore the role of control on the acceptance of smart meters [12]. They extended the Technology Acceptance Model (TAM) by adding subjective control as a construct. A survey of 351 participants found that subjective control was the second-strongest element behind perceived usefulness, and a major determinant of the intention to use smart meters [12].

A summary of existing literature revealed that few articles reflect much depth of appreciation of consumer concerns and what can be done about them. McKenna et al. [14] examined how to minimize data requirements for the main functionalities of smart meter data in order to reduce consumer concerns. However, the method that they propose fails to offer options suitable for different consumer segments. Kranz et al. [13] diagrammatically represented information flow of data to and from smart meter, but did not examine ways to reduce consumer concerns. Berthier et al. [5] listed possible threats targeting an AMI and suggested an architecture that addresses one specific aspect – monitoring and intrusion detection. Their proposal did not, however, identify all of the points of vulnerability in such systems.

Chinnow et al. [7] analysed security and attack scenarios of smart metering architecture and protocols as used in Germany. However, they did not focus on consumer needs, controls and options. Gungor et al. [10] presented an AMI architecture, but again pays very little attention to consumer needs. Wang et al. [17] discussed the communication architecture of the grid as a whole, including smart meters. Berihun & Alavoine [4] represented a 'prosumers' house using a smart meter, and identified possible attacks and threats. However, unlike our own work conducted in parallel with theirs [18], their analysis missed many points of vulnerability because they failed to drill down to sufficient depth.

The remainder of this paper identifies consumer segments, reflects the varying priorities of different categories of consumers, and presents an architecture, design features and a data flow analysis that address the key issues that represent impediments to adoption.

3. Means of Addressing Consumer Concerns

On the basis of the analysis in the preceding sections, we propose a set of constructive measures that address consumer concerns about choice and privacy, and that thereby increase consumer confidence on the system. Four aspects are outlined: categories of data, consumer segmentation, architecture and data flow.

3.1. Categories of smart meter data

Smart metering data can be usefully classified into three categories: (i) Billing operations data; (ii) Demand Response data; and (iii) Grid intelligence data. The third category involves alerts about power-outages and Quality of Service (QoS). Such data is limited in its sensitivity, and disclosures occur very infrequently and with direct benefits to the consumer.

The primary focus of privacy and choice concerns are the other two categories. Table 1 provides a discussion of the nature and purpose of categories i) and ii), and design features that address consumer concerns.

3.2. Consumer Segmentation based on their concerns about smart meters

Consumers' reactions to smart meters vary from extreme resistance to high acceptance. There are consumers who see a smart meter as a device that causes serious health effects and there are also technology enthusiasts who would like to use every possible feature provided by it to manage their power consumption. Some people don't mind detailed meter reading but don't want the smart meter to manipulate or control their appliances. Based on this we have identified 5 smart meter consumer segments as shown in Table 2.

Table 1. Options to reduce consumer concern over Smart Meter data

	Billing Operation	Demand Response operation
Purpose	Electricity is a service that needs to be paid for and hence the utility provider needs details of consumption to charge the consumer.	This data is required for identifying the rise and fall in demand in a locality.
Data Frequency	i) Less frequent and cyclic ii) Intervals: Monthly / Quarterly / etc.	i) More Frequent ii) Intervals : 15 mins/ 30 mins / 1 hr /etc.
Effects on Consumer	Because of the low level of granularity, this data represents a very limited privacy threat, and has long been accepted as being a necessary element of the service.	This data is required frequently with or without a request. The transmission frequency can be programmed in the meter and back-end. This data could breach the security and privacy of the consumer.
Data Requirement	As this data has no other purpose apart from billing, it is only required on request from utility. Utility can send a request to fetch the billing data as per the billing cycle chosen.	Demand response data can be sent at intervals that are programmed at the meter or when triggered by requests sent from utility.
Options to reduce consumer concern		
Permission Control	i) Consumers exhibit limited concern about permission controls for this data. Billing data is the only method by which the consumption can be calculated and hence needs to be performed without any hindrance. ii) Consumers can be given the choice of billing intervals with a limit of one setting per cycle.	i) Consumer should be provided with choices on frequency of data storage, transmission and permissions to modify the energy usage. ii) There should also be options to disable transmission permanently or temporarily.
Storage settings	The data stored should be read-only. The data should be protected from unauthorized deletion and modification. This data should be available for billing verification in case of disputes	The data stored should be read-only. The data should be protected from unauthorized deletion and modification. This data should be available to other organisations only under strict controls. In particular, access for law enforcement purposes requires reasonable grounds for suspicion of relevance to the investigation of a criminal offence, and demonstrated legal authority.
Transmission settings	Billing should be calculated in the meter based on the TOU tariff declared. This eliminates the need to send detailed data for billing purpose. The data that required can be reduced to : a) Final (Present) Meter Reading b) Details of consumption accumulated under each period e.g. peak, off-peak and shoulder. This can be used to verify the bill calculation. c) Bill amount.	End user details are not required for grid operations, hence this data transmitted should be anonymous (when data leaves the smart meter) and aggregated at the data concentrator (this should be a point in the system close to the consumer and remote from the utility) to protect the privacy of the consumer.

Table 2. Consumer Segments based on their reaction to Smart Meter

	User Characteristics	User Reaction
Type 1	They strongly object to the escape of personal data from their premises.	High resistance
Type 2	They don't mind having a communicating device installed but don't trust the meter functionality and they don't want any support and prefer to manage energy personally.	Low resistance
Type 3	They don't mind having a smart meter, but they want a very basic setting programmed into it, and do not want to make changes, preferably ever.	Neutral

Type 4	They would like to receive alerts and information through a smart meter but would personally make the changes.	Low acceptance
Type 5	Technology enthusiast and energy conscious user. They want to take maximum advantage of the functionalities provided, including programming the meter to switch particular appliances off during peak periods.	High acceptance

3.3. Consumer Oriented Smart Metering Architecture

A smart metering system mainly consists of a smart meter, a collector/ concentrator, communication network and a head-end data storage system [11]. An in-house-display (IHD) module is an optional device that helps the consumer monitor their energy usage in real-time. The smart meter consists of the metering module and a communication module with the network interface card (NIC). Some smart meters have a detachable communication module that can be easily plugged into the main module. This provides the advantage of using the metering module even if the communication technology is changed. The communication network ideally requires a comprehensive set of security safeguards which may not be present in current advanced metering infrastructure (AMI) systems. There are also online energy management systems but they are not yet advanced to the stage where consumer can modify their energy profile and meter settings. Currently using the online portal, consumers can check their power consumption, meter profile and receive alerts and message from the utility provider [19].

The proposed architecture of consumer oriented smart metering system is shown in Fig. 1 and Table 3 presents controls and choices that can be provided to different users through this architecture. The critical differences are that consumer has the choice to remove the communication module and consumer also has control over both the data recording intervals and the intensity and frequency of data transmission. These specific features provide consumer with control and choice reducing the intensity of data available to the utility thereby achieving consumer acceptance.

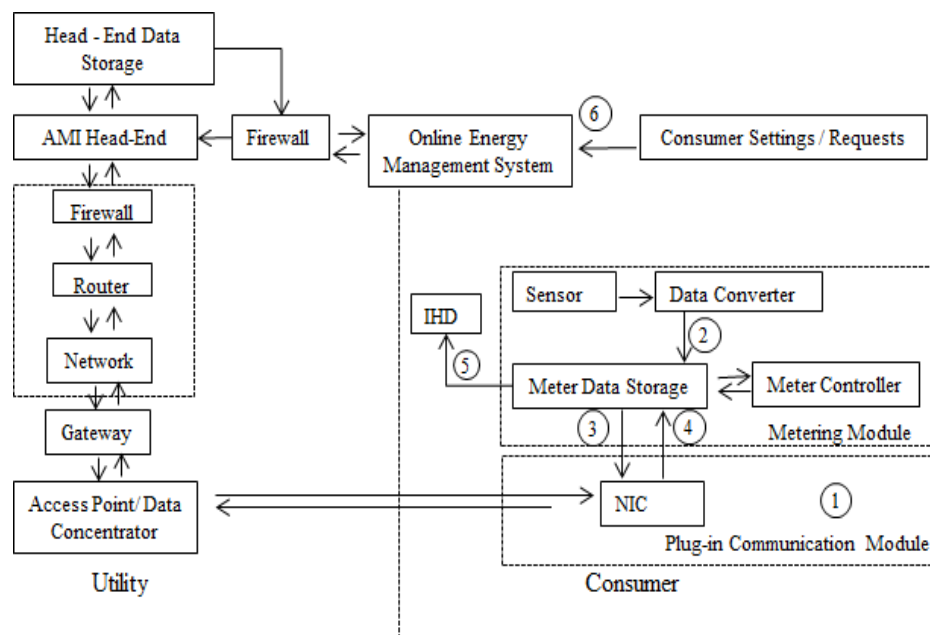


Fig. 1. Consumer Oriented Smart Metering System Architecture

Table 3. Controls/Choices in the smart metering system architecture for different user types

Option	User Type	Remarks
1. Plug –in Comms module	Type 1	<p>1. If the communication module is of plug-in type, it can be removed for consumers that don't want a radiating device in their premises. Such meters have to be manually read and the utility may have to charge those consumers extra for labour cost. In future if they wish to use the data transmission functionality the communication module can be easily plugged in.</p> <p>2. As there is no data transmitted to the head- end, details like outage and issues in QoS have to be communicated manually by the consumer.</p> <p>3. Limitations - Consumers who worry about RF emission health issues may still be affected by radiations from neighbouring consumer's meter or collectors in the locality.</p>
2. Choice in the interval of LP data storage	Type 1	As Type 1 user will not have a communication module, there is no requirement for them to store load profile data. Hence for such consumers there should be options to disable load profile channels and record no data. There could also be options for larger interval if required (e.g. 15 days / 1 month)
	Type 2	As Type 2 user will personally manage their energy consumption, they won't require frequent interval data. There should be option to program such users to larger intervals with just enough to supply information for grid operations.
	Type 3 Type 4 Type 5	These users favour frequent data collection and hence there should be 2or 3 options in the choices of shorter intervals (10 min /15 mins/30 mins)
3. Frequency and interval of data transmission	Type 2 Type 3 Type 4	<p>There should be options to :</p> <p>1. Choose the interval of data transmission. It can be different from the interval in which data is stored.</p> <p>2. Disable data transmission permanently or temporarily. Though the data can be anonymised and later aggregated during transmission there should be choice provided to disable data transmission. This will ease the worries of the consumer who think their energy consumption data could be used to profile them and distinguish if their premises are occupied or not.</p> <p>3. Modifications to the data transmission should be notified to the head-end, so that they can use prior knowledge or other intelligence to calculate demand response.</p> <p>4. Alerts like power outage and variations to QOS from the set thresholds don't affect consumer choices and hence that information should be transmitted to the back end without any interference.</p>
4. Meter actions/ alerts/ Energy usage variations	Type 2	These users prefer not to use any help for their energy management, they only require options to receive alerts. Those alerts can be made available through In-House-Display or Online Energy Management system.
	Type 3	These users prefer not to constantly change their settings. Such consumers can be given the option to have the smart meter modify their energy usage during peak period declaration. If they have equipments with high energy requirement, that are not urgent they could be connected to the LC relay and made to switch off or cycle as per need.
	Type 4	These users prefer to be provided with alerts but wants the freedom to make choice of their energy usage.
5. Displaying usage with IHD	Type 1 Type 2 Type 3 Type 4 Type 5	All users, including the Type 1 user can utilise an IHD display to monitor consumption and other metering data at real-time, but Type 1 users won't be able to display alerts from the utility as they don't have a communication module. The smart meter should have a customisable display list for data to appear in IHD and there should be options to program the meter display based on consumer preference.
6. Setting Profile using online management	Type 4	As these users would prefer to make changes personally, they can be given option through Online Energy Management system to make changes to the LC relay settings. Any equipment that is connected to the LC relay will then perform as per their chosen settings.

system	Type 5	Technology enthusiast and energy conscious user who would like to make frequent changes to their profile settings can be provided with advanced options in online management systems for submitting their requirements. These requests should be first send to the Head-End and upon approval applied to the smart meter profile.
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3.4. Abstract Data Flow Model

The architectural features outlined in the previous section create potentials, but do not in themselves deliver the features. In this section we identify security and privacy requirements at each point of flow of meter data. In Table 4, we have classified data stored in the meter into six categories based on their functionalities. Fig. 2 presents an abstract data flow model for smart meter data. In Table 5, we have listed the security and privacy requirements at each point of the flow which addresses the key consumer concerns.

Table 4. Categories of data stored in the Smart Meter

Meter Data Type	Data Functionality
Detailed Data	This includes load profile data that is recorded at frequent intervals .This information is used for demand response and related operations
Accumulated Data	This includes accumulated consumption data which is not required frequently and in most cases, needs to be only sent when requested by utility. E.g. Billing operations.
Meter Profile Data	This data contains settings that determine how the meter operates. Most smart meters have a load control (LC) relay and they can be made to operate differently from the main load by settings in the meter profile. Settings can also be provided to override operations commands from the utility.
Command Data	This data includes command and control operations received from utility. This data along with meter profile setting controls meter operations.
Display Data	This includes data that be programmed to be displayed in the meter’s display unit and in other devices like IHD.

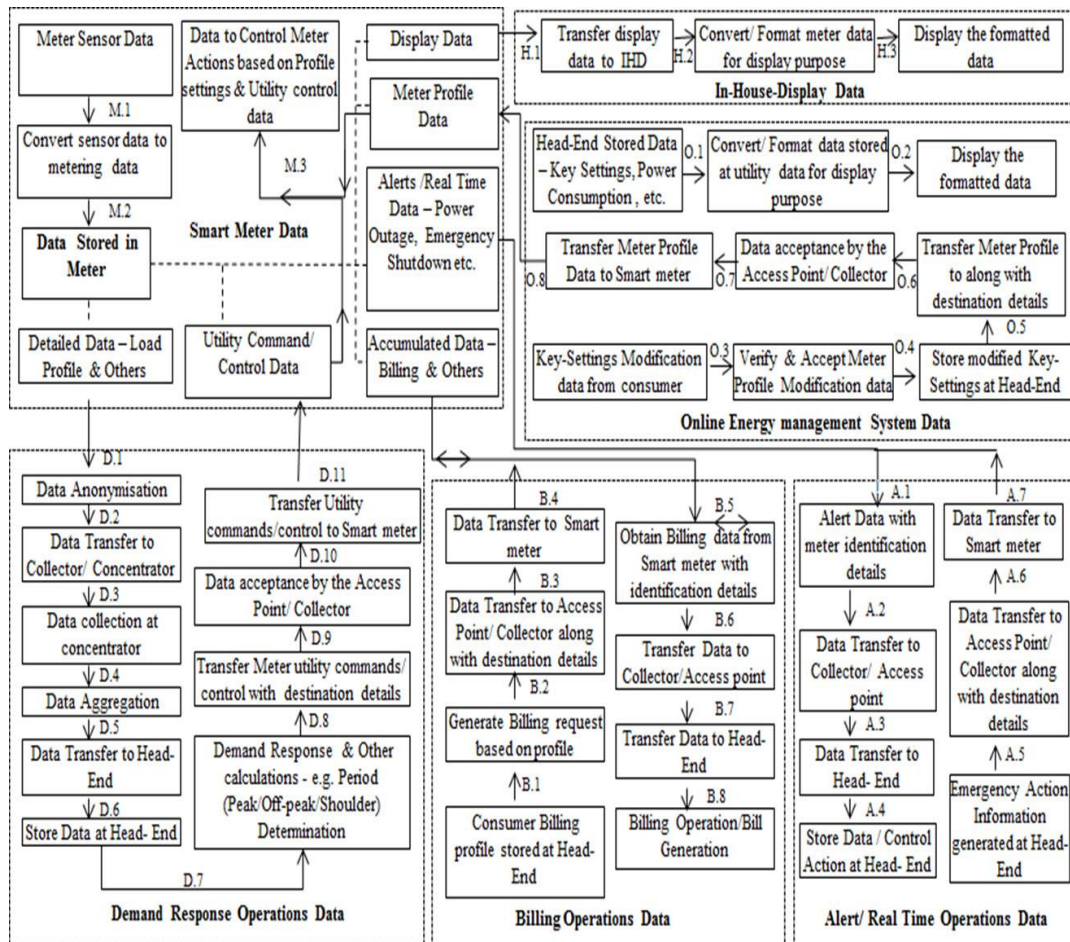


Fig. 2. Abstract Data Flow Model for Smart Metering System

Table 5. Security and Privacy requirements for Meter Data at each point of flow

Security and Privacy requirement		
General requirement		
G.1	There should be measures to ensure accuracy in data conversions and calculations. The integrity and authenticity of the data should be assured.	
G.2	During data transfer, there should be measures to prevent loss and corruption. There should be measures to prevent interception and tampering. The integrity, authenticity and confidentiality of the data should be assured.	
G.3	At various stages metering data will require formatting. Correct profiles and settings have to be chosen for each formatting to provide meaningful information. The integrity and utility of data should be assured.	
G.4	During data storage there should be measures to prevent loss and corruption. There should be measures to ensure the storage is tamper proof. The integrity, authenticity, confidentiality utility of data should be assured.	
Point		Apply
Smart Meter Data		
M.1	Readings from the meter sensors are converted to metering data.	G.1
M.2	The converted sensor data is stored in meter.	G.3 G.4
M.3	Data to control meter operations (e.g. cycling the load, service disconnect etc.) are derived from meter profile setting and commands obtained from the head-end. There should be measures to ensure that the control information is accurately derived based on the priorities set in meter profile. This data is very critical as it has the capability to modify meter operations and even cause disruption of service.	G.1
Demand Response Operations Data		
D.1	For demand response, the identification details of the consumer operations are not essential. To ensure privacy the data should be anonymised. This will reduce consumer concerns of being profiled from frequently communicated data from the meter.	G.1
D.2	The retrieved data is transferred from meter to collector. The data may undergo formatting before transfer.	G.2 G.3
D.3	The linked collector should receive the data after verification.	G.2
D.4	Data aggregation should be done to the demand response data received from multiple end-points linked to a collector. This will further secure the system from privacy threats as the data that is transferred further up the system will be linked to the collector and not a particular individual.	G.1
D.5	The aggregated data should then be transferred to the head-end.	G.2 G.3
D.6	The received data should be accepted and stored at head-end. The data may require conversion to the format suitable for storage.	G.3 G.4
D.7	Based on the interval data, the demand response and related calculations should be made and control operations (TOU determination, breaker and LC relay operations, planned outages) need to be determined.	G.1
D.8	Operation information from utility needs to be transferred along with destination details. As one provider may have many linked collectors, it is essential that control data is matched with the exact collector.	G.3
D.9	The control commands could be broadcasted or sent specifically to the collector. In either case the collector should verify the destination details and accept the data.	G.2 G.1
D.10	The received control commands are sent to all meters linked to the collector.	G.2 G.3
D.11	As data sent to head-end is anonymised and aggregated, the demand response operations will be for all meters linked to the collector. The command operations received from the collector gets stored as utility operations data and after verifying with meter profile data, the meter control actions will be generated.	G.4 G.3 G.1
Billing Operations Data		
B.1	The consumer billing profile data should trigger a billing request based on settings.	G.1
B.2	Billing request generated at utility needs to be transferred along with meter identification details. The meter identification details must be able to locate the linked collector.	G.2 G.3
B.3	As there are meter identification details, the billing requests need to be only transferred from collector to the specific meter.	G.2 G.3
B.4	On reception of billing request, the meter should trigger functionality to retrieve billing data.	G.1
B.5	The fetch process should extract the necessary information from the stored accumulated data.	G.1 G.3
B.6	The retrieved data may be formatted and then transferred from meter to collector.	G.3 G.2
B.7	Data received from the collector is transferred the head-end.	G.2

B.8	The billing data needs to be stored at the head-end. The data may require further conversion to the format suitable for storage. Using the received data, billing statement needs to be issued to the consumer.	G.3 G.4 G.1
Alert/ Real-Time Operations Data		
A.1	The meter has standard set of events that trigger alerts and other events can also be programmed to create an alert. Standard events include power outage and programmable events include variation in QoS where the thresholds are set by the consumer or provider. When such events are triggered, the meter should trigger functionality to immediately generate alert.	G.1
A.2	The retrieved data may be formatted and then transferred from meter to collector.	G.3 G.2
A.3	Data received from collector is transferred head-end.	G.2
A.4	The alert data should either trigger correction measures automatically or notify the utility provider to take necessary actions. This data should also be stored at the head-end and may require formatting before storage.	G.1, G.3 G.4
A.5	If there are critical situations at the head-end, such information should also be informed to the consumer in the form of alerts, so that consumer can be prepared for the situation. For e.g. if there is planned outage, it should be communicated to the consumer in real-time. Such events should immediately generate alerts and this information from utility needs to be transferred along with destination details.	G.1 G.3
A.6	The information from head-end could be broadcasted or sent specifically to the collector. In either case, the collector should verify the destination details and accept the alert data.	G.2 G.1
A.7	The data from the collector could be sent to a specific meter or to all linked meters. In either case, the meter should verify the destination details and should only accept the alert data if the credentials match.	G.2 G.1
In-House-Display Data		
H.1	The meter will have a list of items that can be chosen to be displayed. The usual display items includes, instantaneous and cumulative consumption, import energy, export energy, alert data etc. These can be programmed to the meter profile's display settings. The data for items chosen should be extracted from the stored meter data.	G.1
H.2	Display data is transferred from meter to IHD.	G.3 G.2
H.3	As IHD is meant to enhance consumer understanding of energy usage and choices, the raw data from meter needs to be processed to be informative. There should be options in IHD to set thresholds for relevant display items, so that it could alert the consumer if the thresholds are breached.	G.1 G.3
Online Energy Management System Data		
O.1	Through online energy management systems, any end-user related data that is stored at head-end can be made available to the respective consumer. This system should provide user the opportunity to verify meter data in their premises and that stored at the back-end. The information available through this system can easily profile or identify a consumer; hence like any other online management system, this system should be highly secure.	G.4
O.2	The raw data stored in Head-End from meter needs to be processed to be informative. The data conversion and other functions provided should be accurate and tamper proof.	G.1 G.3
O.3	There should be secure option to modify meter profile settings and only the key settings should be transferred to the Head-End. The head-end should be able to accurately verify the source before accepting the data.	G.2 G.1
O.4	The received data should modify the profile settings stored at the head-end. The data may require conversion to the format suitable for storage.	G.1 G.3 G.4
O.5	After storage at Head-End, the modified meter profile needs to be transferred to collector along with meter identification details.	G.3 G.2
O.6	The collector should be able to verify the meter credentials and accept the profile data of a linked meter.	G.1
O.7	As there are meter identification details, the profile data need to be only transferred from collector to the specific meter.	G.2 G.3
O.8	The meter should verify the destination details and if matched, should accept the modified the meter profile.	G.1 G.4

4. Conclusions and Implications

Smart metering projects are at risk of consumer rejection, and investment failure. Research has identified that subjective loss of control can lead to negative consumer emotions resulting in a lower likelihood of acceptance of a smart meter. This paper has identified ways in which

consumers' privacy and choice concerns about data that is extracted and transmitted from a smart meter could be reduced. It has also proposed a Smart Metering System Architecture and abstract data flow model that identifies security and privacy requirements to ensure consumer control and choice. This addresses the key requirements identified at the beginning of the paper. It builds on prior work by adopting a consumer perspective on data aggregation and anonymisation, and providing a framework, and checklists of features that need to be delivered by the meter manufacturers.

New projects can adopt the conceptual design presented above. This will enable technical analysis and field-piloting, both of which are essential further steps in validating the proposition. In addition, the architecture and data flow model provide a basis for evaluating existing products, enabling projects to adapt their designs towards this model. This will reduce project risk, increase adoption, improve return on investment, and even salvage some projects from impending disaster.

We intend extending this work, in order to identify the best security measures that would be feasible for different contexts such as geographical location, density of population and the communication technology used.

References

1. ABC News: Smart meters could be abandoned. In: Australian Broadcasting Corporation Online News, (2010).
2. Bayar, T.: Will Germany Reject Smart Meters?. In: Renewable Energy World, (2013)
3. Beier, G., Spiekermann, S., and Rothensee, M.: Die Akzeptanz zukünftiger Ubiquitous Computing Anwendungen. In: Mensch und Computer im Strukturwandel, A. Heineke and H. Paul (eds.), pp. 145-154, Oldenbourg, Munich (2006).
4. Berihun, N. G., Alavoine, F.: Smart Metering Scenario CORAS Method. (2013).
5. Berthier, R., Sanders, W. H., Khurana, H.: Intrusion detection for advanced metering infrastructures: Requirements and architectural directions. In: First IEEE International Conference on Smart Grid Communications (SmartGridComm), pp. 350-355, (2010).
6. Betz, J.: 'Smart' Meters Under Fire as Electric Bills Soar. In: Convention for the Protection of Human Rights and Fundamental Freedoms as amended by Protocol No. 11. In: WFAA, (2010).
7. Chinnow, J., Tonn, J., Bsfuka, K., Konnerth, T., Albayrak, S.: A tool set for the evaluation of security and reliability in smart grids. In: Smart Grid Security, pp. 45-57, Springer Berlin Heidelberg (2013).
8. Fan, Z., Kulkarni, P., Gormus, S., Efthymiou, C., Kalogridis, G., Sooriyabandara, M., Chin, W. H.: Smart grid communications: Overview of research challenges, solutions, and standardization activities. In: Communications Surveys & Tutorials, IEEE, 15(1), pp.21-38, (2013).
9. Fang, X., Misra, S., Xue, G., & Yang, D.: Smart grid—the new and improved power grid: a survey. In: Communications Surveys & Tutorials, IEEE, 14(4), pp.944-980 (2012).
10. Gungor, V.C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., Hancke, G.P.: A Survey on Smart Grid Potential Applications and Communication Requirements. In: Industrial Informatics, IEEE Transactions, vol.9, no.1, pp.28,42, (2013).
11. Karnouskos, S., Terzidis, O., Karnouskos, P.: An advanced metering infrastructure for future energy networks. In: New Technologies, Mobility and Security, pp. 597-606, Springer Netherlands (2007).
12. Kranz, J., Gallenkamp, J. V., Picot, A.: Exploring the Role of Control-Smart Meter Acceptance of Residential Consumers. In: Proceedings of the Sixteenth Americas Conference on Information Systems, pp.315. Peru (2010).
13. Kranz, J., Gallenkamp, J., Picot, A.: Power Control to the People? private consumers' acceptance of smart meters. (2010).

14. McKenna, E., Richardson, I., Thomson, M.: Smart meter data: Balancing consumer privacy concerns with legitimate applications. In: *Energy Policy*, 41, pp. 807-814, (2012).
15. Quinn, E. L.: Privacy and the new energy infrastructure. In: SSRN eLibrary, (2009).
16. Špindlerův, M.: How Smart metering pilot project lost illusions and ideas or nothing is just BLACK and WHITE!. Enel, (2012).
17. Wang, W., Xu, Y., Khanna, M.: A survey on the communication architectures in smart grid. In: *Computer Networks*, 55(15), pp. 3604-3629, (2011).
18. Yesudas, R., Clarke, R.: A Framework for Risk Analysis in Smart Grid - Perspective Based Approach. In: *Proc. 8th Int'l Conf. on Critical Information Infrastructures Security (CRITIS)*, Springer International Publishing, pp. 84-95, Amsterdam (2013).
19. Zafar, N., Arnautovic, E., Diabat, A., Svetinovic, D.: System security requirements analysis: A smart grid case study. In: *Systems Engineering*, 17(1), pp.77-88, (2014).

Performance Journey Mapping: A Tool-supported Framework for Service Performance Assessment in SMEs

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Abstract

This paper introduces performance journey mapping as a service performance assessment framework for small and medium sized enterprises (SMEs) as well as its corresponding tools – the performance journey map (PJM) and the performance index. The PJM is a visual tool whereas the performance index represents a key performance indicator (KPI) pool. The framework is developed by connecting the specific characteristics of SMEs to contributions from goal-setting theory and involves adapted components from service management research, e.g. the service strategy scorecard, ITIL, etc. Service design methods are adapted and applied for the visual components. The paper provides an outlook on the evaluation design for the framework based on method triangulation in a case study setting.

Keywords: Performance Measurement, Service Performance Assessment, Service Performance Management Systems.

1. Introduction

The ever increasing importance of services for the economy necessitates a thorough understanding of service performance and valid instruments for its measurement. Over the course of the past decades the contribution of services to the GDP increased and in 2013 services accounted for 63.6 % of the global GDP [3]. In accordance with the current service research literature services are considered in the light of a service-dominant logic [25,26]. Due to both their heterogeneity and the fact that value is created and captured in the course of their consumption, it is a challenge to measure service performance. Traditional controlling tools, e.g. the balanced score card (BSC), often neglect the specific characteristics of services as they are designed for a goods-dominant logic. Several approaches to address this issue exist, e.g. SERVQUAL, ITIL, etc., which suggest measurement systems tailored for services or more specifically IT-services. These require either the implementation of highly sophisticated tools and/or techniques or they are tailored to a specific industry. Moreover they

lack acceptance-triggering characteristics such as ease of use, usefulness, and the like. Those properties would foster their adoption by individuals in organizations [27], which is especially challenging for small and medium-sized enterprises (SMEs) where decisions are usually depending on the opinions and perceptions of a small number of individuals. Moreover prior research indicated that SMEs usually do not implement high-level controlling and management instruments that enable utilization of the renowned performance measurement systems (PMSs) [8].

Taking these factors into account it can be concluded that there is a lack of acceptable service PMSs or instruments suitable for the particular needs of SMEs. The main objective of the presented research project is, thus, the creation of a performance assessment framework that can be adapted to different industries as well as different enterprise environments. The identified research gap is addressed by a theory-driven approach to fulfill the requirements of acceptability. Thus, the framework will be supported by tools that are both easy to implement and enabling co-creation of the individual performance measurement goals within the SMEs. Referring to the goal-setting theory [18] the co-creation aspect will also allow for higher acceptance of the PMS as well as the corresponding benchmark goals and improve performance in addition to its measurement. Design and evaluation of the performance assessment framework are conducted in alignment with the design science principles provided by Hevner et al. [11].

In the remainder of this paper alternative approaches to PMS as well as managerial instruments of performance management are discussed first. The subsequent section is dedicated to the research methodology that was applied as well as design methods and theoretical foundations that influenced this project. Section 4 outlines the framework and the supporting tools, which are discussed in the context of relevant theories in the subsequent section. The paper concludes with some general remarks on findings and an outlook on future research and development.

2. Literature Review and State of Practice

Measuring and enabling high levels of service performance has been targeted by academic publications and tools as well as commercial applications and tools. Predominating approaches of performance measurement and management are outlined and discussed with regard to their applicability in SMEs below.

One of the most popular instruments to measure the abstract and elusive service quality construct is the SERVQUAL scale. Although it was intended to develop a measurement tool broadly applicable in the service industries [21] research has shown that the five underlying quality dimensions are varying across them [5]. Moreover both the reasonableness and purposefulness of the perception-minus-expectation measurements were questioned which led to the development of alternative, performance-based measures such as SERVPERF [4]. The factor instability problem, however, remained unresolved [5] – see e.g. [16] for further theoretical and empirical issues raised during the last 20 years. To apply the instrument in a generic way literature suggests to either develop adapted industry-specific versions or to perform reliability and validity analyses after data collection. This implies that statistical capabilities need to be anchored within SMEs in any case as both the original and a new scale need to be carefully validated.

The IT Infrastructure Library (ITIL) is a reference model capturing best practices regarding service management and designed in such a way that it can be adapted to the specific business environments' and organizational strategies' needs [23]. However, the focus of existing literature on the implementation of ITIL is on large firms whereas SMEs are largely neglected. The framework exhibits a complex and resource-demanding structure of defining processes, roles, etc. Tradeoffs in terms of adaptations and downscaling need to be made in the context of SMEs. Empirical studies demonstrating ITIL's impact on enterprises are scarce, especially in the field of quantitative evaluation. First steps into this direction have been made by McNaughton et al. [19] who developed a multi-layer evaluation framework in

order to objectively and subjectively assess the benefits resulting from the implementation of ITIL. The practical application's results are still pending, though.

The BSC [13] is a management tool that is based on cause-effect relationships. Its principles have been transferred to the context of service management in the form of a service strategy scorecard [14]. The service strategy scorecard adopted the basic dimensions from the BSC: finance, customers & partners, business processes, and learning (adapted from "potential" in the original outline). A causal analysis of the four dimensions was conducted among SMEs with regard to software-as-a-service adoption. The results indicate support of the underlying assumptions with regard to causal relationships between the dimensions [17].

3. Methodology

The development of the performance assessment framework and the supporting tools is based on design science principles as provided by Hevner et al. [11] to ensure a scientific process and outcome of the present research project. Hevner and Zhang [12] transfer the principles to human-computer interaction and outline an iterative approach consisting of three cycles:

- The relevance cycle will provide requirements of practical relevance for the evaluation of the designed artifact. In the present case the main evaluation criterion is the ability of the developed framework and its corresponding tools to support SMEs in their performance measurement activities. The relevance criterion is fulfilled if the framework is accepted and used by individuals within the organization and supports their specified individual performance measurement needs. In a first iteration from Mai to June 2013, twelve semi-structured interviews with SMEs across two different industry sectors (automation technologies and mechanical engineering as well as information and communication technologies) were conducted. The primary goal was to gain first insights with regard to currently employed methodologies and techniques for performance measurement/assessment of services. Immediate anecdotal evidence was obtained that (i) there seems to be very little consensus about what aspects and factors constitute the performance of service at all and (ii) there is a lack of systematic approaches to conduct such service performance analysis, especially among SMEs.
- The rigor cycle ensures contribution to the knowledge base and the innovative character of the research project. In the course of the present research an extensive analysis of performance measurement methods, systems, and instruments was conducted. In addition, the performance assessment framework and its tools were created and analyzed in the light of the goal-setting theory. The latter is an approach for enhancing motivation in work settings. It is based on 35 years of empirical research revealing that goals need to be specific and difficult in order to lead to better motivation and performance. According to the theory best results can be achieved with goals being moderately difficult, neither too easy nor too hard to accomplish [18]. The evaluation design that is briefly outlined in the final section of this paper is based on previously validated evaluation criteria and methods taken from the technology acceptance model [6], goal-setting theory [18], and PMS quality criteria [20].
- The internal design cycle connects the methods used to build and evaluate from the rigor cycle and the requirements from the relevance cycle in a rapid iteration between artifact building activities and feedback mechanisms. A co-creation approach is applied utilizing method triangulation to build and evaluate the artifact iteratively. Early prototypes of the performance assessment framework are tested in SMEs and evaluated with the users, i.e. employees of the SME to obtain instant feedback. This measure ensures that future users of the artifact are involved from the very beginning of the creation process. The visual component of the performance assessment framework is created according to renowned mapping methods from service design. Customer journey maps [22] are a commonly used tool for the visualization and design of customer experiences. Its basic concepts - activities, touch points, and lines

of interaction - are transferred into a company perspective and enhanced by company-specific additives.

4. Assessment Framework

According to Bourne [2] there is a strong consensus in contemporary PMS design research that good performance measures are tightly connected to the business strategy. Moreover all measures should be derived from the corporate strategy. This can hardly be realized for SMEs as many of them do not have an explicit strategy. They have little to no resources at their disposal for data collection and basically tend to emphasize productive activities [8]. Focusing on the SMEs' experience (and business) realm and their actual needs a bottom-up-approach which helps designing performance measures that are tightly connected to their daily business and supports SMEs to improve rather than to monitor their performance was developed.

Instead of deriving performance goals from the company's strategy the starting point is the firm's core service, thus, taking its service process as a basis and the internal stakeholders as reference points. The aim is to create a PMS with full coverage of the service process. For this purpose a three-step-process is employed as outlined in Figure 1: Step 1 is an analysis of the current state identifying the performance measures already in use. Step 2 proceeds from the status quo to the desired state. Gaps in the performance measurement are identified and covered. Step 3 completes the PMS design by adding target values for the new measures. The three steps are conducted in form of one or two workshops (depending on the availability of an existing service blueprint) within the SME involving the relevant stakeholders of the service delivery process in question.

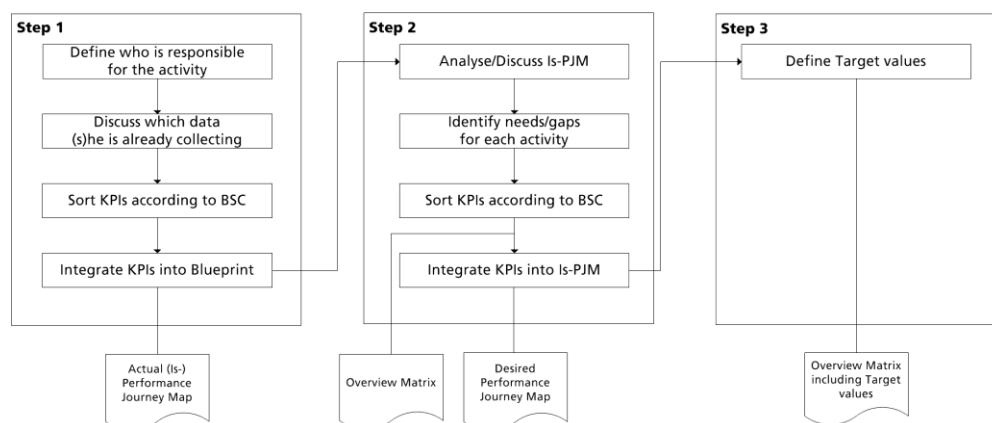


Fig. 1. Outline of the three-step performance journey mapping process.

At the beginning of Step 1 performance measures already in use are collected. Afterwards a service blueprint is utilized to outline the selected core service. A service blueprint [24] is a visual representation of the service process consisting of different layers showing customer touch points, activities, and processes from both customer and company perspective. The activities and processes on company side are in the center of the further proceedings. In a first iteration one after another is focused on and examined: *Which stakeholder is involved? Which measures are already used by them?* The identified measures are listed in an overview table and assigned to the dimensions of the original BSC (financial perspective (*finance*), internal business perspective (*process*), customer perspective (*market*), and innovation and learning perspective (*potential*) [13]). Subsequently the content of the resulting overview table is merged with the service blueprint in a new graphical representation which is depicting the performance measure coverage of the service process and giving insights in the balance or imbalance of current measures among the BSC dimensions at the same time. The resulting representation is the *performance journey map (PJM)*. Measurement gaps appear in the PJM in form of activities without any performance measurement at the moment or activities with imbalanced measurement according to the BSC dimensions.

Step 2 is initiated by a thorough collection of needs and requirements with regard to future performance measurement, followed by the second iteration along the service process. This iteration focusses on the question "What (else) could or should be measured there?" for each activity within the process. Especially measurement gaps that were identified in the course of the first iteration are addressed. The results are discussed while using the *performance index* as a pool of customized measures. The new measures are listed in an overview table, assigned to the dimensions of the BSC, and integrated in the former PJM. The resulting PJM provides a holistic overview of all (current and future) performance measurement activities connected to the service.

As new measures have been integrated in the PJM Step 3 addresses data collection methods and the assessment of these measures. Once this challenge is resolved the target values can be defined and added to the overview list. The target values are defined by the respective stakeholders of the activity as they are the ones who will be measured against these goals. The final PJM is disposing an overview of the PMS and the overview list is dedicated to its operationalization.

The process is suggested to be applied in regular iterations, e.g. annually, to enable evolving performance measurement. This is necessary to ensure appropriateness for the current needs of an SME as well as effective benchmarking with competitors. At the same time the adaptive nature of the PMS will cause a lack of historic comparability within the SME but this is a negligible loss compared to the advantages of competitive performance benchmarking [7].

4.1. Performance Journey Map

The PJM is a supporting tool of the framework in form of a visualization of all performance measures for a service. It is related to the concept of the customer journey map [22] and enables a successive performance measure-oriented analysis and measurement development of the single activities along the service process. The customer journey map represents the perspective of the customer and their experiences of the service, whereas the PJM is the exact complement representing the internal perspective of the SME. Its main advantage lies within the integration of three critical perspectives in the context of performance measurement of services: the service process, the dimensions of the BSC, and the service stakeholders within the company, i.e. employees, managers, departments, business units, etc., who are involved in the service delivery process. Each of these perspectives is contributing to the PMS: Including the service process (represented by a service blueprint) allows for a thorough overview of measures along the process and hence promotes a high coverage. The integration of the BSC dimensions facilitates an overview of the distribution of measures. It reveals dominant dimensions and encourages the creation of a more balanced distribution. Finally the inclusion of stakeholders is increasing the prospects of success for the PMS implementation. Each employee decides if he or she accepts a measure and the corresponding benchmarking target with regard to its usefulness and ease of use according to TAM [27]. The non-acceptance of measures and consequently a lack of acceptance of the PMS will harm its implementation. This negative effect is intensified in the case of SMEs due to their small number of employees. In addition, the early consideration of stakeholders fosters that the right person is claimed responsible for the measure, a powerful premise for the person's motivation and, thus, for his or her performance according to goal-setting theory [18].

The PJM includes a modified version of the service blueprint where all activities/processes on company side are aligned in a horizontal order without overlapping. A vertical extension of the service blueprint integrates the dimensions of the BSC. In the resulting matrix the single measures are placed according to their allocation along the service blueprint and their attributed BSC dimension. The measures are represented by a stickman figure and an identification number referring to the overview table of measures. The stickman represents the responsible stakeholder and the number provides a unique reference to the measure. Two different colors for the stickman figures enable a distinction between measures that have already been in use (white) and those which have been added (grey). The PJM in

Figure 2 is the result of an exemplary application of the performance assessment framework on the simplified process of organizing a workshop in a conference context.

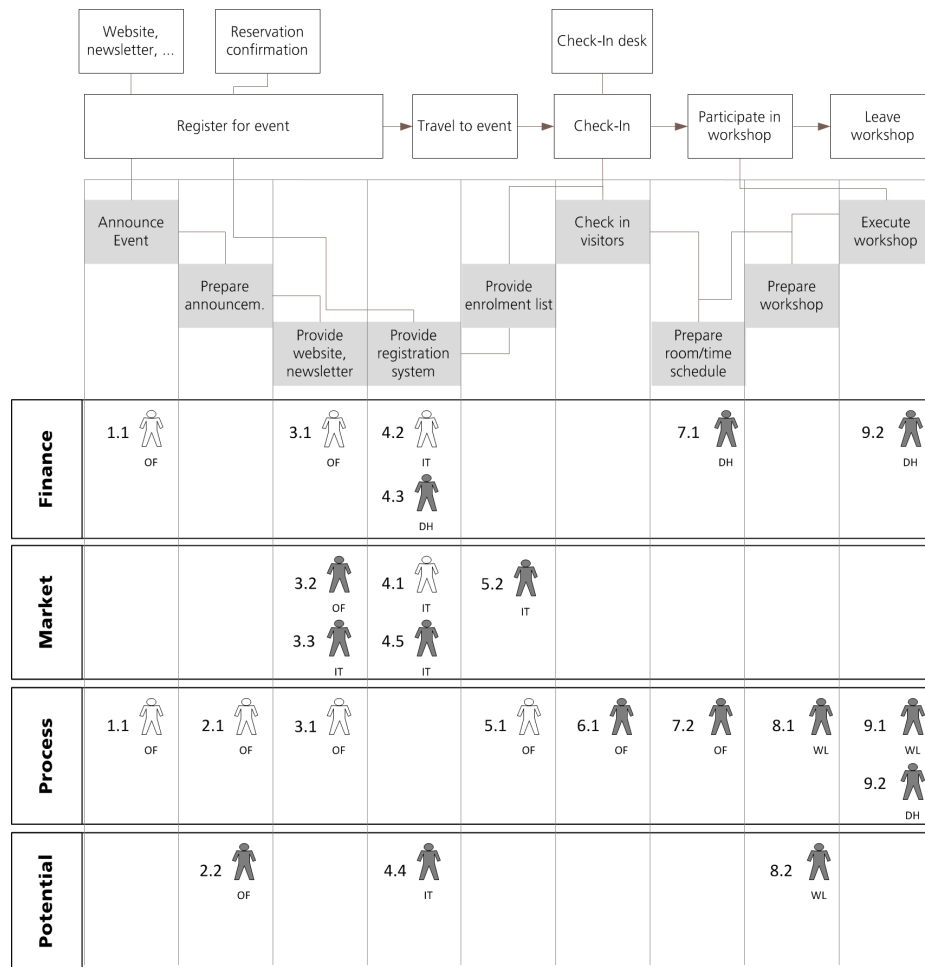


Fig. 2. Exemplary PJM based on a conference’s workshop participation/organization process.

The PJM is the basic tool fostering the process from the current to the future state of performance measurement in the proposed framework. In the first iteration it depicts the current state and already gives an overview of coverage and balance providing insights in potential dominances and gaps. Later it is used for modelling the performance measurement’s future state which aims to resolve the dominances and cover the gaps.

4.2. Performance Index

Varying definitions of the term key figure exist according to current literature. Generally speaking, key performance indicators (KPIs) aid companies to represent complex business information in a comprehensible manner for quality decision-making. Before being able to select a number of helpful KPIs it is necessary for a firm to have a common understanding and a clear idea of what they want to achieve by means of business performance measurement [2]. During the conception and design of the PJM a large number of KPIs was identified based on a literature review, including amongst others [19], [9], and [15]. This pool was too large to be supportive in the collaborative process of working out a PJM together with companies. Thus, the KPI pool had to be significantly reduced by means of a filtering process based on expert knowledge on SME particularities in the first place. The filtering process finally led to a KPI pool composed of a manageable number of key figures that can be concretely addressed when implementing a performance journey mapping process within SMEs.

The outlined bottom-up approach allows for tailored performance measures and benchmarking targets while using a common terminology as suggested in the performance measurement manifesto by Eccles [7]. The performance index provides this mutual basis as it includes commonly used metrics and measures. The pool of KPIs is intended to grow over time. At the same time the application of a joint performance index will enable measurement choices of single SMEs with regard to benchmarking against competitors.

5. Discussion and Outlook

If the implementation of PMS is performed in a three-phase-process, as proposed by Bourne et al. [2], this paper is focused on the design phase. However, research in the field of evaluation or assessment of PMS design is scarce. Bititci et al. [1] provide an audit method which is based on integrity and deployment between the various business areas as core criteria. These principles might be applicable in large companies but can hardly be put into practice in SMEs, as many of them may not even have more than one business area. Prior research (e.g. [10]) indicated that PMS design can only excel if its measures are derived from the company's strategy or the company's objectives respectively. Considering the PJM this requirement cannot be fulfilled as the starting point for the creation of the PJM is not the business strategy but the service process. Neely et al. [20] differentiate between the PMS design process and its output. In addition to criteria related to the design process they gathered a set of key characteristics which should be featured by the measures as process output. These characteristics can be used to evaluate the measures of any PMS no matter which design process had been engaged. The suggested framework and its corresponding tools – the PJM and the performance index – are therefore going to be evaluated with regard to the level of fulfillment of these quality criteria.

In order to obtain meaningful preliminary results it is planned to apply method triangulation (participatory observation, survey, and functional analysis) in the context of a case study design. For the case study a workshop is planned within an SME that is specialized in secure software services. An actual service delivery process will be utilized for the prototypical implementation of the performance assessment framework. The workshop will be conducted with about five to ten employees of the company who will provide the project team with immediate feedback on the acceptability (i.e. TAM) of the framework and tools as well as motivational aspects of the measurement goals that were set (i.e. goal-setting theory) in the course of the workshop. In addition, the workshop will be observed to ensure that acceptance and motivation related information is captured from more than one source for the re-design of the framework and its tools. The resulting PMS for the particular service is then analyzed with regard to Neely et al.'s criteria. The results from this case study will feed into the next iteration of the design cycle. Moreover interesting insights regarding the opportunities of utilizing goal-setting theory and the technology acceptance model to co-create performance measurement systems in SMEs are expected.

References

1. Bititci, U.S., Carrie, A.S., McDevitt, L.: Integrated Performance Measurement Systems: A Development Guide. *Int. J. Oper. Prod. Man.* 17 (5), 522-534 (1997)
2. Bourne, M., Mills, J., Wilcox, M., Neely, A., Platts, K.: Designing, Implementing and Updating Performance Measurement Systems. *Int. J. Oper. Prod. Man.* 20 (5), 754-771 (2000)
3. CIA World Factbook (2014), <https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html>. Accessed March 27, 2014
4. Cronin, J.J., Taylor, S.A.: Measuring Service Quality: A Reexamination and Extension. *J. Marketing* 56 (3), 55-68 (1992)

5. Cronin, J.J., Taylor, S.A.: SERVPERF Versus SERVQUAL: Reconciling Performance-based and Perceptions-Minus-Expectations Measurement of Service Quality. *J. Marketing* 58 (1), 125-131 (1994)
6. Davis, F.D.: Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quart.* 13 (3), 319-340 (1989)
7. Eccles, R.G.: The Performance Measurement Manifesto. *Harvard Bus. Rev.* 69 (1), 131-137 (1991)
8. Garengo, P., Biazzo, S., Bititci, U.S.: Performance Measurement Systems in SMEs: A Review for a Research Agenda. *Int. J. Manag. Rev.* 7 (1), 25-47 (2005)
9. Gladen, W.: Performance Measurement (in German). Gabler, Wiesbaden (2011)
10. Globerson, S.: Issues in Developing a Performance Criteria System for an Organization. *Int. J. Prod. Res.* 23 (4), 639-646 (1985)
11. Hevner, A., March, S.T., Park, J., Ram, S.: Design Science in Information Systems Research. *MIS Quart.* 28 (1), 75-105 (2004)
12. Hevner, A., Zhang, P.: Introduction to the AIS THCI Special Issue on Design Research in Human-Computer Interaction. *AIS Transactions on Human-Computer Interaction* 3 (2), 56-61 (2011)
13. Kaplan, R.S., Norton, D.P.: The Balanced Scorecard: Measures that Drive Performance. *Harvard Bus. Rev.* 70 (1), 71-79 (1992)
14. Kreuzer, E., Schäfer, A., Aschbacher, H.: The Concept of Service Strategy Scorecard - An Integrated Approach for Lean Service Engineering and Service Improvement: Theoretical Framework and Implications for Service Science. In: Proceedings of the 2011 Naples Forum on Service - Service Dominant Logic, Network & Systems Theory and Service Science. Naples (2011)
15. Kütz, M.: Kennzahlen in der IT (in German). dpunkt Verlag, Heidelberg (2009)
16. Ladhari, R.: A Review of Twenty Years of SERVQUAL Research. *International Journal of Quality and Service Science* 1 (2), 172-198 (2009)
17. Lee, S., Park, S.B., Lim, G.G.: Using Balanced Scorecards for the Evaluation of "Software-as-a-Service". *Inform. Manage.* 50 (7), 553-561 (2013)
18. Locke, E.A., Latham, G.P.: Building a Practically Useful Theory of Goal Setting and Task Motivation: A 35Year Odyssey. *Am. Psychol.* 57 (9), 705-717 (2002)
19. McNaughton, B., Ray, P., Lewis, L.: Designing an Evaluation Framework for IT Service Management. *Inform. Manage.* 47 (4), 219-225 (2010)
20. Neely, A., Mills, J., Platts, K., Richards, H., Gregory, M., Bourne, M., Kennerley, M.: Performance Measurement System Design: Developing and Testing a Process-based Approach. *Int. J. Oper. Prod. Man.* 20 (10), 1119-1145 (2000)
21. Parasuraman, A., Zeithaml, V.A., Berry, L.L.: SERVQUAL: A Multiple-Item Scale for Measuring Consumer Perceptions of Service Quality. *J. Retailing* 64 (1), 12-40 (1988)
22. Rawson, A., Duncan, E., Jones, C.: The Truth About Customer Experience. *Harvard Bus. Rev.* 91 (9), 90-98 (2013)
23. Rudd, C., Office of Government Commerce: ITIL V3 Planning to Implement Service Management. The Stationary Office, Norwich (2010)
24. Shostack, G.L.: Designing Services that Deliver. *Harvard Bus. Rev.* 62 (1), 133-139 (1984)
25. Vargo, S.L., Lusch, R.F.: Evolving to a New Dominant Logic for Marketing. *J. Marketing* 68 (1), 1-17 (2004)
26. Vargo, S.L., Lusch, R.F.: Service-dominant Logic: Continuing the Evolution. *J. Acad. Market. Sci.* 36 (1), 1-10 (2008)
27. Wallace, L.G., Sheetz, S.D.: The Adoption of Software Measures: A Technology Acceptance Model (TAM) Perspective. *Inform. Manage.* 51 (2), 249-259 (2014)

Conceptualizing Initial Trust in Internet Banking Services: A Pilot Study

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Abstract

The adoption rate of Internet banking services (IBS) is considered to be relatively high in the developed countries; which is not the case for developing countries. The lack of trust plays a vital role in discouraging users from adopting IBS. Therefore, initial trust could be the starting point of making customers comfortable processing their banking transactions online. This study aims to propose a conceptual model of initial trust in IBS in developing countries. The proposed model integrates its constructs from: the trust literature, diffusion of innovation theory (DoI), and Hofstede's national culture theory. This paper also aims to develop and validate a research instrument in order to examine the proposed model. We conducted a pilot study in Jordan, which is one of the developing countries, and refined the model and its instrument based on the obtained results.

Keywords: Initial Trust, Developing Countries, National Culture, Customer Behavior.

1. Introduction and Background

Internet banking services (IBS) defined as the bank's ability to deliver their services electronically. It started in the early 1980's [6]. The adoption of IBS offers many advantages such as: saving time and cost, availability of the services at any time, and convenience. In developed countries, the usage level of IBS is quite high compared to developing countries. A study published by Statista.com in April 2012 showed that countries in the Middle East and Africa have the lowest rate of IBS penetration [29]. The following figure shows the penetration rate of using IBS for different regions of the world.

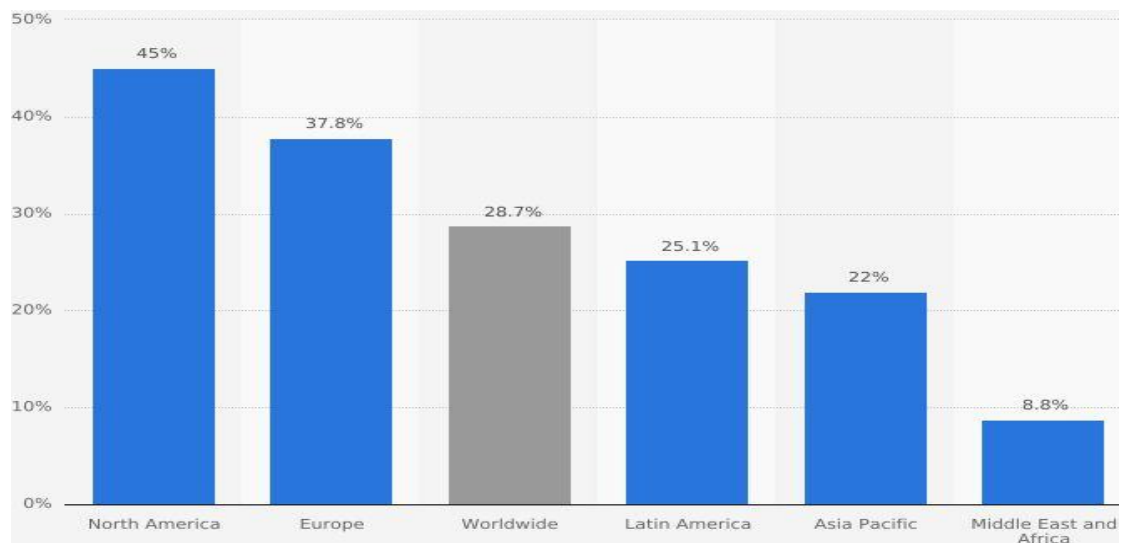


Fig. 1. Global online banking penetration in April 2012, by region (in percent)

The figure above shows a big gap in IBS penetration between developed and developing countries. Understanding the factors that affect IBS adoption is important to justify this large gap. Previous studies argued that many factors affect the penetration rate of using new technological innovations; and they have particularly considered trust to be the most influential factor to adopt new innovations [13, 24, 23] and IBS in particular [17].

Obviously, winning the customer's trust could be the first step to increase the level of IBS adoption. In the context of developing countries, it is important to focus on the first stage of trust, which is known as initial trust. Consequently, investigating initial trust in IBS in developing countries will enhance our understanding of the problem and suggest valuable solutions for it. Therefore, in this paper we focus on initial trust in IBS in developing countries to fill the gap of studies between developed and developing countries.

There are two objectives for this paper: firstly, identify and determine the factors that affect initial trust in IBS to propose a unified model for developing countries. Secondly, developing and validating a research instrument to examine the proposed model empirically. In this paper, we selected Jordan, as one of the developing countries, to validate the developed instrument.

This paper is organized as follows. Section 2 provides a review of related studies. Section 3 presents the research model and the developed instrument of this research. Section 4 presents the pilot study and its major results. Section 5 discusses the outcomes of the pilot study. Finally, the paper rounds off with a conclusion.

2. Literature Review

Trust plays a significant role in affecting customer's behavior to adopt new innovations. In this section we discuss previous studies, which focus on initial trust in online environment, especially IBS. In addition, we present a unified model based on existing studies in the literature, diffusion of innovation theory, and Hofstede's national culture theory.

2.1. Initial Trust in Online Environment

Many studies agreed that initial trust is the milestone of a successful relationship between users and unknown e-vendors [24, 23, 16]. Initial trust is defined by McKnight et al [24] as the construct that measures trust level at the beginning of new relationship and before the customers built their attitude on that relationship.

A systematic literature review for initial trust in online environment was conducted in [2]. The review revealed that most of previous studies were conducted in developed countries, while only a few studies have focused on developing countries. Moreover, the reviewer also showed conceptual models were mainly constructed on the trust literature and other technological theories, such as diffusion of innovation theory (DoI). In addition, large portion of the literature investigated initial trust in online retailers, while internet and mobile banking was investigated in a limited number of studies [15, 17].

2.2. Factors Affecting Initial Trust

In this section, we identify factors that affect initial trust in developing countries and their significance.

Initial Trust Antecedents

Most of previous studies shared the investigation of five antecedents which are: personality based-trust (also known as propensity to trust or disposition to trust), cognition based-trust, institution based-trust, economic trust base, and knowledge based-trust [13]. Kim [16] argued that initial trust is influenced only by personality based-trust, cognition based-trust, and institution based-trust; as initial trust does not depend on previous experience, which is argued to be linked to economic and knowledge based-trust.

In this study we will use disposition to trust as a concept of personality based trust. It is defined as the tendency to believe in the positive attributes of others resulting in trusting them [24]. Many empirical studies found that disposition to trust plays an important role in forming initial trust [24, 17, 16, 34], as it affects the perception of the individual to trust someone initially [10].

The second antecedent is cognition based-trust, which considers the first impression or meeting as the base to build the trust on it. In other words, cognition trust base uses the impression instead of the previous experience to build trust. Reputation is used in the literature to represent cognition based-trust, which was found to be a significant factor for affecting initial trust formation [30].

The last antecedent is institutional based-trust. Gefen et al [13] stated that the level of initial trust that the individual has is positively related to the perception that dealing with trustee is meeting a common standard. In addition, McKnight et al [23] mentioned that this antecedent has two predictors. Firstly, situational normality: it assumes that if the situation is normal, then the success is likely [20]. They examined situational normality and found it to be a significant factor. Secondly, structural assurance: which is studied in this paper from organizational and technological perspective. Moreover, previous studies found that technological structural assurance [13, 15, 17, 23, 24] and organizational structural assurance [20] have significant effect on initial trust. Technological structural assurance is defined as "The belief that the web has protective legal or technological structures that assure that web business can be conducted in a safe and secure manner" [24]. Organisational structural assurance, on the other hand represents the safeguards of a place such as promises, contract, regulations, and guarantees [20].

Diffusion of Innovation Factors

The literature indicates that two factors from diffusion of innovation theory influence the adoption of new innovation; relative advantages and compatibility. Rogers [27] defined relative advantages as those that new services offer rather than the existing service including: economic benefits, enhanced personal image, convenience and satisfaction. Relative advantages affect initial trust significantly and positively [15, 30].

Compatibility is defined as "The degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" [27]. Lin et al [21] stated that compatibility has significant and positive effect on customer's trust in 3G mobile banking services.

National Culture Factors

According to Leidner and Kayworth [19], the Hofstede's national culture theory is considered as the most widely used theory in the field of management information systems. Culture is defined as "the collective programming of the mind, which distinguishes the members in one human group from another" [14]. The relationship between national culture and trust was examined in the literature and found to be significant; where in [13] two dimensions of the Hofstede theory were examined. In this study, we will investigate the effect of all Hofstede's dimensions on initial trust. The following dimensions were introduced by Hofstede [14]: (i) Power distance index (PDI): the extent to which the less powerful members of group or society accept and expect that power is unequally distributed. (ii) Uncertainty avoidance index (UAI): the extent to which the members of group or society feel threatened by unknown situations. (iii) Individualism vs. collectivism (IDV): the extent to which individuals are integrated into groups. (iv) Masculinity vs. femininity (MAS): the extent to which gender roles are assigned in a culture. And (v) long-term vs. short-term orientation (LTO): a society's preference to be more forward looking or future oriented.

Although the culture effect is proven as a significant one on the adoption of new technological innovations [1], a few studies examined it on initial trust in an online environment. For

instance, [12] examined the effect of national culture effect on trust attitude and found it significant. Accordingly the national culture will be incorporated in this study.

Internet Related Factors

Previous studies examined additional factors to those which we mentioned earlier. This group consist of perceived security [23, 30, 3], perceived privacy[15, 19], and computer and internet self efficacy [3].

In this study, we define perceived security as the level in which the users feel that their information on the internet is secure. Previous studies considered security of online environment important for adopting new technological innovations [34]. Also, Susanto et al [30] stated that security in trust context has vital role in building trust or initial trust.

We define perceived privacy as the level in which users feel that their information on the internet is private. Susanto et al [12] examined the impact of perceived privacy and found it significant on customer's trust.

The influence of Computer and internet self efficacy has never been examined on initial trust. However, previous studies considered it as one of the factors that influence the adoption of new innovation [18]. Hence, this factor will also be incorporated in this study.

3. Research Model and Instrument Development

This section presents the proposed model and the first version of the research instruments.

3.1. Research Model

The literature provides some studies that investigate initial trust in IBS [17, 30] and in mobile banking [15]. This study extends the models of those studies to create unified model of initial trust in IBS. The key elements of the proposed model are adopted from the existed models. Figure 2 shows the elements of the proposed model elements and their relationships.

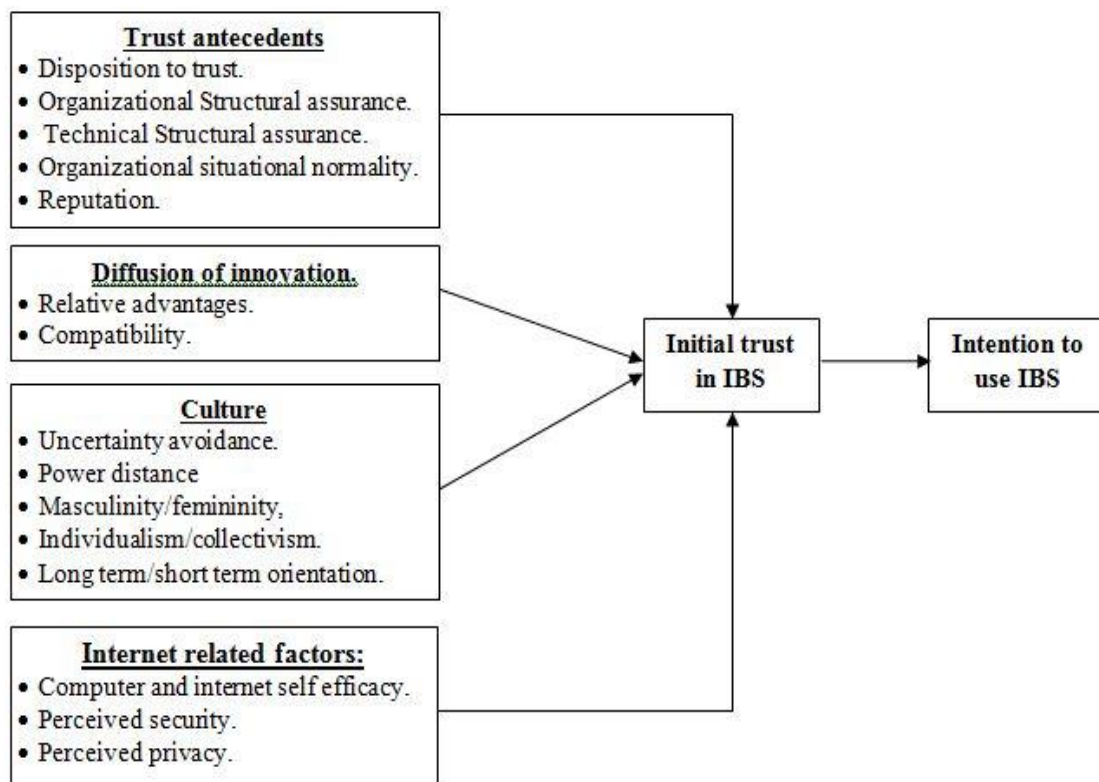


Fig. 2. Research model.

3.2. Research Instrument

The factors of our model are constructed based on the systematic literature review, as well as that we conducted and existing theories. The items of the instrument are adopted or adapted from previous empirical research. Each factor has three items or more to be measured as recommended by [9]. The following table explains the number of items for each factor and the source of those items.

Table 1. The first version of the research instrument.

Group name	factor	Number of Items	The source
Trust antecedents	Disposition to trust	4	[11]
	Organisational structural assurance	3	[20]
	Technological structural assurance	3	[24]
	Organisational situational normality	3	[23]
	Reputation	4	[9]
National culture	Power distance	5	[4]
	Uncertainty avoidance	5	[2]
	Individualism vs. collectivism	3	[2]
	Masculinity vs. femininity	3	[2]
	Long-term vs. short-term orientation	3	[2]
Diffusion of innovation theory	Relative advantages	4	[25]
	Compatibility	4	[25]
Internet related factors	Internet and computer self-efficacy	5	[33]
	Perceived security	4	[18, 7]
	Perceived privacy	5	[7]
Dependent variables	Behavioural intention to use	4	[15, 3]
	Initial trust	3	[32]
Total		65	

4. Pilot Study

The pilot study is defined as an experimental study aimed to complete the ‘trying out’ or pre-testing of a specific research instrument of investigation [5]. The importance of the pilot study is clearly shown in the research methodology books, such as [31]. Performing a pilot study helps in refining the research instrument and increasing the accuracy of the method and the anticipated results.

We conducted our pilot study in Jordan and targeted employees from the education sector as they are educated, have experience in using computers and the internet. 56 valid responses have been collected out of the 75 surveyed subjects.

In this pilot study, we started with validating the content of the instrument using face, content, and construct validity. Then, we conducted detailed item analysis (person’s correlation) techniques to find the correlation between variables in order to remove redundant variables. Finally, a reliability test is used to clean up and optimize the measure of each variable.

4.1. Instrument Validity

Validating the research instrument is considered essential before conducting the main survey. Different types of validity are used to assess whether the instrument is valid: face, content, criterion, and construct validity. However, face validity is considered the key of other types [28]. Face validity is defined as the level in which a group of measurement items represent the concept under investigation [28]. To assess the validity of the instrument under study; we sent the instrument to two PhD students and four expert in the field of management information system. The process is started by sending the questionnaire to two PhD students, who were asked to provide feedback on the wording of the items and their clarity level. The

items were refined based on the received comments and sent to the four experts to examine if the items properly represented the variables and their degree of ambiguity and redundancy. Finally, the instrument has been modified based on the experts' comments.

4.2. Correlation Coefficient Analysis

The Pearson correlation coefficient reflects the strength of linear relationship between two variables. Thus, measuring the correlation between the factors will help in determining the nature of the relationship between them; and consequently, will enable us to identify redundant factors. Statistically, correlation is denoted by r ($-1 \leq r \leq +1$). It is stated in page 314 of Sekaran [28] "if correlations were higher (say, .75 and above), we might have had to suspect whether or not the correlated variables are two different and distinct variables ...". According, if the correlation is greater than .75, then the variables might not considered to be different and hence can be combined.

The correlation coefficient analysis of our data revealed that few variables have high correlation between as follows:

- The correlation between technological structural assurance and security is .867.
- The correlation between technological structural assurance and privacy is .871.
- The correlation between organizational structural assurance and organizational situational normality is .877.

Based on these results, we combined the factors which have high correlation to avoid factors redundancy and multicollinearity.

4.3. Instrument Reliability

According to Sekaran[28], reliability of a research instrument is concerned with its consistency and stability. Inter-item consistency (also known as internal consistency) of a group of items reflects the degree to which this group is homogeneous. To examine the internal consistency of the research instrument, we employ Cronbach's alpha [26], as it has been widely adopted by many researchers [8].

To measure the reliability of the research instrument; we used SPSS 16.0 to test the internal consistency for each construct's items individually. The analysis resulted in: eliminating some items to increase the alpha coefficient. In the current study, the results of the reliability function are used to refine the research instrument. We assessed the items of the instrument, if the results revealed that one or more of the items decrease the reliability of the instrument, they were removed. Malhotra [22] considered a value of Cronbach's alpha more than 0.6 as a satisfactory level, even though many researchers determined 0.7 as a cut-off for the accepted reliability.

We deleted some items based on the results of our data analysis to increase the value Cronbach's alpha; the new version of the instrument has 46 items out of 65.

5. Discussion

The current paper has twofold: firstly it proposes a model of initial trust in IBS in the context of developing countries. The proposed model extends the previous models, which examined initial trust in IBS [17, 30] or mobile banking [15]. The model's factors are mainly extracted from existing related models, as well as from literature of initial trust and IS/IT adoption. In spite of the similarity between our model and previous models, our model has many distinctions. The model discusses initial trust in IBS in the context of developing countries where there is hardly any thorough study in this context. In addition, our model adds the crucial and important factor of national culture. Literature of IS/IT in developing counties showed the importance of national culture in adopting new technological innovations [1]. Also, the proposed model integrates factors from different perspectives such as psychological, technological, social, and organizational.

Secondly, this paper shows the steps of developing an instrument to examine our research model. All the instrument's items are adopted or adapted from existing empirical studies. After we created a pool of items, we validated the content of our instrument. Furthermore, we conducted the pilot study using the instrument and collected the data from 56 subjects and analyzed it. Based on the analysis results, we deleted some items to increase the value of Cronbach's alpha. Moreover, the results showed a high correlation between some factors. Therefore, we combined those factors; for example, we considered technological structural assurance as the represented factor for perceived security and privacy. The literature supported our decision [18]; although they used the same set of items to measure technological structural assurance, they named their variable "trust in the internet" instead of technological structural assurance; they defined it as security and privacy of the internet.

Finally, based on the results of the pilot study we refined the proposed model by combining the high correlated variables, validated our instrument and refined the reliability of the variables, and decreased the number of the items from 65 to 46.

6. Conclusion

This paper proposed a conceptual model of customer's initial trust in IBS in developing countries. The model included factors from different disciplines and perspectives: trust antecedents (disposition to trust, organizational structural assurance, technical structural assurance, organizational situational normality, and reputation), diffusion of innovation factors (relative advantages, compatibility), national culture factors (uncertainty avoidance, power distance, masculinity/femininity, individualism/collectivism, long term/short term orientation), and internet related factors (Computer and internet self efficacy, perceived security, perceived privacy). In addition, we developed a questionnaire to measure the importance of the model's factors and their impact on initial trust; consequently, intention to use IBS. The first version of the questionnaire has 65 items. However, after analyzing the data of the pilot study, 46 items remained. The final version of the questionnaire will be used in the future to conduct a large survey.

In the future work, the researchers intend to extend their work to examine and test the model on new eServices or internet business and shopping. That will help in predicting the level of trust that the new customers will have on new developed services; as well as, fostering trust in newly developed services.

7. Reference

1. Al-Hujran, Al-dalahmeh Mahmoud, Aloudat, A.: The Role of National Culture on Citizen Adoption of E-government Services: An Empirical Study. *Electron. J. E-Gov.* 9 (2), 93–106 (2011)
2. Al-Jaafreh, Gill, A., Al-Ani, A., Al-adaileh Raid, Alzobi, Y.: Factors Influencing Customer's Initial Trust of Internet Banking Services in the Jordanian Context: A Review. In: *The 22nd IBIMA conference on Creating Global Competitive Economies: 2020 Vision Planning & Implementation*. IBIMA Publishing (2013)
3. Alomari, M., Woods, P., Sandhu, K.: Predictors for e-government adoption in Jordan: Deployment of an empirical evaluation based on a citizen-centric approach. *Inf. Technol. People.* 25 (2), 207–234 (2012)
4. AlSukkar: the application of information systems in the Jordanian banking sector: a study of the acceptance of the Internet. Wollongong University (2005)
5. Baker, T.L., Risley, A.J.: *Doing Social Research*. McGraw-Hill, New York (1994)
6. Bidgoli, H.: *The internet encyclopedia*. John Wiley and Sons, New York (2004)
7. Cheung, C.M., Lee, M.K.: Understanding consumer trust in Internet shopping: A multidisciplinary approach. *J. Am. Soc. Inf. Sci. Technol.* 57 (4), 479–492 (2006)
8. Crocker, L., Algina, J.: *Introduction to Classical and Modern Test Theory*. ERIC (1986)
9. Cronbach, L.J.: Coefficient Alpha and The Internal Structure of Tests. *Psychometrika.* 16 (3), 297–334 (1951)

10. Fukuyama, F.: *Trust: The Social Virtues and the Creation of Prosperity*. Free Press New York (1995)
11. Gefen, D.: E-commerce: The Role of Familiarity and Trust. *Omega*. 28 (6), 725–737 (2000)
12. Gefen, D., Heart, T.H.: On the Need to Include National Culture as a Central Issue in E-commerce Trust Beliefs. *J. Glob. Inf. Manag. JGIM*. 14 (4), 1–30 (2006)
13. Gefen, D., Karahanna, E., Straub, D.W.: Trust and TAM in Online Shopping: an Integrated Model. *MIS Q.* 51–90 (2003)
14. Hofstede, G.: *Cultures and organizations: software of the mind*. McGraw-Hill, New York (1997)
15. Kim, G., Shin, B., Lee, H.G.: Understanding Dynamics Between Initial Trust and Usage Intentions of Mobile Banking. *Inf. Syst. J.* 19 (3), 283–311 (2009)
16. Kim, J.B.: An Empirical Study on Consumer First Purchase Intention in Online Shopping: Integrating Initial Trust and TAM. *Electron. Commer. Res.* 12 (2), 125–150 (2012)
17. Kim, K.K., Prabhakar, B.: Initial Trust and the Adoption of B2C E-Commerce: The Case of Internet Banking. *ACM Sigmis Database*. 35 (2), 50–64 (2004)
18. Koufaris, M., Hampton-Sosa, W.: The Development of Initial Trust in an Online Company by New Customers. *Inf. Manage.* 41 (3), 377–397 (2004)
19. Leidner, D.E., Kayworth, T.: Review: A Review of Culture in Information Systems Research: Toward a Theory of Information Technology Culture Conflict. *MIS Q.* 30 (2), 357–399 (2006)
20. Li, X., Hess, T.J., Valacich, J.S.: Why Do We Trust New Technology? A Study of Initial Trust Formation with Organizational Information Systems. *J. Strateg. Inf. Syst.* 17 (1), 39–71 (2008)
21. Lin, J., Lu, Y., Wang, B., Wu, S.: Initial Trust and Adoption of Mobile Brokerage Service. *Int. J. Mob. Commun.* 9 (2), 124–143 (2011)
22. Malhotra, N.K.: *Marketing Research: An Applied Orientation, 5/E*. Pearson Education India (2008)
23. McKnight, H., Choudhury, V., Kacmar, C.: Developing and Validating Trust Measures for E-Commerce: An Integrative Typology. *Inf. Syst. Res.* 13 (3), 334–359 (2002)
24. McKnight, H., Choudhury, V., Kacmar, C.: The Impact of Initial Consumer Trust on Intentions to Transact with a Web Site: a Trust Building Model. *J. Strateg. Inf. Syst.* 11 (3), 297–323 (2002)
25. Moore, G.C., Benbasat, I.: Development of an instrument to measure the perceptions of adopting an information technology innovation. *Inf. Syst. Res.* 2 (3), 192–222 (1991)
26. Nunnally, J.C.: *Psychometric Theory*. McGraw-Hill, New York (1978)
27. Rogers, E.M.: *Diffusion of innovations*. Free press, New York (1995)
28. Sekaran, U.: *Research Methods for Business: A skill building approach*. John Wiley Sons Inc N. Y. (2003)
29. Statista: development of global online banking penetration in April 2012 by region (percent). (2012)
30. Susanto, A., Lee, H., Zo, H., Ciganek, A.P.: User Acceptance of Internet Banking in Indonesia: Initial Trust Formation. *Inf. Dev.* 1–14 (2013)
31. De Vaus, D.: *Research design in social research*. UCL Press, London (1993)
32. Venkatesh, V., Davis, F.D.: A theoretical extension of the technology acceptance model: four longitudinal field studies. *Manag. Sci.* 46 (2), 186–204 (2000)
33. Wang, A.Y., Newlin, M.H.: Predictors of web-student performance: the role of self-efficacy and reasons for taking an on-line class. *Comput. Hum. Behav.* 18 (2), 151–163 (2002)
34. Zhou, T.: An Empirical Examination of Initial Trust in Mobile Banking. *Internet Res.* 21 (5), 527–540 (2011)

Supporting Organizational Agility in a Software Company through Boundary Spanning and Knowledge Brokering

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Abstract

We demonstrate how boundary spanning and knowledge brokering as a dual approach support the organizational agility of a software development company. We present the case of an organizational unit whose members engage in both activities within as well as between the company and its environment. We analyze the team's and its members' approach and identify well functioning practices as well as challenges and problems and contribute to an improved understanding of an intertwined strategy of boundary spanning and knowledge brokering to provide a balancing mechanism between flexibility and stability, which characterize organizational agility to effectively respond to changes in the environment while simultaneously being efficient and productive.

Keywords: Organizational Agility in ISD, Boundary Spanning, Knowledge Brokering.

1. Introduction

Increasingly, information systems (IS) development and software development take place in dynamic and constantly changing situations as well as environments with rising complexity [27]. This underscores the need of IS development and software development companies to become more agile [12,21]. Organizational agility, also called enterprise or business agility, is the ability to be flexible enough to speedily respond to customer requests, market dynamics, emerging technology options, and to adapt to a turbulent environment [19,26]. It also means to be stable enough to show patterns and to have efficient processes, and sufficient frameworks and structure to avoid disorderly disintegration and to be productive [19].

Organizational research on environmental turbulence has suggested that one important mechanism to cope with increasing complexity is boundary spanning [1,2] to manage interfaces at the organizational boundaries between the organization and its environment [28,29] as well as between organizational units [2,16,17]. Beyond boundary spanning at organizational unit boundaries, knowledge brokering is important for facilitating knowledge sharing [5,22,23]. It takes place at knowledge boundaries between diverse occupational groups or different communities of practice. These groups of people are bound together by a collective understanding of what their community is about, as well as a shared repertoire of resources [31]. Although the concepts of boundary spanning and knowledge brokering are similar, the concepts remain theoretically distinct and describe different types of interaction [9]. They have not been investigated together in much detail, except for open innovation communities [9]. The current role and interplay of both for ensuring organizational agility in the software industry by balancing flexibility and stability is unclear. Therefore, we address the following research question: *“How and why do boundary spanning and knowledge brokering enable organizational agility in the software industry?”*

In this paper, we report from the results of an extensive field study. We explore the role of boundary spanning and knowledge brokering for balancing between stability and flexibility

within a medium-sized software development company. We present the example of an organizational unit whose members engage in both knowledge brokering and boundary spanning between the company and its environment as well as within the company, and we analyze the team's and its members' approach. We identify well functioning activities and practices as well as challenges and problems. As such we contribute to an improved understanding of an intertwined strategy of boundary spanning and knowledge brokering to provide a balancing mechanism between flexibility and stability. The remainder of the paper is structured as follows. The next section discusses the related work and theoretical background of our study, introducing the concepts of boundary spanning and knowledge brokering in more depth. We then present results from the exploratory study of a specialized unit within a software development company and develop an explanation of how this unit engages into boundary spanning and knowledge brokering, balancing flexibility and stability. We summarize and discuss our findings, and conclude with an indication of limitations and an outlook on further research.

2. Related Work and Theoretical Background

2.1. Boundary Spanning and Boundary Spanners

One critical implication of today's business context and the changing emphasis on organizational agility is the importance of teamwork and cross-boundary collaborations, not simply inside a firm but importantly across organizational boundaries [24]. If increased collaboration between organizational units and between firms is a primary route to organizational agility, boundary spanning becomes of growing interest. Research indicates that boundary spanning may help to manage the trade-off between flexibility and stability [13].

Research on boundary spanning has a rich conceptual and empirical history within the organizational learning and social psychology domain [2,3,4,28]. Seminal studies in organization theory on research and development projects [28,29] found that communication with the external environment under turbulent environmental conditions is not distributed evenly in teams but takes place through a limited set of individuals. These boundary spanning individuals link their subunits to external areas and serve to buffer their more locally oriented colleagues from environmental turbulence. These studies also show that high performing teams facing changing environments had significantly more boundary spanning individuals than did high performing teams facing stable environments. Accordingly, boundary spanners are individuals who are part of one organizational entity and who engage in boundary spanning activities towards other organizational entities than their own [2]. Boundary spanning takes place at organizational boundaries and comprises external boundary spanning between a firm or organization and its environment as well as internal boundary spanning between different organizational units within the same firm or organization [2,16,17]. Ancona and Caldwell [2,3] identified and summarized specific boundary spanning activities such as *ambassadoring*, *coordinating tasks*, *scouting*, and *guarding*, which they discovered in their studies of new product development teams:

Ambassadoring covers buffering activities (e.g., absorbing pressures and protecting the team) and representational activities (e.g., persuading others to support the team or keeping higher levels informed of team activities). These activities contain both protective and persuasive goals such as obtaining the personnel, funding, equipment, and legitimacy from management. *Task coordination* consists of interactions aimed at coordinating technical or design issues (e.g., discussing design problems with others, obtaining feedback on the product design, coordinating and negotiating with outsiders). *Scouting* involves general scanning for ideas and information about the competition, the market, or the technology (e.g., more general scanning than task coordination). Both task coordination and scouting manage the dependence on other functions or groups that have critical information, expertise, and creative ideas. Finally, *guarding* comprises controlling the team's release of information (e.g., activities

aimed at keeping information within the team's boundaries in order to protect the team or present a specific image of the team to outsiders).

Boundary spanning thus includes political manoeuvring, management, and coordination as well as knowledge sharing activities [3], which goes beyond Fleming and Waguespack's [9] view, who see boundary spanning as primarily bridging technological boundaries. Studies on boundary spanning in IS development projects [10,11,21] confirm these results.

2.2. Knowledge Brokering and Knowledge Brokers

The knowledge that is required for the design of software and IS resides with different stakeholders [8], thus knowledge sharing, the process through which knowledge is exchanged among stakeholders [5,6], is an integral part of software and IS development. Research and theories of situated learning in communities of practice [7,30] have coined the concept of knowledge brokering to explain and focus on knowledge sharing within organizations.

Knowledge brokering refers to activities of individuals who participate in multiple communities and facilitate the transfer of knowledge across the communities' knowledge boundaries [9,22,23]. Knowledge brokers may be weakly linked to several communities at once, but not be a full member of any [19,22]. Pawlowski and Robey [22] and Pawlowski et al. [23] identified and summarized specific knowledge brokering activities, which they discovered in their studies of IT professionals. These are crossing boundaries, surfacing and challenging assumptions, translating and interpreting information, as well as relinquishing ownership and maintaining a facade of objectivity.

Crossing boundaries involves not just crossing knowledge boundaries or social boundaries, which Fleming and Waguespack [9] see as the primary boundaries that brokers are crossing, but also crossing organizational boundaries between units to share information, and to leverage resources. It also includes the effort of gaining permission from business units to cross organizational boundaries that are closed to others. *Surfacing and challenging assumptions* comprises stimulating reflection and change. *Translating and interpreting information* involves the framing of elements of the world-view of one group in terms of the perspective of another. *Relinquishing ownership* and *maintaining a facade of objectivity* includes the creation of the illusion that one is impartial and prepared to support any solution, even though a particular one is favored. Primarily, however, knowledge brokering focuses on knowledge sharing and processes of translation, coordination, and alignment between perspectives [30].

We have identified differences between knowledge brokering and boundary spanning. But the concepts are related at least with regard to knowledge sharing across boundaries. Fleming and Waguespack [9] argue that knowledge brokers can span boundaries, but not all boundary spanners are knowledge brokers. Some authors, however, provide conceptually rather unclear definitions and distinctions. Wenger [31], for example, states that knowledge brokering can take many forms, including what he calls roaming as "going from place to place, creating connections, moving knowledge", and more explicitly boundary spanning as "taking care of one specific boundary over time". Pawlowski and Robey [22] put forward that "it is likely that brokers perform an amalgam of roles, including those of scout and ambassador", which are usually attributed to boundary spanners. Fleming and Waguespack [9] also propose that knowledge brokering and boundary spanning may correlate strongly in commercial companies because firm boundaries are more formal, longer lived, and may support the transformation and hardening of technological, unit boundaries into social, knowledge boundaries. However, in line with Fleming and Waguespack [9], who likewise highlight that both concepts are theoretically distinct, we treat them as distinct for analytical purposes.

Based on Ancona and Caldwell's [2,3] categorization of boundary spanning activities and Pawlowski and Robey's [22] classification of knowledge brokering activities, in the following we study knowledge brokering and boundary spanning together, but analyze them separately as they occur simultaneously in a specific organizational unit as a dual strategy to support the organizational agility of the software development company under investigation.

3. Research Design and Method

We conducted an single in-depth case study [32] to develop an understanding and theoretical explanation of how boundary spanning and knowledge brokering together enable organizational agility in the software industry. The case organization is a medium-sized German software solutions provider called *SoftCorp* (anonymized) that has recently undergone a transformation towards a more agile and flexible organization. The company is doing well in its dynamic environment. Over the last three years, the number of sold licenses has increased by 80%, and the numbers of acquired major customers as well as customer satisfaction have steadily risen; the fiscal year 2012 was the most profitable one in the company history according to the annual report, despite a time of prolonged economic downturn in Europe and the Euro zone. The selected case organization represents the main unit of analysis, but the individual departments, groups, and employees each represent analytical subunits, which allows for a multi-level analysis as called for by Marrone et al. [18] and is in line with multi-perspective innovation studies (cf. [14] for a detailed argument).

The two main methods for data collection were interviews and observation. During a period of 9 months (Oct. 2011 until Jun. 2012), we visited the company three times for one to three days at each visit. We conducted 9 open interviews with selected key informants¹ (4 leaders Product Management Team, 1 developer Product Management Team, 1 manager Product Management Team, 1 Professional Services consultant, 1 manager Professional Services, 1 CEO, 1 manager Marketing), 8 group interviews(3x Product Management Team, 1x apprentices Product Management Team, 2x manager and leader Product Management Team, 1x lead developer and manager Core Development, 1x manager Product Management & Professional Services consultant), and observations of activities (1 Retrospective, 1 Review Meeting, Daily Stand-up Meetings on 3 days). We also reviewed various product and internal company documents. All interviews, which lasted from 30 to 120 minutes, and meetings were audio-recorded as well as transcribed. We followed a two-stage process of inductive and deductive coding of data [20]. First, both authors scrutinized and coded the data independently of each other. Based on previous work on boundary spanning [2,3] and on knowledge brokering [22,23] we started with initial seed codes for the identified activities and searched for evidence of knowledge brokering and boundary spanning in relation to organizational agility. Subsequently, both authors discussed their interpretations in person or using e-mail and teleconferencing. This resulted in the following analysis.

4. Case Report and Analysis

4.1. Software Development at SoftCorp

SoftCorp is a German software development company, founded in 1999 and now a subsidiary company of an exchange-traded IT service provider. SoftCorp employs around 70 staff at its headquarters, with about 90 employees in total and sales offices across Europe and the US. The core software product of SoftCorp is a content management system (CMS). Numerous companies from many industries worldwide use the CMS for managing their Internet presences as well as their intranet portals. Professionals from SoftCorp or selected partner companies provide consultancy and project services such as implementation, tailoring, or configuration of the CMS to end customers. SoftCorp's strategy as regards the CMS is product-driven following an own product vision. It is not customer-driven following customer requests or market trends. As a result, SoftCorp focuses on the development of a stable software core that is compatible between release versions. End customers have to run their own development projects, possibly supported by professionals from SoftCorp or partner companies, for customer-specific extensions of the CMS' core features. Such projects can range from simple extensions, so-called "modules", to complex web application projects. For

¹ See next section for the company's organizational structure

example, modules allow the application of e-mail marketing, the display of content on mobile devices, or the integration with enterprise application servers. Most of the time, these extensions are later not integrated into the core features of the CMS.

In SoftCorp's organizational structure consulting services and support for Internet and intranet projects of end customers are provided by consultants and project managers from the "Professional Services" unit (31 employees). The unit "Research & Development" (21 employees) is responsible for developing and maintaining the CMS as the core product. This is done exclusively by the so-called "core development team" at SoftCorp's headquarter (eight developers plus one manager). The core development team continuously develops and advances the CMS. In general, a release cycle takes several months, resulting in a gap between major releases of several years (e.g., version 4 in 2007 and version 5 in 2012). The development process follows a mixture of practices from traditional software engineering (e.g., variants of stage-gate models) and modern approaches (e.g., time boxing). The strategy to shield the core development team from outside pressure, developing the core product in a sustainable and stable way, thus results in a kind of "wall" to the environment and to other departments. Since spring 2011, the "Product Management" sub-unit (the *PM team*) of the Professional Services unit provides a second development team (six full-time employees and four apprentices). The PM team is responsible for developing modules for the CMS that address specific non-core features (e.g., video management). The PM team as a second development unit was created because of a felt need to be able to accelerate the development of modules in order to be able to react more quickly and faster to end customers' and partners' requests as well as to internal feature requests.

Thus, a specialization exists as regards software development. While the core development team develops the CMS as a stable core product in a steady way, with a pace and time horizon of years between releases, the PM team develops modules much faster, with a time horizon of months. This specialization using two distinct development teams allows SoftCorp to react more quickly to customer demands, without having to jeopardize the stability of its core asset. The PM team employs a different approach to software development than the core development team, using a variation of lean software development [25].

4.2. The PM Team: The "Jack of All Trades"

However, the PM team is not only responsible for software development in the form of new or customer-specific software modules for the CMS. In parallel, a variety of other tasks are situated with the team and it sometimes acts as an internal 'fire-fighter', or indeed a 'jack of all trades'. As such, the team is addressed by colleagues from Marketing, Sales, and other units and by external partners with regard to a variety of topics related to the CMS and it acts as "internal help desk" and internal product support. But it also develops 'show cases' which comprises the design and implementation of concepts and presentations for new CMS features and modules to support Marketing and Sales at end customer demonstrations or fairs. In addition, the team provides intranet care, and maintains and supports SoftCorp's intranet, both content-wise and infrastructure-wise. Furthermore, it supports the 'CMS community', where end customers and partner companies have the possibility to exchange ideas, knowledge, and experiences with each other and with employees from SoftCorp using an Internet-based bulletin board. The PM team answers questions regarding the CMS and provides content for the community members respectively. Finally, three team members serve as stand-by men and are infrequently used as consultants for internal product within end-customer projects.

4.3. Knowledge Brokering in the PM Team

Knowledge brokering within the PM team includes 'crossing boundaries' as well as 'translating and interpreting'. During the tasks concerning internal product support and the development of 'show cases' – due to the PM team members' extensive technical knowledge of the CMS – the team brokers knowledge between the core development team and other departments. The PM team routinely crosses internal boundaries between other departments

and units within SoftCorp, which would otherwise not talk to each other by holding open review meetings. The PM team members also have direct access to members of the core development team, which members from other departments do not have. The PM team frequently translates and interprets elements of the technical views of the core development team regarding the core product CMS in terms of the perspective of other units and departments such as Sales, Professional Services, or Marketing. They are the internal contact for all departments that have questions regarding the product.

Specifically during the development of modules for the CMS, the PM team engages into ‘surfacing and challenging assumptions’ activities. This includes both product-level (technical and business perspectives) as well as organizational-level topics. As regards the former, the PM team continuously questions the way things are done in the CMS during the development of modules, and tries to find new architectural solutions, e.g., challenging the ‘pre-generation of content’ paradigm of the CMS in certain areas. The PM team also regularly challenges the existing practices and ways of doing things at SoftCorp, for example, by actively choosing to manage projects differently than the core development team, using lean software development, and by being much more communicative than the core development team.

4.4. Boundary Spanning in the PM Team

We found that especially the community work of the PM team presents a very interesting case of boundary spanning. It includes ‘ambassadoring’, ‘coordinating’, ‘scouting’, and ‘guarding’ activities on behalf of SoftCorp with regard to ‘outsiders’ such as external partners and end customers as well as to ‘insiders’: staff from Marketing, Sales, and other employees from Professional Services. The answering of questions that arise out of the community, including solutions to problems, in turn prompt activities such as scouting and feed back to new knowledge for the members of the PM team, e.g., existing issues with the CMS or new ideas for novel functionalities. Moreover, the PM team engages into ‘ambassadoring’ activities during their tasks as stand-by men when they visit partners and discuss the product and explore improvement possibilities. The PM team’s task of developing new modules for the CMS also involves frequent instances of ‘coordinating’ and ‘scouting’ activities, both coordinating technical or design issues by e.g. conducting workshops. In addition, they jointly with sales, presales, and professional services staff define module requirements.

Similarly, other tasks such as consulting support as stand-by men involves ‘scouting’ activities of the external environment in form of the competition, the market in general, or innovative technologies. As regards ‘guarding’, the PM team responds, quickly, to staff, and especially to customer and market demands, and thus shields the core development team from external and internal contacts so that the latter can concentrate on developing the CMS.

4.5. Balancing Flexibility & Stability

SoftCorp has to balance flexibility and stability based on market demands: the market expects for the core product at least a 3 years development roadmap, while for the modules there is a maximum of 12 months. The company has decided to do this by having two separate units, one that can react more quickly and nimbly to market, staff, and customer requests and one, the original development unit, that provides stability by allowing the core development team to design the CMS with a long-term vision.

The individual members of the PM team who are organized in this unit have business as well as detailed technical knowledge of the core product CMS, its software code, and the CMS implementation projects because of their diverse tasks. Gathering these skill sets in one dedicated organizational unit created a broad knowledge base which is considered beneficial for the organization. Against this background the PM team is central for both knowledge brokering of diverse kinds and boundary spanning between SoftCorp’s different units and towards SoftCorp’s environment as the interface between all departments. This provides the core development team with a solidity that has another positive effect: customers report less problems and their satisfaction has increased massively.

Boundary spanning and knowledge brokering as performed by committed individuals who are organized in one dedicated organizational unit in SoftCorp then contributes to increased flexibility and stability and balances flexibility and stability by simultaneously supporting (1) reacting faster to customer requests and influences from the market and the external environment, (2) spotting opportunities faster, and (3) augmenting speed-to-market while taking pressure from and shielding the core development team to pursue a sustainable long-term vision and allow for a steady development pace and to develop a stable product core. In terms of ambassadoring, this is achieved through the PM team's engagement in a range of activities for SoftCorp, especially with the internal and external community tasks, their own development tasks, and as stand-by men in customer projects. With respect to coordinating tasks, this is reached when the PM team takes on various activities related to managing design and/or technical issues again through their performance of development tasks, their community tasks, and their role as stand-by men. In the identified scouting activities the PM team explores the external environment, the market in general, their competitors as well as novel and innovative technologies on behalf of SoftCorp during their work tasks. Finally, when guarding SoftCorp, especially the core development team, from outside and inside influences so that the core development team can concentrate on developing the core of the CMS, the PM team through their development work, performance of community tasks, but also as stand-by men plays a significant role in balancing stability and flexibility. In terms of crossing boundaries, the PM team contributes to both stability and flexibility by routinely crossing internal boundaries between other departments and units within SoftCorp, which would otherwise not talk to each other. With regard to surfacing and challenging assumptions, the PM team regularly challenges the existing product design decisions as well as organizational practices and ways of doing things at SoftCorp. Lastly, when engaging in translation and interpretation the PM team frequently outlines elements of the technical views of the core development team regarding the core product CMS in terms of the perspective of other units and departments such as Sales, Professional Services, or Marketing and it also translates market, customer and staff requirements to technical concepts which they either themselves develop into modules or pass on to the core team.

The role of the PM team as specialized unit that engages into both, knowledge brokering and boundary spanning between other departments, partners, end customers, and the market, thus contributes to SoftCorp's organizational agility. The PM team provides flexibility as it reacts to changes much more flexible and interactive, both with the outside environment and with other units. It neither only conducts knowledge brokering nor boundary spanning; it does both in an intertwined way as part of a dual strategy. The core development team is intentionally shielded from outside and inside influences, and only has minimal contact to the environment and to other units. This increases SoftCorp's stability as it allows for a sustainable development of the core product with a long-term vision.

5. Discussion and Conclusion

We performed a study that investigated boundary spanning and knowledge brokering, and demonstrated how they go together and are interwoven as a dual strategy organized in one organizational unit. In such a setting they supplement each other and balance flexibility and stability. As such they enable and support organizational agility. The results suggest the PM team serves an important function for SoftCorp. It offers a structure to balance the demand for more flexibility in a dynamic and increasingly complex environment and the demand for stability that is needed for the efficient development of the core product. The PM team provides a mechanism through which SoftCorp can act more quickly and make sense of changes in its environment, at the same time shielding the core development team from these influences. Importantly, the PM team's dual roles of boundary spanning and knowledge brokering are both necessary for maintaining SoftCorp's viability. This helps with keeping the core development team isolated in order to develop the CMS in a stable, slow-paced manner and allows SoftCorp to react quickly to changes in its environment. This dual strategy of "stable core product" vs. "fast modules" enables SoftCorp to implement organizational agility

as a basis for their success. As a contribution to practice, our findings may help other companies to decide whether having an institutionalized “knowledge brokering & boundary spanning” unit is worthwhile in their situation or not in order to create organizational agility.

Previous literature points to the importance of such specialized units for balancing flexibility and stability (e.g., [13,15]). The data reported here support these arguments. In contrast to Harter and Krone [13], who revealed the role of a cooperative support organization acting as a boundary spanner and thereby helping the cooperative’s member organizations to balance change and stability, we found that SoftCorp has a dedicated team inside its own organization that contributes to balancing flexibility and stability, and not only by boundary spanning but also by knowledge brokering. Our work supplements the work of Kotter [15], who advocates to extend traditional organizational units with a second ‘operating system’ that uses an agile, network-like structure and different processes to assess the business, the industry, and the organization, and that reacts with greater nimbleness, speed, and creativity than the existing units. Kotter [15], however, does not consider how knowledge in such structures is shared with the organization. Moreover, while the literature provides evidence for boundary spanning and brokering as two separate sets of activities (e.g. [16,19,22]), we extend, based on our case, the common body of knowledge and establish that a unit that intertwines these activities can be useful to contribute to organizational agility, effectively balancing stability and flexibility. Having a dedicated unit, with members with complimentary skill sets and knowledge sets in order to be able to both span boundaries or to broker knowledge between others, is a promising strategy for other companies which also want to achieve organizational agility. In previous work, Fleming and Waguespack [9] have studied brokering and spanning together, however in open innovation communities, which are different from individual commercial companies. We provide an empirical confirmation for their proposition that boundary spanning and knowledge brokering are closely related in such a setting. They also put forward that brokers can perform spanning activities and spanners can perform brokering activities, but found that performing these activities simultaneously can have negative consequences with regard to the individuals’ roles in these communities. This might be related to the environment in which they performed their study and their focus on individuals. We do not find these negative effects; on the contrary, both sets of activities in our setting contribute to organizational agility without jeopardizing the individuals involved. Taking a starting point in individuals acting as knowledge brokers, others have also struggled with the conceptual distinction of knowledge brokering and boundary spanning [22,31]. As we focus on an organizational unit as a whole, this difficulty, as important as the distinction is for our analysis, jeopardizes the results of our study. We actually provide some new insights about the distinctive and the shared features of knowledge brokers and boundary spanners, but our results also indicate that more work has to be done to understand the idiosyncratic and the common characteristics of the involved sets of activities.

Finally, as a word of caution, we investigated one single case in depth and it may not be prudent to generalize beyond this individual case setting. Another limitation of our study is that we focused on boundary spanning and knowledge brokering from the outset and did not employ other lenses for scrutinizing our data, e.g., the role of “boundary objects” or the role of different “technology frames” surrounding the various units, which may play a role in this setting as well. These are subject to future research.

References

1. Aldrich, H., Herker, D.: Boundary spanning roles and organization structure. *Academy of Management Review* 2(2), 217-230 (1977)
2. Ancona, D.G., Caldwell, D.F.: Beyond boundary spanning: Managing external dependence in product development teams. *The Journal of High Technology Management Research* 1(2), 119-135 (1990)
3. Ancona, D.G., Caldwell, D.F.: Demography and Design: Predictors of New Product Team Performance. *Organization Science* 3(3), 321-341 (1992)
4. Ancona, D.G., Caldwell, D.F.: Rethinking team composition from the outside in.

- Research on managing groups' and teams' composition 1, 21-37 (1998)
5. Argote, L., Miron-Spektor, E.: Organizational Learning: From Experience to Knowledge. *Organization Science* 22(5), 1123-1137 (2011)
 6. Argote, L., McEvily, B., Reagans, R.: Managing knowledge in organizations: An integrative framework and review of emerging themes. *Management Science* 49(4), 571-582 (2003)
 7. Brown, J.S., Duguid, P.: Organizational Learning and Communities-of-Practice: Toward a Unified View of Working, Learning, and Innovation. *Organization Science* 2(1), 40-57 (1991)
 8. Cabrera, A., Cabrera, E.F. Knowledge-Sharing Dilemmas. *Organization Studies* 23(5), 687-710 (2002)
 9. Fleming, L., Waguespack, D.M.: Brokerage, boundary spanning, and leadership in open innovation communities. *Organization Science* 18(2), 165-180 (2007)
 10. Gasson, S.: A genealogical study of boundary-spanning IS design. *European Journal of Information Systems* 15(1), 26-41 (2006)
 11. Gopal, A., Gosain, S.: The Role of Organizational Controls and Boundary Spanning in Software Development Outsourcing: Implications for Project Performance. *Information Systems Research* 20(8), 1-23 (2009)
 12. Harris, M.L., Collins, R.W., Hevner, A.R.: Control of Flexible Software Development under Uncertainty. *Information Systems Research* 20(3), 400-419 (2009)
 13. Harter, L., Krone, K.: The boundary-spanning role of a cooperative support organization: managing the paradox of stability and change in non-traditional organizations. *Journal of Applied Communication Research* 29(3), 248-277 (2001)
 14. Kautz, K., Nielsen, P.A.: Understanding the implementation of software process improvement innovations in software organizations. *Information Systems Journal* 14(1), 3-22 (2004)
 15. Kotter, J.P.: Accelerate! *Harvard Business Review* 90(11), 43-58 (2012)
 16. Levina, N.: Collaborating on Multiparty Information Systems Development Projects: A Collective Reflection-in-Action View. *Information Systems Research* 16(2), 109-130 (2005)
 17. Levina, N., Vaast, E.: The emergence of boundary spanning competence in practice: implications for implementation and use of information systems. *MIS Quarterly* 29(2), 335-363 (2005)
 18. Marrone, J.A., Tesluk, P.E., Carson, J.B.: A Multilevel Investigation of Antecedents and Consequences of Team Member Boundary-Spanning Behavior. *Academy of Management Journal* 50(6), 1423-1439 (2007)
 19. Mathiassen, L., Pries-Heje, J.: Business agility and diffusion of information technology. *European Journal of Information Systems* 15(2), 116-119 (2006)
 20. Miles, M.B., Huberman, A.M.: *Qualitative Data Analysis: A Sourcebook of New Methods*. Sage, Beverly Hills, CA, USA (1994)
 21. Overby, E., Bharadwaj, A., Sambamurthy, V.: Enterprise agility and the enabling role of information technology. *European Journal of Information Systems* 15(2), 120-131 (2006)
 22. Pawlowski, S., Robey, D.: Bridging User Organizations: Knowledge Brokering and the Work of Information Technology Professionals. *MIS Quarterly* 28(4), 645-672 (2004)
 23. Pawlowski, S.D., Robey, D., Raven, A.: Supporting shared information systems: boundary objects, communities, and brokering. In: *ICIS 2000 Proceeding*, pp. 329-338, Brisbane, Australia (2000)
 24. Piercy, N.F.: Strategic relationships between boundary-spanning functions: Aligning customer relationship management with supplier relationship management. *Industrial Marketing Management* 38(8), 857-864 (2009)
 25. Poppendieck, M., Poppendieck, T.: *Lean Software Development: An Agile Toolkit*. 1st Ed. Addison-Wesley Longman, Amsterdam (2003)

26. Sambamurthy, V., Bharadwaj, A., Grover, V.: Shaping Agility through Digital Options: Reconceptualizing the Role of Information Technology in Contemporary Firms. *MIS Quarterly* 27(2), 237-263 (2003)
27. Sommerville, I., Cliff, D., Calinescu, R., Keen, J., Kelly, T., Kwiatkowska, M., McDermid, J., Paige, R.: Large-scale complex IT systems. *Communications of the ACM* 55(7), 71-77 (2012)
28. Tushman, M.L. Special Boundary Roles in the Innovation Process. *Administrative Science Quarterly* 22(4), 587-605 (1977)
29. Tushman, M.L.: Work Characteristics and Subunit Communication Structure: A Contingency Analysis. *Administrative Science Quarterly* 24(1), 82-98 (1979)
30. Wenger, E.: *Communities of Practice: Learning, Meaning, and Identity*. Cambridge Uni. Press (1998)
31. Wenger, E.: Communities of Practice and Social Learning Systems. *Organization* 7 (2), 225-246 (2000)
32. Yin, R.K.: *Case Study Research: Design and Methods*. 3rd Ed. SAGE Publications, Thousand Oaks, CA, USA (2003)

An Emergent-Based Approach for Deriving Business/IT Alignment Models and Measures through IS Enactment

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Abstract

Business/IT Alignment is an information systems research field with a long existence and a high number of researchers and represents a central thinking direction over the entanglement between business and information systems. It aims to achieve a paradigm, on which there is a high degree of visibility and availability of information about the information systems sociomateriality. Complex-networks constitute an approach to the study of the emergent properties of complex-systems that strongly focuses and relies on models and measures, through which the system interdependence is built. Several characteristics of complex-networks are: structural or functional topology; domain independent; quantification of elements' relationships; visibility and capture of emergent properties. We introduce a set of models and measures through the dimensions of a profiling framework illustrated with an exploratory case. The introduced models and measures intend to derive information systems effects in Business/IT Alignment.

Keywords: Emergent, Business/IT Alignment, Profiling Framework, Complex-Networks.

1. Introduction

IS scholars are gradually moving away from the traditional static, reductionist view of the entanglement, to conceptual models highlighting the entanglement process as complex. The complexity resulting from the emergent enactment only exists on the whole. To have an entity that describes this emergent enactment as a whole is fundamental. A virtual organization (VO) can describe this coordination of complexity, as well as the interdependent power relationships and decision-making within the emergent enactment entanglement.

In fact, IT alignment to business is best described not as a one dimension phenomenon but as a superset of multiple, simultaneous component entanglements that bring together an organization's structure, strategy, and culture at multiple (IT, business unit, and corporate) levels, with all their inherent demands. It becomes a sociomaterial construction as defined by Orlikowski [17]. It emphasizes principles of interdependence and coevolution where decision-making and business processes are being overhauled to fit better with "networked".

The principles of complex-networks are understood as a theoretical lens and a tool particularly suitable for capturing the emergent enactment as a whole. Instead of reducing a phenomenon to a set of causal variables and an error term, the complex-networks demonstrate how aggregated structures arise from simple representations and interactions of microstate events within a context. The complex-networks allow opportunities for analysing the emergent phenomena without abstracting away the entanglement. Accordingly, are viable for

a more comprehensive and cross-level research in the drive of the information systems sociomaterial coevolution [16].

The work presented in this paper tries to describe some of these properties by (1) providing an profiling framework relevant for extracting information systems enactment models and measures and from them (2) define a comprehensive set of dimensions for deriving the relationships existing among IS elements and then from the models and measures (3) infer about Business/IT Alignment. The proposed approach aims to improve the Business-IT alignment efforts through models and measures of information systems enactment. The rest of the paper is organized as follows. Section 2 motivates the research and outlines the overall research line in which this work is framed. Section 3 proposes a framework for profiling the information systems emergent virtual organization. Section 4 presents the IS enactment data transformation. Section 5 derives the functional models and measures. Section 6 reviews some of the lessons learned. Section 7 draws the conclusions and future works.

2. Motivation

It is not difficult to argue that over the years, information systems research, dedicated a high volume of time and resources to the understanding of the alignment, between the organization and information technology, as a determinant of organizational sustainability [6]. This transformation was so dramatic that Nicolas Carr challenged that "*IT doesn't matter*" [5] and, Davenport assumed that processes would become simple commodities [7]. Moreover, evolving from a long existence of GRID architecture, this transformation commercially consolidated under the Cloud concepts [10]. Technological agency theoretical position assumes that users enact technology in prescribed ways. However, it is observable that "*They can use it minimally, invoke it individually or collaboratively, and improvise in ways that produce novel and unanticipated consequences* [3]." This observation advises that is the enactment of information technology that produces shapes, and not simply its existence [9].

The ubiquity and described observations guided information system scholars to argue that information systems organizational determinants (information systems competencies) emerge from enactment in practice [16]. Designer images of enactment are partial since improvised action occurs in practice, taking features for purposes other than initially intended [1]. As enactment occurs in practice, significant organizational changes may result over time. In a social agency perspective, information systems competencies are not only realized from the representation of social process into technology. Rather, "*[...] every engagement with a technology is temporally and contextually provisional, and thus there is, in every use, always the possibility of a different structure* [3]."

VOs are a phenomenon supported by the concepts of ubiquitous information systems [25] and mass collaboration [24]. Entities such as individuals, groups, enterprise units or entire organizations, collaborate to accomplish common goals. A VO represents a linked structure of that infrastructures collaboration. This allows the VO to assume an increasingly prominent function in the context of today's dynamic linking [12].

The information systems competencies [19] are virtual organizations from the practice. Orlikowski defines this phenomenon as the sociomaterial construction of information systems competencies [17]. Functional models facilitate the understanding of the enactment in practice and can represent the emergent virtual organizations of information system structures (competencies). They can destroy or create the conditions for the enterprise architecture to achieve alignment [28, 29]. However, capturing and using information systems virtual organizations and the necessary model acquisition approach and dimensions remain challenging. Determined on capturing organization's "**WHAT**", enterprise architectures provide process-centered, and role-based languages not concerned with *emergence* resulting from the enactment of IT prearranged subjects. *The virtual organization* that performs the work (work system), *when* perform it and "**HOW**" social and IT interact with each other, are not also a concern.

Complex-network analysis can describe significant properties of complex-systems by statistically quantifying and modelling the emergent network topology [11]. Complex-

network concepts are applied on situations from biology to human creations (enterprises), and social interactions [2], in the pursue of answers to questions like: what does the Internet structure and the propagation of HIV infections have in common or how companies evolve. Many aspects of those systems are relevant and worthy to be studied [13]. Some researchers study the individual components while others study the nature of the interactions [13].

However, there is another aspect of the interacting systems, sometimes neglected, but crucial to the understanding of the emergence, which is the anatomy of the connectivity enactment [13]. In this case, the fundamental concern is to discover the anatomy of the structures because patterns always affect the function [23].

3. Profiling Framework

Firstly, from the business domain emerges a functional VO a result of the enactment of the information system structural competencies to address a business goal. This domain outlines the unit of analysis for which has to be gathered the enactment raw data. Secondly, the analytical domain describes the emergent virtual organization or organizations through multidimensionality. This results from the application of the complex-network metrics to the enactment raw data. The raw data through its connectivity must be able to describe the VO sociomateriality construction. Finally, the resulting models and metrics become available for exploitation, as images of the organization, at the model domain.

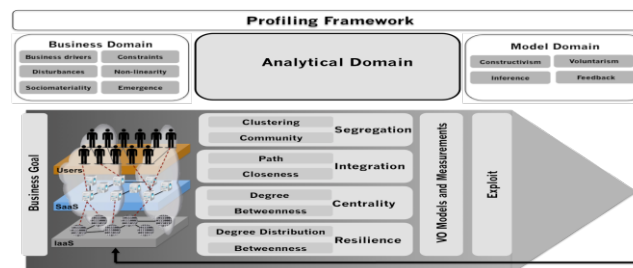


Fig. 1. Information system virtual organization modelling.

In resume, the Profiling Framework (Fig. 1) develops the alignment in a continuous process of three dimensions studied through analytically discovering the emergent “*HOW*” in the raw data representing the enactment as sociomateriality connectivity. Taking into account that, for each top-down structure, there is a subjacent bottom-up emergent course, during its enactment, we can devise a dimension on enactment: the “Business Domain”. At the business domain, designers use abstraction techniques to construct the systems.

They focus on processes, integration models, code generation and other techniques in order to realize a system that meets the functionality set by the corresponding business profile. However, the system sociomaterial enactment occurs as a rationalization of information flow through the “*HOW*”. In the enactment rationalization between technological functionalities and users emerges a virtual organization as a representation of that “*HOW*”. The classification of the enactment into categories according to its properties or capabilities is just one of the dimensions concerning the global understanding of the information system emergent virtual organization. A set of functionalities, emergent in the system through sociomaterial enactment of the resources are here named “Virtual organization emergent profile”(VOEP).

The study of the emergent virtual organization aims to develop strongly based models and measurement properties. Such approach allows reduction of semantic gaps, enables higher independence and resilience of domain models from characteristics and changes on VBE and promotes automation of the development tasks, enabling reuse of knowledge relative to either best practice on the enactment or to the organization VBE. They describe the voluntarism and the constructivist nature of the enactment, the possibility of inference and the feedback nature. The exploitation is for Jeanne Ross [21] the most difficult part of

information systems management, but the one that through minor changes produces big results in a process from small data to big impact.

3.1. Measurements of Segregation Model

Segregation is a functional property and describes the extent of the neighbourhood of a given node in the network. It is associated with the emergence resulting from the enactment rationalization and describes the network transitivity capability. The clustering develops in a process that a friend of a friend is also my friend, where if the node u connects to the node v , and v connects to w , then u also connects to w . A high number of such triangles imply segregation. The fraction of triangles around an individual node is known as the clustering coefficient (C) [8], [13].

The clustering (C) is the probability that if a triple of nodes in a network is connected by at least two links, then the third link is also present. Measures of segregation can also find the exact size and composition of individual groups. Subdividing the network into such groups of nodes reveals the complex-network community structure. The community is defined by the appearance of densely connected groups of nodes (patterns or motifs), with only lighter connections between groups (Mark Newman, 2006). When not knowing the structure of an organization and study it by gathering a network through real data, it would be possible to deduce the existence of groups by observing its community structure.

3.2. Measurements of Integration Model

Integration describes the extent to which a given node is apart from others in the network. It describes the flexibility for quickly combine specialization from distributed elements. It relates to decisions made at design and configuration phases, regarding the coupling of systems. Integration metrics description focuses on the complex-network measure of path.

Paths are sequences of distinct nodes and links [8], [13] that define the ease of communication. This complex-network metric represents the potential routes for information flow between pairs of nodes. The paths lengths, therefore, estimate the flexibility for functional integration between elements. Additionally, functional connectivity data already contain such information for all pairs of nodes. They may not correspond to the defined information flow on structural connections. The average shortest-path length (l_i) (closeness centrality) between all pairs of nodes in the network is known as the characteristic path length of the complex-network [13].

The closeness centrality of a node in a network is the inverse of the average shortest-path distance from the node to any other node in the network. It can be viewed as the efficiency of each node (individual) in flowing information to all other nodes. The larger the closeness centrality of a node, the shorter the average distance from the vertex to any other node, and thus the better positioned the node is in flowing information to other nodes [13], [20]. A long path mainly influences the characteristically path length as short paths mainly influence the global efficiency. This may enable the global efficiency characterization through integration. In networks, visual representations of connection lengths typically are dimensionless and do not represent spatial or metric distance [22].

3.3. Measurements of Centrality Model

Centrality describes the extent to which a given node connects or can connect to others in a network. It relates with power, influence in decision-making and innovation. Key hub nodes often interact with many other nodes, facilitating functional enactment. The degree, k , of a node is the total number of its links [8]. The degree has a straightforward interpretation that is: nodes with a high degree, structurally or functionally actively link, in the complex-network. Then the degree may be a sensitive measure of centrality in complex-networks.

Metrics of centrality focus on the idea that central nodes participate in many short paths within a complex-network topology and consequently acts as important controls of network

flow. A related metric is betweenness centrality, defined as the extent, to which geodesic paths (shortest-paths) in a complex-networks, pass through a given node [13, 14]. It can be used to detect important structural or functional topology through the not measurement of the well connected but the links that fall between.

3.4. Measurements of Resilience Model

Resilience is a property, describing the extent to which a node or link, removal or addition affects the network. It is the process that transforms the metrics into prediction or conclusion about the overall systems behavior. One of the goals of resilience is to understand how these events, affect the network as a whole. Metrics of resilience quantify features that comprise complex-network vulnerability to removal or change.

The total distribution of nodes degree of an entire network is its characteristic degree distribution [8], [13] and as a central role on the characterization of resilience. Another, suitable metric of resilience is the betweenness centrality. Betweenness measures the influence a node has over the spread of information through the complex-network. Counting only shortest paths definition implicitly assumes that information spreads only along those shortest paths. The efficiency goal is to reduce wiring costs. Direct measures of complex-network resilience test the complex-network before and after a presumed change.

4. Transforming the Data

The functional VO can be modelled and measured using complex-networks through the following four steps (Fig. 2) if from the gathered sociomaterial connectivity raw data is possible to: (1) define the network nodes; (2) define the association between nodes; (3) generate an association matrix by compiling all pairwise associations between nodes to produce a matrix of connectivity and (4) measure and model the network parameters of interest.

The step 1 of Fig. 2 defines the unit of analysis being modelled and measured. In this definition can be used prior structural criteria or functional profile evaluation. It can also be informed from the profiles of the functional connectivity of the different information systems. The functional process is the discovery of the emergent virtual organizations from the structural VBE. The step 2 gathers the corresponding data. This gathering uses the available raw data in the digital logs at the technological systems, in the functional case, and in the design data, in the structural case.

At step 3, occurs the transformation of the gathered data into models and measurements. It is a critical transformation since the resulting data will be used as complex-network input. Different data will produce complex-networks of different topology. In this step the raw data transformation, to ensure the limits and quality of the data follows the KDD [18] process. Finally, at step 4 from the complex-networks models and measurements as images of the enactment is possible to infer and shape the information system alignment ought-to-be.

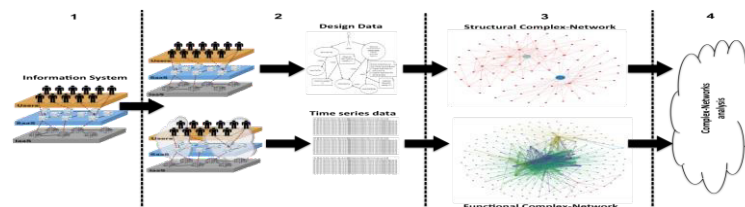


Fig. 2. The Virtual organization complex-networks sourcing process.

The addressed technological artefacts are software-based artefacts such as packages, modules or web applications. The web applications are represented by the web page id that describes the web application functionalities. The enactment of these artefacts occurs at the SaaS level and is constrained by the structural decisions. The connections between packages

and modules or the structure of the web application represent those constraints. The sociomaterial nature of the emergent virtual organization results undirected since technology or users can trigger the enactment and develop the link although the direct nature of the software technology [15]. Moreover, the structural nature of the VBE develops with direct links through expected behavior at the design phase.

5. Deriving the Functional Models and Measures

This paper examines a Web Portal information system as an exploratory case through the presented profiling framework. A process of the exploratory case is illustrated in the Fig. 3.

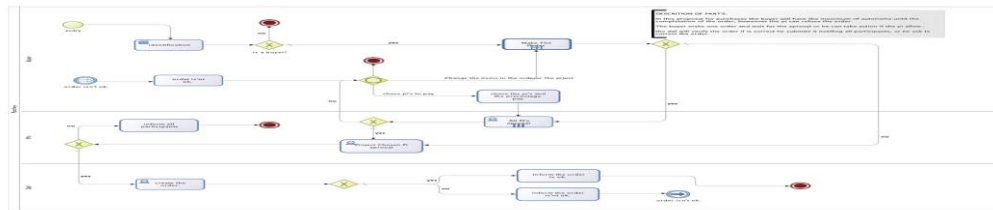


Fig. 3. The Web Portal communities’ topology filtered from the global topology.

This analysis starts with the description of the sociomaterial virtual breeding environment (SVBE) as a complex-network. Moreover, focuses in the discovery of the virtual organization emergent profile (VOEP), from the enactment recorded into the Web portal logs raw data. Can the defined profiling framework achieve the Web Portal “HOW” from its technological enactment logs? The process starts through the definition of the SVBE that in this case is the Web Portal enactment defined as an organizational management tool. The enactment is represented into the logs of the Web Portal Http Server and after the data transformation to produce an edge list that represents the enactment as a complex-network, is used as input for the profiling framework. Table 1 illustrates the context.

Table 1. The context of the Web portal network.

Measuring	Measures	Values
Context	Nodes	749
	Links	6636
	Type	Undirected

Table 2. The Web Portal communities’ measurements.

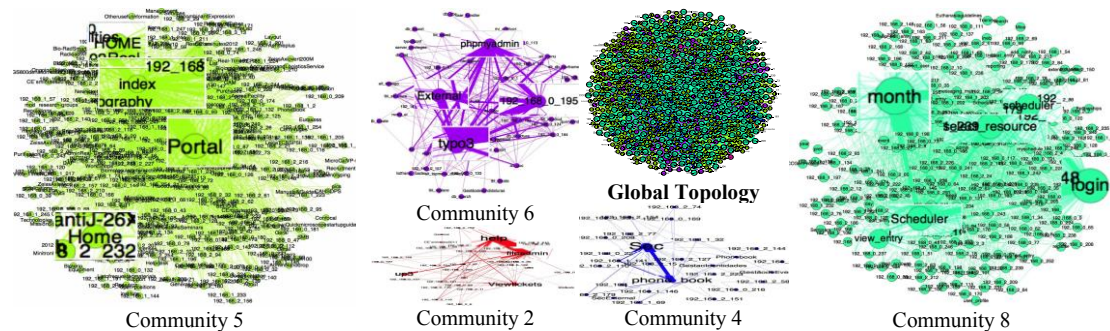
Measuring	Measures	Values
Communities	5	(5.2.27%)
	8	(3.1.24%)
	6	(6.8.1%)
	2	(4.5.4%)
	4	(3.7.4%)
	1	(0.6.7%)
	7	(0.2.7%)
	3	(0.2.7%)
	0	(0.2.7%)

Due to size limitation of this paper it is only described the segregation dimension. Through communities measurement emerged nine communities that are illustrated in the Table 2. Two of the communities, the communities 5 and 8, presented a value of more than 83% of the overall topology, with values of 52,2% and 31,24% respectively. The communities 6, 2 and 4 presented values, 6,81%, 4,54% and 3,74% respectively. The community 1 presented a value of 0,67%. Finally, the communities 7, 3 and 0 presented the same value, 0,27%. Each colour represents a different community to facilitate the overall view of the topology and to make possible the identification of each community more easily. The Table 3 illustrates the Web Portal global topology and five most relevant communities. The topology is zoomed to facilitate the visualization of the nodes. However, in some cases that is not completely achieved.

The community 5 presented stronger links between the nodes, *home*, *HOME*, *index* and *Portal*. The community 8 presented stronger links between the nodes *month*, *select_resource* and *login*. The community 6 presented stronger links between the External, *typo3*, *phpmyadmin* and *192_168_0_195*. The community 4 presented in the topology a stronger link

between *Sec* and *Phone book*. In the Table 3 the community 2 presented a stronger link between the nodes *help*, *fileadmin*, *viewtickets* and *UP3*.

Table 3. The Web Portal communities' topology filtered from the global topology.



6. Lesson Learned

The described emergent virtual organization presented a structure semantically related to the organizations' functional structure. The answer to the first question is then that the profiling framework through the segregation dimension is able to define the emergent virtual organization and in that way characterize the organizational “**HOW**” from the sociomaterial enactment logs. This conclusion is related to other research such as [26, 27], [4], where the communities are able to uncover the emergent dynamics of the sociomateriality.

Additionally, the nodes considered structural for the Web Portal presented the smallest values. This measuring allows the inference that they are nodes that functionally deal with restricted information that does not flow to the other nodes. However, the node index is a special case. By having the smallest value, 1,17, it determines that this node is not able to deal with information flow. It is possible to infer about the alignment when the introduction or removal of an element increases the path and decreases the closeness since they are inverse. The drive of the alignment would represent a decreasing in the average path and an increasing in the closeness centrality. The node phone book is relevant since that it is responsible for managing the active users policies in the Web Portal. This allows the inference that sociomateriality enactment intervention in elements with high betweenness improves the drive of alignment focused on few assets. Moreover, the *Resources* node is responsible for the management of the facilities that a user can use. They need to be subscribed in the Web Portal to be available. The *phpmyadmin* node represents the tool that is used by the administrator to manage the database tables that compose the system. As the interface for those tables it is central in their management.

The profiling framework develops a holistic view of the emergent virtual organization. It shows that sociomateriality enactment is a fully key driver. Focusing that the enactment exploitation is a differentiator enhancement for verification/specification of information system's enactment. Complex-Networks show that it is possible to collect the emergence of sociomaterial enactment. This points the modelling and measuring as a trigger for unique governance exploitation. A main limitation of the present exploratory case is that it does not compare two moments in time where occurred changes in the elements of the Web Portal.

7. Conclusions and Future Work

We are developing that profiling the “**HOW**” from the emergent virtual organizations that occurred through the sociomaterial enactment can provide the development of an augmented reality exploitation of the information system business alignment. With this augmented reality of the Business/IT Alignment is possible to infer proper approaches that can be used to drive the information systems. Moreover, presents the sociomaterial characteristic that allows the

system to easily evolve or fail. Moreover, one can expect that a progression towards emergent virtual organization modelling and measuring to be suitable.

Complex-networks are described as suitable to be adopted in the study of the information systems emergent virtual organization. A set of four analytical dimensions is described in consonance with the adoption of the complex-network approach. These dimensions are used to profile the Business/IT Alignment as an emergent property of the information systems virtual organization. It defines a profiling framework that introduces, integrates and describes the models and measures that sustain the four dimensions relevant to the Business/IT Alignment. This profiling framework is a mechanism to study the emergent virtual organizations resulting from the information systems sociomaterial enactment. Further exploratory cases must be done to accent its contribution for the Business/IT Alignment.

Can the development initiatives of the information systems alignment be more effective as a result of the profiling framework? One could argue that they can because, without knowing the existing information flow, “only” by modelling and measuring the sociomaterial enactment we can trace an image of the organizational entanglement. It is an approach from small data to big impact where the information systems entanglement can change “everything”.

References

1. Alter, S.: Exploring the Temporal Nature of Sociomateriality from a Work System Perspective. Presented at the AMCIS, Seattle (2012)
2. Barabasi, A.-L.: Network Theory--the Emergence of the Creative Enterprise. *Science*. 308 (5722), 639–641 (2005)
3. Boudreau, M.-C., Robey, D.: Enacting Integrated Information Technology: A Human Agency Perspective. *Organization Science*. 16 (1), 3–18 (2005)
4. Candia, J. et al: Uncovering individual and collective human dynamics from mobile phone records. *J. Phys. A: Math. Theor.* 41 (22), 224015 (2008)
5. Carr, N.G.: IT doesn't matter. *Eng. Management Review, IEEE*. 32 (1), 24–24 (2004)
6. Chan, Y.: Why haven't we mastered alignment? The importance of the informal organization structure. *MIS Quarterly Executive*. (2002)
7. Davenport, T.H.: The coming commoditization of processes. *Harvard Business Review*. 83 (6), 100–8– 149 (2005)
8. Dorogovtsev, S.N., Mendes, J.F.F.: Evolution of networks. *Advances in Physics*. 51 (4), 1079–1187 (2002)
9. Leonardi, P.M., Barley, S.R.: What's under construction here? *The Academy of Management Annals*. 4 (1), 1–51 (2010)
10. Mell, P., Grance, T.: The NIST definition of cloud computing (draft). NIST special publication. 800 145 (2011)
11. Mitchell, M.: Complex systems: Network thinking. *Artificial Intelligence*. 170 (18), 1194–1212 (2006)
12. Nami, M.R., Tavangarian, D.: Virtual Organization: A New Approach in IT. CIT 2007. 7th IEEE International Conference, (2007)
13. Newman, M.: *Networks: an introduction*. Oxford University Press (2010)
14. Newman, M.E.J.: A measure of betweenness centrality based on random walks. *Social Networks*. 27 (1), 39–54 (2005)
15. Newman, M.E.J.: The Structure and Function of Complex Networks. *SIAM review*. 45 (2), 167–256 (2003)
16. Orlikowski, W.J.: Sociomaterial Practices: Exploring Technology at Work. *Organization Studies*. 28 (9), 1435–1448 (2007)
17. Orlikowski, W.J., Scott, S.V.: Sociomateriality. *The Academy of Management Annals*. 2 (1), 433–474 (2008)
18. Pabarskaite, Z., Raudys, A.: A process of knowledge discovery from web log data. *Journal of Intelligent Information Systems*. 28 (1), 79–104 (2007)

19. Peppard, J., Ward, J.: Beyond strategic information systems: towards an IS capability. *The Journal of Strategic Information Systems*. 13 (2), 167–194 (2004)
20. Preparata, F.P., Wu, X., Yin, J.: Proceedings of the 2nd annual international workshop on Frontiers in Algorithmics. FAW '08, June (2008)
21. Ross, J.W.: Creating a strategic IT architecture competency: Learning in stages, (2003)
22. Rubinov, M., Sporns, O.: Complex network measures of brain connectivity: Uses and interpretations. *NeuroImage*. 52 (3), 1059–1069 (2010)
23. Strogatz, S.H.: Exploring complex networks. *Nature*. 410 (6), 268–276 (2001)
24. Tapscott, D., Williams, A.D.: *Wikinomics*. (2008)
25. Tilvawala, K., Myers, M., Sundaram, D.: Design of ubiquitous information systems for digital natives. *Information Systems Journal*. 1–13 (2012)
26. Tyler, J.R., Wilkinson, D.M., Huberman, B.A.: Email as Spectroscopy: Automated Discovery of Community Structure within Organizations. arXiv. 3264 (2003)
27. Vespignani, A.: Predicting the behavior of techno-social systems. *Science*. 325 (5939), 425–428 (2009)
28. Wand, Y., Weber, R.: Research commentary: information systems and conceptual modeling—a research agenda. *Information Systems Research*. 13 (4), 363–376 (2002)
29. Zacarias, M. et al: Adding a Human Perspective to Enterprise Architectures. DEXA, (2007)

What Do We Know about ERP in SMEs? Identifying Gaps in Research

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Abstract

Enterprise Resource Planning (ERP) was originally meant for large enterprises (LEs), hence most attention on ERP research focuses on LEs. However, ERP vendors have diverted their attention also to small and medium sized enterprises (SMEs) in order to cater for their needs. This paper presents a systematic mapping study of ERP in the context of SMEs. The study concentrated on the ERP adoption and implementation issues that have already been studied and identified gaps where further research is needed. It also investigated what research methodologies have been employed in the studies.

Keywords: SME, ERP, Enterprise Resource Planning, Systematic Mapping, Small and Medium-sized Enterprises.

1. Introduction

ERP systems are developed to integrate business processes in enterprises, resulting in effective management of the whole enterprise [20]. Even though ERP has proved to have many advantages, it has mostly been utilized by large organizations (LEs). The decision to adopt ERP is usually accompanied by investments such as time, financial and human resources [23]. LEs usually have these capabilities, in addition to defined business processes which makes the implementation process easier when compared to small and medium enterprises (SMEs) [13].

While SMEs continue to be productive drivers of economic growth, they often face numerous challenges in implementing technologies such as ERP systems [1]. They are usually core business focused, they lack human and financial resources and technical know-how to support such initiatives. They also operate their businesses manually, without standardized procedures [15]. However, ERP vendors have diverted to developing ERP software packages to suit the needs of SMEs, considering costs and functional scopes that go into the implementation process [38].

Over the years, many studies have focused on ERP implementation success factors in SMEs, but there are still reports of failures in SME ERP implementations. Therefore there is still a need to research on best practices that will lead to simplified ERP implementations in SMEs. The purpose of this study is to analyze the existing literature on ERP implementation in SMEs, in order to identify what areas have already been covered and establish a gap for future research.

The next section discusses the research method. Section 3 explains the procedure used for searching for primary studies. Section 4 discusses the inclusion and exclusion of papers. Section 5 gives an overview of relevant papers. Section 6 presents the findings. Finally in section 7, we discuss the results and conclude the paper.

2. Research Method

The research method used followed the procedure suggested by Peterson et al. [31] as shown in Figure 1.

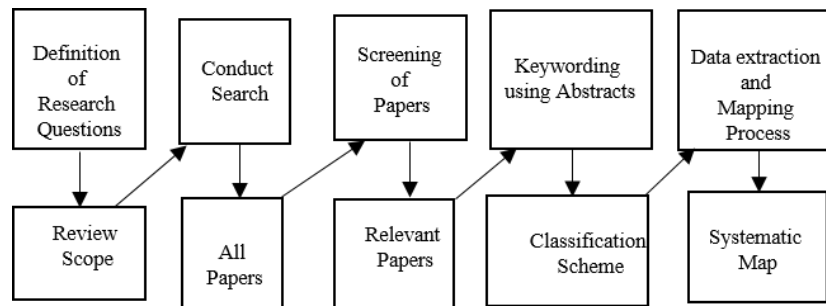


Fig. 1. A systematic study process

By following this process, first the research questions were defined, and then the appropriate keywords were identified. Then the search was conducted using those keywords in order to find the relevant papers. After the papers were found, they were screened using the inclusion and exclusion process in order to filter out papers that do not contribute to answering the defined research questions. The remaining papers were then categorized according to keywords used in abstracts. Data is then extracted from those papers and presented as a systematic map.

With this systematic mapping study, we intend to get an overview of the results that have been published in this research area, and to establish an overview of what still needs to be investigated. Our research questions are the following:

RQ1. What main issues have already been addressed in studies of ERP in SMEs?

RQ2. What research methods have been used in studies of ERP in SMEs and how have they changed over time?

RQ3. What areas of ERP in SMEs need further research?

3. Search for Primary Studies

We chose to search from the relevant and appropriate digital databases that target conferences and journals in information systems and software engineering. Five databases have been identified, namely: ACM, IEEEXplore, Science Direct, Springer, and EBSCO. We believe that these databases cover most of the essential studies of the topic. The search was limited to papers published between 2004 and 2014.

Table 1. Number of relevant publications out of the publications found

ACM	IEEEXplore	Science Direct	EBSCO	Springer
109/312	9/23	34/95	21/61	7/14
				180/505

The combination of the search terms “ERP Adoption”, Enterprise Resource Planning”, “SME”, “Small and Medium Enterprises” as well as “ERP implementation” were used in the search. Table 1 shows the results of the search, including the number of the relevant papers out of the total number of publications found. In cases when a publication was already chosen in one database as relevant, it is regarded irrelevant in the rest of the databases, hence some databases yielded fewer relevant publications.

4. Inclusion & Exclusion of Papers

We have only included papers that are relevant for answering the research questions. Another crucial condition that has to be met for a paper to be selected is that, it has to have been published in either a peer reviewed journal or conference proceedings. A total of 505 articles were identified. The search from different databases however yielded duplicates, therefore these duplicates were removed. After a thorough reading of abstracts of the papers, we identified those whose context does not contribute to the purpose of the research and excluded them. These papers concentrated on topics such as whether other software is more appropriate for SMEs than ERP. Other papers that were also excluded were those written in languages other than English.

The study also excluded papers that did not include any empirical evidence, but were only presenting discussions, opinions and ideas. Some papers also focused on Information Systems (IS) generally and only included ERP as an example. Such papers were also excluded. In total, 180 out of 505 papers were regarded as relevant.

The papers were screened further, and more papers were rejected because of the following reasons:

1. The paper focused only on the technical aspects of implementation.
2. The paper focused on a specific line of business such as banking, and did not produce any evidence on ERP and SMEs in general.

After this round of screening, 42 papers were found to be relevant, and these were read thoroughly.

5. Relevant Articles Overview

The publication year was considered in order to examine the trend of how the area has been studied. Figure 2 shows the publication trend from 2004 to date.

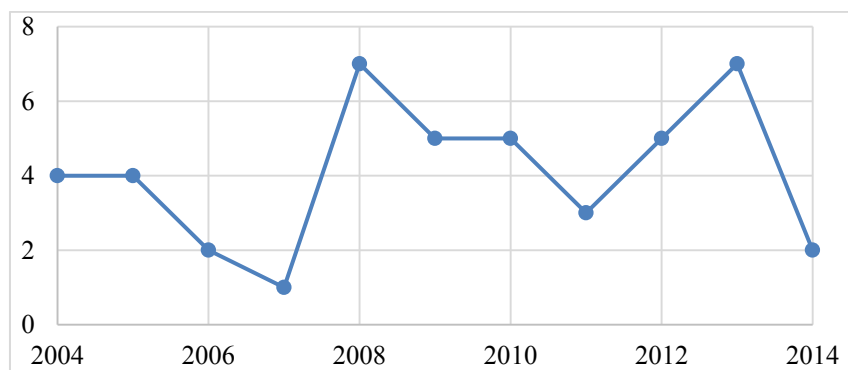


Fig. 2. Number of publications per year

The research methodologies used also varied amongst the publications as shown in Figure 3. The main used is a survey methodology.

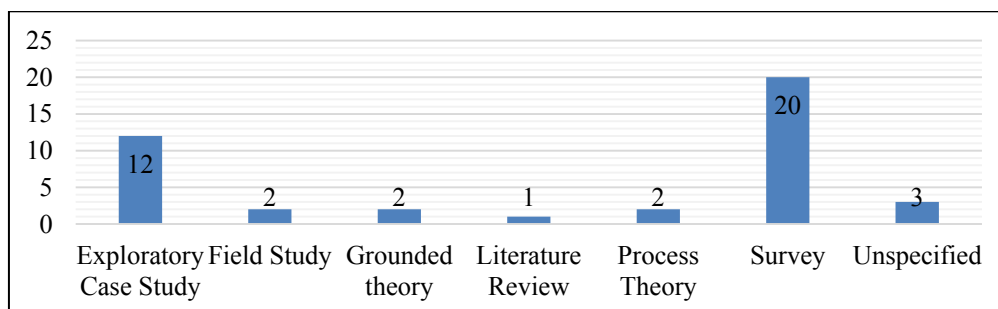


Fig. 3. Research methodologies used

The publications covered a range of research themes (Table 2). We have categorized them according to the phases of the ERP life cycle framework proposed by Esteves and Pastor [10]. This framework structures the ERP system life cycle into six stages that enable the allocation of different research issues in different stages. The stages are: Adoption Decision, Acquisition, Implementation, Use and Maintenance, Evolution and Retirement.

In the Adoption Decision phase, the managers agree upon acquiring an ERP system and also define the system requirements. In the Acquisition phase, the ERP system deemed best to fit the requirements is selected. The implementation costs as well as maintenance services are also defined and analyzed. In the Implementation phase, the selected ERP system is customized and adapted into the organization. Whereas, in the Use and Maintenance phase, the implemented system is maintained in order to keep the expected benefits returning. In the Evolution phase, new capabilities are added in order to advance the system and to provide additional benefits. The Retirement phase takes place when managers decide to replace the ERP system with a new system for any given reason. The authors have selected this framework in order to make it possible to see which area has received a lot of research attention, as well as to identify areas that have been abandoned.

Table 2. A summary of the relevant papers

Life Cycle Phase	Focus Area	Methodology	References
Adoption Decision	Project Management	Survey	[4], [10],[12],[14],[37]
		Field Study	[12]
	Adoption decision	Survey	[3]
	Best Practices	Survey	[28]
	Adoption Indicators	Survey	[22],[44]
	Perception on Factors	Exploratory Case Study	[34]
Acquisition	Costs	Survey	[19],[44]
		Exploratory Case Study	[18],[32]
Implementation	Success Factors	Field Study	[35]
		Survey	[1],[2],[38],[42]
		Process Theory	[26]
		Exploratory Case Study	[13],[17], [18], [21],[36]
	Contextual Issues	Exploratory Case Study	[25]
	Risk Management	Process Theory	[31]
	Customization	Case Study	[43]
		Process Theory	[31]
	Impact of Consultants	Survey	[4]
		Ground Theory	[21]
	Strategies	Exploratory Case Study	[5],[11],[15]
	Challenges	Exploratory Case Study	[23],[26]
		Survey	[24]
		Unspecified	[7]
Methods	Literature Review	[40]	
Influence	Exploratory Case Study	[29]	
Use & Maintenance	Performance evaluation	Survey	[8],[20],[36],[33]
	Benefits	Field Study	[9],[10]
	Determinants of Use	Survey	[16],[27]
Evolution			
Retirement			

6. Findings

Buonanno et al. [3] in their study found that SMEs do not regard financial constraints as the main reason for not adopting ERP systems, but suggested structural and organizational reasons as the major cause. Shahawai and Idrus [35] proposed a strategy for determining specifications in adopting an ERP system successfully. Chang and Hung [4] also developed a theoretical model of ERP adoption. They found the CEO's attitude towards IT adoption, and his IT knowledge as well as the ERP system cost, complexity and compatibility to be the main determinants in ERP adoption for SMEs [4].

Chien et al. [6] concluded that a balance of centrifugal and centripetal forces promotes successful ERP implementation. Centripetal forces refer to centralizing decision making in the organization, a use of a formal defined procedure with a clear guidance and clear project goals, whereas centrifugal forces refer to free flow of information within an organization, communication with end users and awareness of information not necessarily related to project goals [6].

Tasevka et al. [38] argued that project planning practices are crucial in the success of an ERP implementation, and likewise Chien et al. [6] recommended a procedural plan clearly defining all activities that have to be executed for the implementation team to follow. Huin [16] and Xu et al. [41] in their studies found that one main challenge in implementing ERP in SMEs is that, the decision making usually lies with one person, usually a Chief Executive Officer or a Chief Financial Officer, who does not necessarily have project management nor technical background. They are usually concerned with costs and due dates and hence their sole decision making does not always lead to feasible implementation.

Several papers have identified critical success factors in ERP implementation, and the top ten are summarized in Table 3. Different implementation methods have also been studied [40], as well as implementation issues [7], [24], [25], [26].

Due to lack of knowledge on requirement specifications, SMEs are usually at the mercy of ERP vendors, and due to the fact that SME owners often withhold important information. This leads to a misfit between the system and the organization [30]. Vilpola and Kouri [39] have proposed a new method for SMEs requirement specifications whereby key personnel from major business functions are interviewed in order to analyze and collect the main business processes, the needs and problems experienced in current processes. As a result of these interviews, the discrepancies between standard ERP operations and the existing company processes will be identified.

Table 3. CSFs for Successful ERP Implementation

CSFs	References
Top Management Support	[12],[13],[17],[26],[35], [36]
Organizational Culture	[36],[41]
Effective Communication	[5], [13],[26]
Team Work	[26],[28],[35],[36]
Central Decision Making	[5],[6],[41]
Use of consultants	[5],[13],[26],[35]
Risk Management	[5],[28],[31]
Training	[7],[13],[17],[21],[35]
Change Management	[3],[7],[13],[35]
User Involvement	[7],[21],[35]

In the Use and Maintenance phase, Federici [11] and Ruivo [34] have analyzed the effects ERP systems have in organizations, while Equey and Fragnière [8]; Kale [32] carried out a study to evaluate the organizational performance and benefits after implementation. In our search, we did not find publications that cover areas under the evolution and retirement phases.

7. Discussions and Conclusions

After a thorough search for publications from relevant databases, it was unexpected to discover that only few papers were available on the topic. Considering the amount of research that has been done in the ERP research area, 42 papers is not a good number. It clearly shows that a lot of attention still focuses on ERP implementation in LEs.

Based on the ERP lifecycle framework developed by Esteves [10], many publications have addressed issues in the Adoption decision, Acquisition and Implementation phases. Adoption decision factors have been well covered and several adoption models have been proposed. Critical success factors for successful adoption and a successful implementation have also been discussed. However failure factors have not been well covered. This is necessary in order to avoid repeated failures in SME ERP implementations.

Several papers also covered implementation issues such as challenges, strategies as well as other general issues, but there is still a need for further research about different implementation methods and how they have worked for SMEs.

The literature also lacks focus on the effects of implementation in SMEs, as well as evaluation of post implementation performance. In addition, no publications were found on the evolution nor the retirement phase, and considering that the ERP has been adopted by many SMEs around the world, there is a need for research in this area to discover how ERP systems can be expanded in order to maintain organizational satisfaction. There is also a need for research on the effects, challenges and methods of replacing ERP systems in case of retirement.

Considering that SMEs vary in sizes, there is also a need to explore further whether small- size enterprises experience challenges or benefits of ERP more in comparison to medium-sized companies or vice versa. Furthermore, since many SMEs are opting for on-demand solutions [44], research is needed to compare the benefits and constraints experienced from implementing standard ERP and implementing CloudERP.

From the perspective of the first author of the paper, another gap realized in research in this mapping study is that most studies have been done in Asia, America, Australia, and Europe, but no study has been done in African SMEs. There is a need to understand whether there is a difference between developed and developing countries in relation to ERP and SMEs, therefore studies in African SMEs are recommended.

References

1. Achanga, P., Shehab, E., Roy, R., Nelder, G.: Critical success factors for lean implementation within SMEs. *J. Manuf. Technol. Manag.* 17 (4), 460–471 (2006)
2. Ahmad, M.M., Pinedo Cuenca, R.: Critical success factors for ERP implementation in SMEs. *Robot. Comput.-Integr. Manuf.* 29 (3), 104–111 (2013)
3. Buonanno, G., Faverio, P., Pigni, F., Ravarini, A., Sciuto, D., Tagliavini, M.: Factors affecting ERP system adoption: A comparative analysis between SMEs and large companies. *J. Enterp. Inf. Manag.* 18 (4), 384–426 (2005)
4. Chang, S.-I., Hung, S.-Y., Yen, D.C., Lee, P.-J.: Critical Factors of ERP Adoption for Small- and Medium- Sized Enterprises: An Empirical Study. *J. Glob. Inf. Manag.* 18 (3), 82–106 (2010)
5. Chen, R.-S., Sun, C.-M., Helms, M.M., Jih, W.-J. (Kenny): Role Negotiation and Interaction: An Exploratory Case Study of the Impact of Management Consultants on

- ERP System Implementation in SMEs in Taiwan. *Inf. Syst. Manag.* 25 (2), 159–173 (2008)
6. Chien, S.-W., Hu, C., Reimers, K., Lin, J.-S.: The influence of centrifugal and centripetal forces on ERP project success in small and medium-sized enterprises in China and Taiwan. *Oper. Manag. China.* 107 (2), 380–396 (2007)
 7. DIXIT, A., YADAV, S.: A Study of Issues & Challenges Affecting ERP Implementation in SMES. *Glob. J. Enterp. Inf. Syst.* 54–62 (2011)
 8. Equey, C., Fragnière, E.: Elements of Perception Regarding the Implementation of ERP Systems in Swiss SMEs: *Int. J. Enterp. Inf. Syst.* 4 (3), 1–8 (2008)
 9. Esteves, J.: A benefits realisation road-map framework for ERP usage in small and medium-sized enterprises. *J. Enterp. Inf. Manag.* 22 (1/2), 25–35 (2009)
 10. Federici, T.: Factors influencing ERP outcomes in SMEs: a post-introduction assessment. *J. Enterp. Inf. Manag.* 22 (1/2), 81–98 (2009)
 11. Grandhi, S., Chugh, R.: Implementation Strategies for ERP Adoption by SMEs. In: Kim, T., Ko, D., Vasilakos, T., Stoica, A., and Abawajy, J. (eds.) *Computer Applications for Communication, Networking, and Digital Contents.* pp. 210–216. Springer Berlin Heidelberg (2012)
 12. Guido, C., Gail, C., Nancy, J., Pierluigi, R.: A Planning-Oriented Approach for ERP Implementation in SMEs. In: D’Atri, A., De Marco, M., Braccini, A.M., and Cabiddu, F. (eds.) *Management of the Interconnected World.* pp. 105–112. Physica-Verlag HD (2010)
 13. Ha, Y.M., Ahn, H.J.: Factors affecting the performance of Enterprise Resource Planning (ERP) systems in the post-implementation stage. *Behav. Inf. Technol.* 1–17 (2013)
 14. Handayani, P.W., Hidayanto, A.N., Budi, I.: Business Process Requirements for Indonesian Small Medium Enterprises SMEs in Implementing Enterprise Resource Planning ERP and ERP Systems Comparison. 9. 8 2437–2441 (2013)
 15. Huin, S.F.: Managing deployment of ERP systems in SMEs using multi-agents. *Int. J. Proj. Manag.* 22 (6), 511–517 (2004)
 16. Hustad, E., Olsen, D.: ERP Post-implementation Issues in Small-and- Medium-Sized Enterprises. In: Cruz-Cunha, M., Varajão, J., Powell, P., and Martinho, R. (eds.) *ENTERprise Information Systems.* pp. 290–299. Springer Berlin Heidelberg (2011)
 17. Hustad, E., Olsen, D.H.: ERP Implementation in an SME: a Failure Case. In: *Information Systems for Small and Medium-sized Enterprises.* pp. 213–228. Springer Berlin Heidelberg (2014)
 18. Jha, R., Saini, A.K.: An exploratory factor analysis on pragmatic Lean ERP implementation for SMEs. *Parallel Distrib. Grid Comput. PDGC 2012 2nd IEEE Int. Conf. On.* 474–479 (2012)
 19. Johansson, B., Sudzina, F.: Actual vs. Planned ERP Systems Implementation Costs in European SMEs. In: *3rd European Conference on Information Management and Evaluation, IT University.* pp. 232–238. (2009)
 20. Kale, P.T., Banwait, S.S., Laroia, S.C.: Performance evaluation of ERP implementation in Indian SMEs. *J. Manuf. Technol. Manag.* 21 (6), 758–780 (2010)
 21. Koh, S.C.L., Gunasekaran, A., Cooper, J.R.: The demand for training and consultancy investment in SME-specific ERP systems implementation and operation. *Transp. Logist. Phys. Distrib. Interlocking Inf. Syst. Int. Supply Demand Chains Manag. ICPR19.* 122 (1), 241–254 (2009)
 22. Laukkanen, S., Sarpola, S., Hallikainen, P.: ERP System Adoption - Does the Size Matter? In: *Proceedings of the Proceedings of the 38th Annual Hawaii International Conference on System Sciences - Volume 08.* p. 226.2. IEEE Computer Society (2005)
 23. Lee, C.K.: Successful implementation of ERP systems in small businesses: a case study in Korea. (2008)
 24. Lewandowski, J., Salako, A.O., Garcia-Perez, A.: SaaS Enterprise Resource Planning Systems: Challenges of Their Adoption in SMEs. In: *Proceedings of the 2013 IEEE 10th International Conference on e-Business Engineering.* pp. 56–61. IEEE Computer Society (2013)

25. Liang, H., Xue, Y.: Coping with ERP-related contextual issues in SMEs: a vendor's perspective. *Spec. Issue Underst. Context. Influ. Enterp. Syst. Des. Implement. Use Eval.* 13 (4), 399–415 (2004)
26. Loh, T.C., Koh *, S.C.L.: Critical elements for a successful enterprise resource planning implementation in small-and medium-sized enterprises. *Int. J. Prod. Res.* 42 (17), 3433–3455 (2004)
27. De Loo, I., Bots, J., Louwrik, E., Meeuwsen, D., van Moorsel, P., Rozel, C.: The effects of ERP-implementations on the non-financial performance of small and medium-sized enterprises in the Netherlands. *Electron. J. Inf. Syst. Eval.* 16 (2), 101–113 (2013)
28. Malhotra, R., Temponi, C.: Critical decisions for ERP integration: Small business issues. *Int. J. Inf. Manag.* 30 (1), 28–37 (2010)
29. Manfrinato Pimentel, A.C., De Mesquita Spinola, M.: ERP implementation influence in SMEs organizational structure. *Technol. Manag. IT-Driven Serv. PICMET 2013 Proc. PICMET 13.* 1535–1541 (2013)
30. Muscatello, J.R., Small, M.H., Chen, I.J.: Implementing enterprise resource planning (ERP) systems in small and midsize manufacturing firms. *Int. J. Oper. Prod. Manag.* 23 (8), 850–871 (2003)
31. Poba-Nzaou, P., Raymond, L., Fabi, B.: Adoption and risk of ERP systems in manufacturing SMEs: a positivist case study. *Bus. Process Manag. J.* 14 (4), 530–550 (2008)
32. Quiescenti, M., Bruccoleri, M., La Commare, U., Noto La Diega, S., Perrone, G.: Business process-oriented design of enterprise resource planning (ERP) systems for small and medium enterprises. *Int. J. Prod. Res.* 44 (18-19), 3797–3811 (2006)
33. Ruivo, P., Oliveira, T., Neto, M.: ERP Post-adoption: Use and Value – An Empirical Study on Portuguese SMEs. In: Rahman, H., Mesquita, A., Ramos, I., and Pernici, B. (eds.) *Knowledge and Technologies in Innovative Information Systems.* pp. 67–81. Springer Berlin Heidelberg (2012)
34. Shahawai, S.S., Idrus, R.: Malaysian SMEs Perspective on Factors Affecting ERP System Adoption. *Model. Symp. AMS 2011 Fifth Asia.* 109–113 (2011)
35. Shaul, L., Tauber, D.: CSFs along ERP life-cycle in SMEs: a field study. *Ind. Manag. Data Syst.* 112 (3), 360–384 (2012)
36. Snider, B., Silveira, G.J.C. da, Balakrishnan, J.: ERP implementation at SMEs: analysis of five Canadian cases. *Int. J. Oper. Prod. Manag.* 29 (1), 4–29 (2009)
37. Tasevska, F., Damij, T., Damij, N.: Project planning practices based on enterprise resource planning systems in small and medium enterprises — A case study from the Republic of Macedonia. *Int. J. Proj. Manag.* 32 (3), 529–539 (2014)
38. Upadhyay, P., Dan, P.K.: An Explorative Study to Identify the Critical Success Factors for ERP Implementation in Indian Small and Medium Scale Enterprises. In: *Proceedings of the 2008 International Conference on Information Technology.* pp. 295–299. IEEE Computer Society (2008)
39. Vilpola, I., Kouri, I.: Improving ERP Requirement Specification Process of SMEs with a Customer-Centered Analysis Method. *Front. E-Bus. Res.* 140–151 (2005)
40. Vilpola, I.H.: A method for improving ERP implementation success by the principles and process of user-centred design. *Enterp. Inf. Syst.* 2 (1), 47–76 (2008)
41. Xu, L.X.X., Wang Feng Yu, Lim, R., Lua Eng Hock: A methodology for successful implementation of ERP in smaller companies. *Serv. Oper. Logist. Inform. SOLI 2010 IEEE Int. Conf. On.* 380–385 (2010)
42. Yuanqiang Xia, Lok, P., Song Yang: The ERP implementation of SME in China. *Serv. Syst. Serv. Manag. 2009 ICSSSM 09 6th Int. Conf. On.* 135–140 (2009)
43. Zach, O., Munkvold, B.E.: Identifying reasons for ERP system customization in SMEs: a multiple case study. *J. Enterp. Inf. Manag.* 25 (5), 462–478 (2012)
44. Zhao, F., Kirche, E.: Continuing On-Premise or Adopt On-Demand? An Empirical Study of ERP Adoption in SMEs. In: Kurosu, M. (ed.) *Human-Computer Interaction. Users and Contexts of Use.* pp. 492–500. Springer Berlin Heidelberg (2013)

The Life Cycle Challenge of ERP System Integration

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Abstract

To serve its purpose as a backbone for business integration, Enterprise Resource Planning (ERP) systems need to be integrated with other information systems inside and outside the boundaries of an enterprise. An inductive case study was made to examine a long-term ERP system of a large manufacturing enterprise to better understand the nature and importance of ERP system integration. Our results can be summarized as four findings about the current life cycle models: 1) integration should be a major consideration when choosing ERPs, 2) deployments are continuous, 3) external integration is not just an extension phase after the project and 4) integration remains as a continuous challenge which is never fully achieved due to the constantly changing business requirements and organizational landscape. The results can help managers when making decisions on integration issues, yet effective approaches for integration governance are needed in order to avoid the increased costs and complexity.

Keywords: Information Systems, Enterprise Systems, ERP, Enterprise Resource Planning, Integration, Life Cycle, Case Study, Manufacturing Enterprise.

1. Introduction

Originally, Enterprise Resource Planning (ERP) systems integrated the core business functions of an enterprise [1]. Later, due to the requirements of collaborative business, the challenge of integration evolved from inside the company to consider also the customers and business partners [2]. In a modern enterprise, a multitude of different systems exists ERP being just one of them and integration of these systems is an unavoidable evil [3].

ERP systems have been investigated comprehensively since the mid-1990s. Especially, the implementation process of an ERP system [4] and critical success factors in ERP implementation projects [5] have been studied. ERP systems have become de facto standards in providing the backbone for enterprise integration and more attention has been paid to extending the ERP system through external integration with supply chain [6].

However, in the field of Information Systems (IS), *integration* has been identified as an “omitted variable” and a misunderstood concept [2, 6]. In addition, studies on ERP integration often focus on the integration of an ERP system and a specific target system [7]. We propose a broader perspective on ERP system integration by setting the following research question: *How does integration evolve during the ERP system life cycle?* We made an inquiry into the practice by conducting an inductive case study in a large manufacturing enterprise. Based on our meetings and interviews with practitioners, we concluded that the existing life cycle models fail to describe the nature of ERP system integration. After presenting the background of this study and briefly describing the research approach and the

case organization, we present the findings and compare them with the existing life cycle models. Before concluding the paper, we consider the reasons why our findings conflict with the existing models and discuss about our future research intents.

2. Background

2.1. ERP System Integration

As a term, *integration* is ambiguous and has different meanings. In the domain of IS, it is often considered as data exchange between two or more systems, standardization of business processes as well as cooperation and coordination between human actors [1]. There has been advances especially in integration technologies such as those related to EAI (Enterprise Application Integration) and SOA (Service Oriented Architecture) to overcome the technical challenges of integration [22]. However, it has been concluded that solving integration problems often requires combining of different technical approaches, instead of being solved by a single approach [10]. Moreover, integration has been identified as a socio-technical challenge that includes, besides the technical side, also organizational and social aspects [2].

Integration of business functions is the goal of an ERP implementation as the ERP system integrates business functions inside the organization and enables data flow between different units of an organization [9]. Moreover, numerous other information systems, such as Decision Support Systems (DSS) [12] and Manufacturing Execution Systems (MES) [13] are still needed, and application-level integration with these systems is necessary. The functionality of an ERP system is often enhanced by bolt-on applications, such as CRMs (Customer Relationship Management), and WMSs (Warehouse Management System) [21]. Because the purpose of a contemporary ERP is to provide the backbone for business collaboration, external integration with business partners' systems has to be done [2]. Another form of ERP system integration is to provide interfaces for users to access the system on mobile. This type of integration is called portal-oriented application integration where an interface is built to display the desired information needed by the intended user group [10]. Thus, we understand ERP system integration as a multidimensional *activity* that includes building of interfaces and managing of interconnections between the ERP and other internal and external systems during the ERP system life cycle aiming at *interoperability* between the systems.

2.2. Existing ERP System Life Cycle Models

We define life cycle as *a progression through a series of differing stages of development*¹. By this we mean that an ERP system evolves through certain steps or milestones from the point when the acquisition decision is made to the point when the system is abandoned. We distinguish the life cycle models from software development methodologies. We see that development of an ERP system may utilize a variety of development methods. For example, the pilot version of the system may evolve through a strict waterfall process starting with a comprehensive definition phase and later, more features to the system can be implemented with agile approaches. Since our intent is to examine how integration evolves through different stages in the life cycle, comparing our findings to the life cycle models instead of development methods is necessary.

To our knowledge, four ERP system life cycle models have been proposed [5, 11, 16, 17]. Due to the limited space available for this paper, a comprehensive presentation of these models is omitted. Instead we focus on high-level comparison of the models and investigate how integration is presented in each of them. We intuitively classified the phases of the models according to the following categories: planning and design, implementation, using the system, improvement and extension and migration to a new system. In Figure 1, the phases of the life cycle models are shown and categorized.

¹ <http://www.thefreedictionary.com/life+cycle>

	Planning and design	Implementation	Using the system	Improvement and extension	Migration to a new system
Model 1: Esteves and Pastor (1999)	Adoption Decision, Acquisition	Implementation	Use & Maintenance	Extension	Retirement
Model 2: Ross and Vitale (2000)	Design	Implementation	Stabilization	Continuous Improvement	Transformation
Model 3: Markus and Tanis (2000)	Project Chartering	The Project (configure & rollout)	Shakedown	Onward and Upward	
Model 4: Rajagopal (2000)	Initiation, Adoption, Adaptation		Acceptance, Routinization, Infusion		

Fig. 1. Classification of the phases in the existing life cycle models.

Model 1 and Model 4 emphasize the planning and design by dedicating more than one phase for it. Model 4 does not have a dedicated phase for implementation unlike the others. Instead, the system is implemented in between “Adaptation” and “Acceptance”. All the models identify the phase when the system is used. Model 1 and Model 2 have similar phases in post-implementation (the phases after implementation) considering adding more capabilities to the system, and migrating the system to another while the other two models do not have such emphasis on post-implementation. Unlike Models 1 and 2 that are waterfall-style models, Models 3 and 4 are iterative in which all the previous phases are revisited when an upgrade or retirement of the system is made.

Models emphasize integration differently. Model 1 has a dedicated phase for integration, “Extension”. During this phase, more capabilities are integrated into the system and external collaboration is considered. Similarly, Model 2 considers “Continuous improvement” as a phase in which new modules and bolt-on applications are added to the system. Model 3 highlights system integration and roll-out during the project phase of the system. In addition, “Onward and upward” continues until the system is replaced by an upgrade or extension, which then starts a new cycle. Model 4 treats integration as milestones during the phases after implementation. “Integration of functional units” happens in the acceptance phase, “Organizational integration” is realized in the routinization phase and “IT integration at global level” is realized in the infusion phase. To summarize, in these models integration is either regarded an activity during or after the implementation or it is considered as “milestones” that are reached during the life cycle.

3. Research Approach

Adopting Organization (AO, the organization taking the ERP system into use) is a large and global manufacturing enterprise with an annual turnover over 9 billion euros. AO decided to build a fully-customized ERP system for sales and logistics in order to replace several legacy systems and also to overcome the year 2000 problem without having to make the necessary updates to all the systems. The implementation started in the middle of 1990s and during that time the existing ERP packages did not have the desired functionality to support business processes of the domain and control the complex supply chain in AO’s specific business field. The ERP project went through major challenges, including redesigning the insufficient system architecture and a large merger of two companies during the early phases of the implementation. Eventually, the project greatly exceeded the intended budget. However, at the time of writing, the system is currently in a global use and it is still in constant development. Benchmarking against ERP products in the market is constantly being done, but for the time being, AO has decided to keep the system to handle its core business processes. Figure 2 displays the timeline of the ERP system of AO including some of the key events that have occurred in the life cycle.

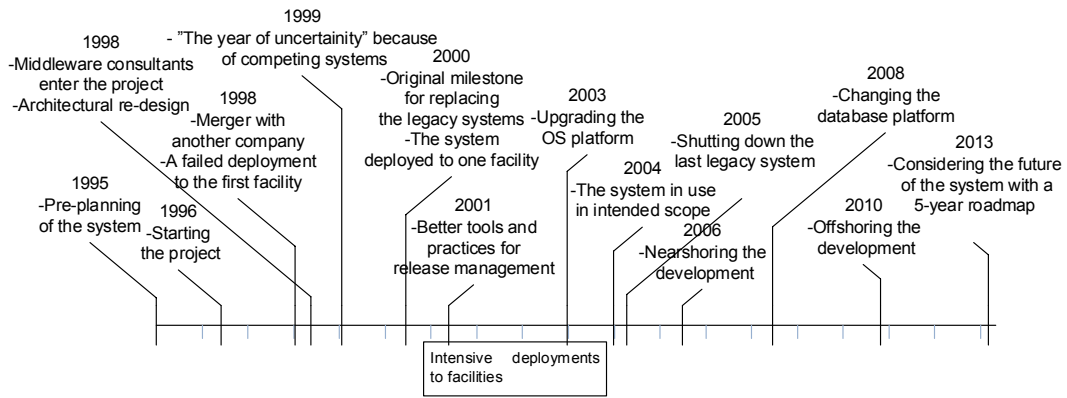


Fig. 2. ERP system timeline of the case organization.

The data for this study was collected with theme-based interviews, conducted between February and May 2013. The main goal of the interviews was to understand the role and practice of ERP system integration. The inquiry into a complex organizational phenomenon led to an approach in which, instead of determining a large number of fixed questions addressing specific areas of interest, the questions for the interviews were open-ended, focusing on the interviewee’s experiences during ERP system development. For example, major challenges and successes experienced in ERP development were asked. The more detailed questions were asked based on the received responses. This way, we were able to get a rich set of data for further investigation.

<p>Interviewees from AO: AO1: Business-IT negotiator AO2: IT manager of a business area AO3: Programme manager AO4: Enterprise architect AO5: IT manager of sales AO6: IT support manager AO7: Representative of logistics AO8: Project manager</p>	<p>Interviewees from Vendor: S1: Software manager S2: Service owner S3: Continuous service manager S4: Infrastructure manager S5: Project manager S6: Lead software developer S7: Service manager</p>	<p>Interviewees from Middleware Provider: MP1: Middleware manager MP2: Technical consultant</p>
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Fig. 3. Roles of Interviewees.

The data collection started with discussions with our key contact person from the upper management of AO. The goals of the research project were briefly presented to him in order to identify the right persons to interview. In general, the snowballing technique [3], in which the next interviewee is a referral from the previous one, was used for selecting the interviewees to get different viewpoints to the same issues. In total we interviewed 17 industrial experts that had different positions, ranging from upper management to mid-level management and developers, and included people from AO, the supplier (the company that implemented the system) and the middleware provider (a consulting company that helped adding a middleware product to the system). Interviewees’ roles and their organizations are listed in Figure 3. Due to the long duration of the ERP system development, the roles and responsibilities of the interviewees have been constantly changing. Some of the interviewees have been intensively involved in the early implementation of the system whereas others are currently working with the system. The duration of interviews ranged from 26 to 73 minutes, the average being 45 minutes. The interviews were transcribed and the data was analyzed by using the coding techniques of Grounded Theory [3] by using a software tool called ATLAS.ti, but because of the limited space available for this paper, the detailed description of the analysis is omitted.

In next section, we present four findings on ERP system integration that are in contrast with existing life cycle models, arguing that the models do not give a realistic image on integration in ERP system lifecycle.

4. Findings

4.1. Finding 1: The Emphasis on Integration in the Early Phases

Making decisions on system architecture and choosing the integration technologies turned out to be critical in the beginning of the project. The system architecture had to be redesigned because of the poor performance of the system that occurred when deploying the system to the first facility. It appeared that the scope of the system was not fully realized and it further increased as a merger with another company took place during the implementation phase:

"We underestimated the amount of staff and system and architecture solutions. Overall we had a large underestimation of the scale, which was then corrected along the way by bringing in the middleware [...]" –S5

Technical consultant argued that more comprehensive validation of technological solutions should have been done when making decisions on technologies in the design phase of the system development:

"I think [when investing several tens of millions to an ERP system] it's weird if there is no money for an extra validation round to be done in the very beginning. [...] implementing one part of the system fast to see that will the chosen technology work at all, will it fly? [...] You should never believe in the sales speeches of salesmen, the organization should have sangfroid to test the options." –MP2

Even though the current life cycle modes have dedicated phases for the acquisition phase of an ERP project, none of the models emphasizes the integration capabilities of the ERP system. Model 1 highlights minimizing the need for customization and analyzing the maintenance services in the acquisition phase. Model 2 suggests that decisions on process change and standardization have to be made in the design phase. Model 3 lists general tasks that are to be done in project chartering, such as selecting the package, identifying project manager and approving the budget and schedule. Model 4 suggests choosing of appropriate technology and cost benefit analysis as tasks that are carried out in adoption phase. We claim that integration capabilities of the ERP system have to be emphasized in the early phases in the ERP system lifecycle.

4.2. Finding 2: Deployments and Therefore New Integrations are Continuous

It appeared that integrating the ERP system with internal systems was a challenging endeavor, because existing production planning systems in facilities were different and therefore needed their own integration approaches. As the company grew bigger, the scope of the ERP system increased and introduced more facilities that the system had to be integrated with. The last legacy system was shut down in 2004 and the project phase of the ERP system development, originally indented to be completed before the year 2000, was considered completed. However, roll-outs to new facilities were ongoing ever since. After the project phase, the business of AO extended to new geographical locations and some of the original facilities were shut down. Deployments to new facilities were going on in Europe, South America and Asia. The system was deployed to new facilities according to the global ERP strategy of AO:

"[The ERP system] replaces the existing system because of the synergy and integration benefits so it has been always taken into use." –AO4

Unlike in our case, the existing life cycle models mainly suggest that internal integration of the ERP system (including the deployments to facilities and also replacing the legacy systems) takes place during the project phase. Model 1 considers deployment of the system as the activity of the project phase. Similarly, Model 3 suggests that system integration and rollout takes place during the project phase. According to Model 2, the system goes live during the implementation phase and is later stabilized. Model 4 suggests that integration of functional units is realized during the acceptance phase and organizational integration is realized during the routinization phase. We claim that unlike the existing life cycle models suggest, deployments of an ERP system are continuous, instead of being realized during the project phase and stabilized after it.

4.3. Finding 3: External Integration with Supply Chain Should Start Early

Because the ERP system of AO was very much supply chain oriented, integration with external systems and collaboration with customers and business partners started already during the project phase of the system. An infrastructure to support a web interface to the system was initiated in order to let the customers to access the desired information. Furthermore, to enable the supply chain collaboration, e-business standardization activities were considered during the project phase:

"In logistics, for integration purposes we have had connections to global business integration standardization agencies. We have been cooperating with competitors and other companies of this industry in order to get our way of doing to these standards." –AO6

Moreover, it appeared that the system had to enable the integration with external systems, originally not intended to be integrated with:

"It was not originally specified as a requirement of the system – this transportation cost management system came there...One benefit of [the system] is that it has many things that allows external partners to operate in it." –AO7

According to Models 1 and 2, external integration takes place after the implementation. Models 3 and 4 suggest that extending the system starts a new cycle, which revisits all the previous phases. However, they do not emphasize the role of standardization or other organizations involved in ERP system integration during the life cycle. Thus we claim that external integration with supply chain should start in the early phases of the life cycle. It involves, besides the integration of systems, collaboration with business partners and standardization organizations.

4.4. Finding 4: Integration is Never Fully Achieved

Besides extending the system with additional capabilities, it was necessary to adjust the system with organizational changes. These changes introduced a need of such kind of integration that cannot necessarily be considered as "extension" or "adding new capabilities to the system":

"The scope has changed somewhat, as far as logistics goes we've moved away from [the system] and we've replaced it with external ERP systems, and integrated those with [the system]" –AO3

It appeared that certain application logic previously being automated by the ERP system was replaced by integrating the system with additional external systems. Because of this, the IT architecture became more complex which led to increased costs:

"[Logistics] started making separate islands by freezing [the system] in a certain point and integrating additional systems to it. Now this has been going on for ten years already and we have ended up to problems as costs have increased in this area. [Consultants] have evaluated these systems and concluded that it's a complete spaghetti, which needs an additional transportation management system." –AO1

In contrast with existing life cycle models, it appeared that integration is never fully achieved, due to the constantly evolving organizational landscape and business environment. This was especially highlighted by conflicting political agendas of different managerial organs of AO:

"You never reach the ideal world, you end up having different kinds of stuff [different systems] here and there, maybe all the possible ERP vendors in some way. And the you have the company-level roadmap of the system, it's being developed and it constantly evolves" –AO1

We claim that ERP system integration is never fully achieved. This calls for approaches to govern ERP system integration throughout the lifecycle to avoid the increased complexity and costs.

5. Discussion

We can identify several reasons why that the existing ERP system life cycle models fail to see the nature and importance of ERP system integration. First, the models have been published in early 2000s. In our earlier study we noted that the interest towards ERP system integration emerged as late as mid-2000s – after the life cycle models were developed [7]. In addition to our study, the limitations of the existing life cycle models have also been discussed in a study about maintenance and support during the ERP system life cycle [8], which concluded that maintenance and support is an activity taking place during the whole life cycle instead of just in the post-implementation phase.

Moreover, the purposes of the life cycle models seem to be different than our interest to view these models. For example, Model 4 seems to be more user-centric, as relations of users to the system is described whereas Models 2 and 3 focus on organizational performance. Moreover, Models 3 and 4 were not originally developed for ERP systems, but instead they are based on general models of information system adoption. The authors of Model 3 suggested that their model may not be suitable in the context of an extended ERP where the system is collaborating closely with the supply chain. Our findings support this claim since the ERP system of AO was very much oriented towards the supply chain, where standardization and integration with partners' system were essential since pre-implementation of the system.

Besides the four models, we were not able to find more recent models to describe the lifecycle of ERP systems. Since the 1980s, the concept of life cycle has been criticized, e.g. in [12]. Life cycle models seem to be too generic ones without practical applicability, and this might be the reason why new models have not been developed. The lifecycle models can describe certain aspects of the ERP systems, such as organizational performance as described in Model 3, but as our findings suggest they do not describe the nature of ERP system integration. Relying on them when making decisions on integration issues may lead to undesired consequences. Indeed, our findings reflect the principles of agile paradigm, such as early involvement of customers and the continuous nature of integration. Applying agile principles in integration governance are therefore necessary.

Investigating the ERP system life cycle of one case only is a limitation of this study. Even though AO had a fully customized ERP system instead of a packaged solution, we believe that integration challenges remain similar in other context where packaged ERP solutions are adopted. In future, our interest is not to create a new life cycle model but instead to study how integration can be effectively governed during the life cycle of the system. Especially, we are interested in other organizations' (such as the ERP vendor, consultants and customers of AO) role in ERP system integration. Finally, if compared to other life cycle phases, there is much less research on the final phase of ERP life cycle, retirement [4]. Indeed, we have just recently begun to have opportunities to investigate the retirement phase as companies are moving to new ERP solutions. At some point of time an ERP system becomes obsolete and needs to be replaced. There is a void of research on how to manage the interconnections with ERP and other systems when retiring the system. In future, the retirement phase of the ERP system should be studied from the integration point-of-view.

6. Conclusions

In this study, an inquiry into the practice was made to observe the ERP system life cycle of a large manufacturing enterprise, from the perspective of ERP system integration. According to our findings, integration should be a major consideration when choosing an ERP system. Deployments are continuous and so is external integration which starts already in the early phases. Finally, instead of being realized at the given point of time, integration is a continuous effort, constantly evolving with organizational changes. The findings reflect the agile principles and point out that practices for integration governance should not be based on the existing lifecycle models. The main contribution of this study is better understanding of the

nature of integration and its evolution during the life cycle of an ERP system which can help managers when making decisions on integration issues.

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References

1. Barki, H., Pinsonneault, A.: A Model of Organizational Integration, Implementation Effort, and Performance. *Organ. Sci.* 16 (2), 165–179 (2005)
2. Chowanetz, M., Legner, C., Thiesse, F.: Integration: An Omitted Variable in Information Systems Research. In: *ECIS 2012 Proceedings*. (2012)
3. Corbin, J.M.: *Basics of qualitative research: techniques and procedures for developing grounded theory*. Sage Publications, Inc, Los Angeles, Calif (2008)
4. Esteves, J., Bohorquez, V.: An Updated ERP Systems Annotated Bibliography: 2001-2005. *Commun. Assoc. Inf. Syst.* Vol. 19 (Article 18), (2007)
5. Esteves, J.M., Pastor, J.A.: An ERP Life cycle - based Research Agenda. In: *First International workshop in Enterprise Management and Resource Planning: Methods, Tools and Architectures.*, Venice, Italy (1999)
6. Gullidge, T.: What is integration? *Ind. Manag. Data Syst.* 106 (1), 5–20 (2006)
7. Kähkönen, T., Smolander, K.: ERP Integration - A Systematic Mapping Study. Presented 15th International Conference on Enterprise Information Systems (ICEIS 2013), (2013)
8. Law, C.C.H., Chen, C.C., Wu, B.J.P.: Managing the full ERP life cycle: Considerations of maintenance and support requirements and IT governance practice as integral elements of the formula for successful ERP adoption. *Comput. Ind.* 61 (3), 297–308 (2010)
9. Lee, J., Siau, K., Hong, S.: Enterprise integration with ERP and EAI. *Commun. ACM.* 46 (2), 54–60 (2003)
10. Linthicum, D.S.: *Next generation application integration: from simple information to Web services*. Addison-Wesley, Boston (2004)
11. Markus, M.L., Tanis, C.: The enterprise systems experience—from adoption to success. In: *Framing the domains of IT research: Glimpsing the future through the past*. (2000)
12. McCracken, D.D., Jackson, M.A.: Life cycle concept considered harmful. *ACM SIGSOFT Softw. Eng. Notes.* 7 (2), 29–32 (1982)
13. Møller, C.: ERP II: a conceptual framework for next-generation enterprise systems? *J. Enterp. Inf. Manag.* 18 (4), 483–497 (2005)
14. Momoh, A., Roy, R., Shehab, E.: Challenges in enterprise resource planning implementation: state-of-the-art. *Bus. Process Manag. J.* 16 (4), 537–565 (2010)
15. Pekkola, S., Niemi, E., Rossi, M., Ruuskamo, M., Salmimaa, T.: ERP Research at ECIS and ICIS: a fashion wave calming down? In: *ECIS 2013*. (2013)
16. Rajagopal, P.: An innovation—diffusion view of implementation of enterprise resource planning (ERP) systems and development of a research model. *Inf. Manage.* 40 (2), 87–114 (2002)
17. Ross, J.W., Vitale, M.R.: The ERP Revolution: Surviving vs. Thriving. *Inf. Syst. Front.* 2 (2), 233–241 (2000)
18. Schlichter, B.R.S., Kraemmergaard, P.: A comprehensive literature review of the ERP research field over a decade. *J. Enterp. Inf. Manag.* 23 (4), 486–520 (2010)
19. Stefanou, C.J., Revanoglou, A.: ERP integration in a healthcare environment: a case study. *J. Enterp. Inf. Manag.* 19 (1), 115–130 (2006)
20. Umble, E.J., Haft, R.R., Umble, M.M.: Enterprise resource planning: Implementation procedures and critical success factors. *Eur. J. Oper. Res.* 146 (2), 241–257 (2003)

21. Watts, C.A., Mabert, V.A., Hartman, N.: Supply chain bolt-ons: investment and usage by manufacturers. *Int. J. Oper. Prod. Manag.* 28 (12), 1219–1243 (2008)
22. Xu, L.D.: Enterprise Systems: State-of-the-Art and Future Trends. *IEEE Trans. Ind. Inform.* 7 (4), 630–640 (2011)

Factors Influencing Students' Embedment with, and Embracement of Social Networking Sites: An Analysis

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Abstract

This study investigated the undergraduates' embedment with, and embracement of social networking sites (SNS) with a modified theory of planned behavior (TPB). It is recognized that social influence, perceived behavioral control, enjoyment, as well as embracement and embedment, are pertinent to the discourse. Data was collected from undergraduates in four (4) culturally diverse countries. Hypotheses were developed to test the proposed research conceptualization. The partial least squares (PLS) technique was used for data analysis. The results confirmed that perceived enjoyment and perceived behavioral control positively influenced students' behavioral intentions for the use of SNS while subjective norm did not. However, subjective norm has positive impacts on students' embedment with, and embracement of such tools. Students' behavioral intention to accept SNS has a positive influence on students' embedment with, and embracement of SNS.

Keywords: Social Networking Sites, Theory of Planned Behavior, Embedment, Embracement.

1. Introduction

Social networking sites (SNS) offer users a new way of communicating, interacting, cooperating, and collaborating with others [12]. Popular SNS include Facebook and Twitter. EMarketer [13] reported that "nearly one in four people worldwide will use social networks in 2013. The number of social network users around the world will rise from 1.47 billion in 2012 to 1.73 billion this year, an 18% increase. By 2017, the global social network audience will total 2.55 billion." With regard to information on SNS in this study's settings (Malaysia, China, Nigeria, and Canada), the following insights are provided:

First, "there are 12,747,100 Facebook users in Malaysia, which makes it No.18 in the ranking of all Facebook statistics by Country. This also means that 48.73% of the Malaysian population is on Facebook" [26]. Second, Zhang and Pentina [37] commented that "approximately 54.7 percent of Internet users in China own or visit blogs and 47.3 percent have an account on one or more SNS. More than 25 percent write 10 or more posts on forums, blogs, or SNS every day, and 92.3 percent of Internet users visit social media pages at least three times a week." TechinAsia [30] noted that the largest sections of China's social media users, i.e. 30%, are aged 26 to 30, which is a perfect target for advertisers. As a whole, 91% of Chinese [net citizens] have social accounts, which is way above the 67% in the US. Third, the embracement of social media in Nigeria, particularly among the youth and the middle aged, is progressively increasing. In 2012, there were 48 million Internet users of which 6.6 million use Facebook and Twitter regularly [31, 32]. As per Facebook use, Nigeria is ranked 32nd in the world. Fourth, 40% of Canadians "had embraced either Facebook or Twitter by 2010. By 2012, almost half of the population had joined social media sites" [36]. Similarly, Maclean [25] indicated that "more than 19 million Canadians are now logging onto Facebook at least once every month—that's more than half the population—while 14 million check their newsfeed every single day." Maclean's report also noted that daily usage of Facebook in Canada is higher than both the global and U.S. averages.

Despite the increasing popularity of SNS among young people, little is known about psychosocial factors influencing their embedment with, and embracement of SNS. This study

seeks to make a contribution to the extant literature in that regard. Particularly, this research will attempt to provide an answer to the following question: what influence do factors related with subjective norm, perceived enjoyment, and perceived behavioral control have on students' embedment with, and embracement of SNS?

2. Background Information and Theoretical Framework

As indicated above, most SNS users tend to be young adults aged 18 to 29 years [23, 28]. In particular, college students' use of SNS is high; a study found that 94% of United States (US) undergraduates use Facebook and spend between 10 and 30 minutes online daily [23]. Prior research investigating the acceptance or adoption of technological innovations have used constructs such as perceived usefulness and perceived ease of use taken from the technology acceptance model (TAM) and theory of reasoned action (TRA) [11,14]. Some SNS researchers investigating an individual's use of SNS and related tools have also based their studies on such theoretical perspectives [18, 24, 29, 35]. These frameworks have increased understanding of factors influencing the acceptance of SNS by individuals.

However, researchers have started to express doubts about the suitability of classical individual-based models in investigating an individual's adoption of emerging tools, such as SNS, which are primarily designed to accommodate complex social communication and interaction [8, 9]. There is a strong need for researchers to employ theoretical models that accommodate social imperatives of technology's use. It is safe to suggest that individual-based models have their inherent limitations because they tend to downplay "the nature of technology acceptance in social computing situations, where the technology is embraced rather than simply accepted by the user, and where the action made possible by technology is seen as a behavior embedded in society" [33, p.149].

The theory of planned behavior (TPB) [1] would seem a reasonable option given its inclusion of social influence as an important motivation for an individual to accept or engage in a specified behavior. Accordingly, some SNS researchers examining students' SNS use behavior have utilized it or fused it with other models [2, 5, 22, 27]. The TPB posits that individual behavior is influenced by attitude, subjective norms, and perceived behavioral control. Attitude refers to an individual's positive or negative feelings toward engaging in a specified behavior, subjective norms describe an individual's perception of what people who are important to them think about a given behavior, and perceived behavioral control refers to an individual's perception of the difficulty of performing a behavior. The dependent variable in TPB, i.e. behavior, tends to encompass variables, including frequency and intensity of use, actual use, continuance participation, and so forth [2, 22, 27]. Others [7] have argued that researchers using the TPB "also need to better conceptualize system usage so as to include a broader perspective of what users actually do in and around the notion of system use."

In light of how people use SNS, two behavioral variables, i.e. embracement and embedment, which are relevant to the use of technological innovations in social milieu, are included in this study. Embracement refers to the degree to which technology is being accepted willingly; it also refers to the degree to which technology is being viewed in a positive light [33]. Embedment refers to the extent to which the user views the technology as being a necessity to them and others in their group [6, 33]. This study replaced attitude in the TPB model with perceived enjoyment, given that SNS researchers [21, 22] found the latter to be an important factor in stimulating the acceptance of such tools. In summary, attitude was not considered in this study because prior researchers [e.g. 29, 35] have already used it to examine technology acceptance; however, few have explored the role of perceived enjoyment on SNS acceptance. That said, Venkatesh [34, p. 351] described perceived enjoyment as the extent to which "the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use." Indeed, Ajzen [1] noted that the TPB can be strengthened with theoretically justifiable constructs to improve its predictive power.

3. Research Hypotheses

Following the foregoing discussions, this study modifies the TPB in examining factors that could influence students' embedment with, and embracement of SNS. This study's research model (with the hypothesized paths) is shown in Figure 1. The impact of relevant control variables such as age, gender, discipline (program of study), year of study, national culture (i.e. individualism-collectivism) [17], and experience with web surfing were considered. None of these impacted the dependent variables.

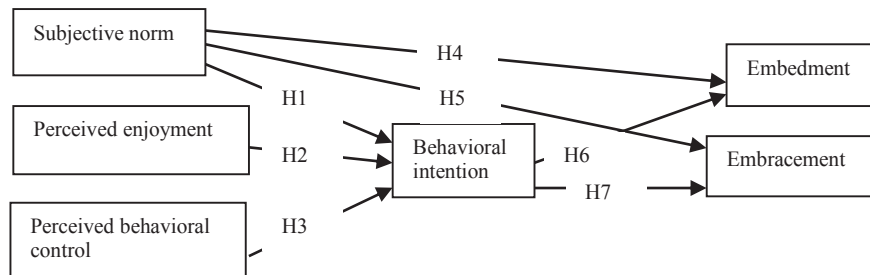


Fig. 1. The research model

It is expected that perceived enjoyment, perceived behavioral control, and subjective norm will positively influence students' SNS behavioral intention. Prior studies in the literature confirmed such relationships [8, 22, 35]. Given that subjective norm is consistently found to be a weaker predictor of behavioral intentions compared to perceived behavioral control [1, 4], and for the fact that other studies [5, 9, 22] examining the impact of subjective norm on SNS behavioral intention failed to confirm such a relationship, it was decided to model the direct effects of subjective norm on the embedment and embracement of SNS. Because decisions tend to be made based on indirect experiences and the views of others [1, 2, 5, 12]. Indeed, empirical evidence suggests that during pre-acceptance phases, subjective norm positively influenced behavioral intention [2, 5]. Beyond the intention phase, sustained use of social-based technologies becomes more intense if users believe that their group has placed more value on such tools [2, 12, 22, 28, 33 37]. Thus, it is expected that subjective norm will positively influence students' embedment with, and embracement of SNS. It is also expected that behavioral intention will positively influence students' behavioral roles of embedment with, and embracement of SNS. Previous meta-analytic studies of findings across diverse settings confirmed the significant association between intention and behavioral roles [4]. Hence, the following hypotheses are formulated:

H1: Perceived enjoyment will positively influence students' SNS behavioral intention

H2: Perceived behavioral control will positively influence students' SNS behavioral intention

H3: Subjective norm will positively influence students' SNS behavioral intention

H4: Subjective norm will positively influence students' embedment with SNS

H5: Subjective norm will positively influence students' embracement of SNS

H6: Behavioral intention will positively influence students' embedment with SNS

H7: Behavioral intention will positively influence students' embracement of SNS

4. Research Methods

4.1. Procedure and Participants

The research model was tested using a field survey. For the purposes of this study, it was decided to use a convenience sample of university students who use SNS. To overcome the Western-culture bias [17, 37], which tends to dominate research in the area, and to increase the generalizability of this study, it was decided to sample views from across differing cultural contexts. A pilot test was conducted to enhance the study's content validity. Forty (40)

individuals, including professors and students, participated in the pre-test of an initial draft of the questionnaire. Comments from the pre-test helped improve the quality of the final questionnaire, which was approved by the university research ethics board. Contacts, including professors in the four (4) countries - Malaysia, China, Nigeria and Canada - collected data from students who actively use at least one SNS tool. The countries were chosen for illustration purposes and for the fact that the researchers have reliable contacts in them. In each setting, a paper-based questionnaire was administered in person. Each country was different from the other on Hofstede's individualism-collectivism dimension [17]. A data sample size ranging from 200 to 220 responses per country was considered ideal. Data was collected from more than one source or location for each of the countries. To be sure that participants understood what key terms meant, the key items were defined in the questionnaire.

On average, the response rate for each country was about 93%, which is considered high. Completed questionnaires with a high degree of missing data and poorly completed responses were removed from the sample. Namely, missing data refers to entries that were left unanswered by the respondents. Usable questionnaires numbering 204, 201, 210, and 200 collected from Nigerian, Canadian, Chinese, and Malaysian undergrads, respectively, were used. A total of 815 questionnaires were used for analysis. There were 427 females and 378 males in the sample with 10 missing data. The participants' ages were normally distributed for a sample of undergraduates. The data showed that 96% used Facebook, which means that the majority of the respondents were familiar with the most popular SNS [13, 25, 26]. The data has a good distribution of students studying varying subjects, such as science and engineering (30%) and social science, humanities, and art (70%). Seventy eight percent (78%) of the participants were aged between 19 and 27 yrs. Data normality tests, using Kolmogorov-Smirnov or Shapiro-Wilk indicators, showed that the respondents' years of Internet usage, frequency of SNS use, and so forth was normally distributed.

4.2. Research Constructs and Measures

The measuring items were taken from previously validated works. The scales for subjective norm (SUBN), perceived enjoyment (PENJ), and perceived behavioral control (PERC) were adapted from Venkatesh and Bala [34]. The behavioral intention's (BEHI) scale was modified from Cheung and Lee [8]. Measures for embracement (EMBR) and embedment (EMBE) constructs were developed from discussions in Baron et al. [6] and Vannoy and Palvia [33]. The multi-items were anchored on a seven-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (7), in which participants were asked to indicate an appropriate response. The measurement items and their factor loadings are provided in Table 1.

Table 1. The questionnaire's items, their descriptive statistics, and item loadings (Contd.)

Construct	Measuring item	Mean	S.D.	Loading (t value)
Subjective norm (Mean = 4.3321; S.D. = 1.5882)	People who influence me think that I should use SNS (e.g. Facebook).	4.1571	1.5892	0.8416 (14.5882)
	People who are important in my life think that I should use SNS (e.g. Facebook).	4.1215	1.5919	0.8649 (19.8934)
	My friends think I should use SNS (e.g. Facebook).	4.7178	1.5835	0.8562 (22.5480)
Perceived enjoyment (Mean = 5.0101; S.D. = 1.4360)	Using SNS (e.g. Facebook) provides me with a lot of fun.	4.9926	1.4177	0.7731 (10.0730)
	I have fun using SNS (e.g. Facebook).	5.0982	1.4212	0.9276 (54.9068)
	The process of using SNS (e.g. Facebook) is pleasant.	5.0810	1.3784	0.9088 (36.5104)
	SNS (e.g. Facebook) does not bore me.	4.8687	1.5266	0.8150 (14.5965)
Perceived behavioral control (Mean = 5.375; S.D. = 1.3476)	My interaction with SNS (e.g. Facebook) is clear and understandable	5.2969	1.3638	0.8582 (22.6969)
	It is easy for me to use SNS (e.g. Facebook).	5.5497	1.2915	0.8555 (19.4674)
	I find it easy to get SNS (e.g. Facebook) do what I want it to do.	5.3988	1.3635	0.8614 (26.3450)
	Learning to use SNS (e.g. Facebook) to enhance my social life is easy for me.	5.2564	1.3716	0.7989 (13.3153)
Embedment (Mean = 4.7371; S.D. = 1.4490)	I accept that SNS (e.g. Facebook) is an important embedment in my social life.	4.8356	1.4426	0.8749 (30.3305)
	My group of friends accepts that SNS (e.g. Facebook) is an important embedment in their social lives.	4.9448	1.3386	0.8257 (16.9020)

	I accept that SNS (e.g. Facebook) is a firm part of my well-being.	4.4049	1.5566	0.8475 (17.154)
	My group of friends accepts that SNS (e.g. Facebook) is a firm part of our well-being.	4.7632	1.4584	0.7753 (10.3748)
Embracement (Mean = 5.0067; S.D. = 1.3855)	I foresee no difficulty in embracing SNS (e.g. Facebook) use.	5.0736	1.4602	0.8470 (20.8765)
	My group of friends using SNS (e.g. Facebook) sees no difficulty in embracing this social tool.	5.2110	1.3373	0.8643 (21.7955)
	The embracement of SNS (e.g. Facebook) is both important and relevant to me.	4.7767	1.3973	0.8635 (24.9072)
	The embracement of SNS (e.g. Facebook) is both important and relevant to my group of friends.	4.9656	1.3471	0.8300 (15.4857)
Behavioral intention (Mean = 5.3301; S.D. = 1.4886)	Assuming I had access to the Internet, I intend to use SNS (e.g. Facebook).	5.1791	1.4612	0.8928 (33.0649)
	I predict I will use SNS (e.g. Facebook) in the coming 2 weeks.	5.3681	1.4868	0.9348 (59.980)
	I am certain that I will use SNS (e.g. Facebook) to interact with my friends in the coming 2 weeks.	5.4429	1.5178	0.8870 (22.7314)

5. Data Analysis

The partial least squares (PLS) technique was used for data analysis. PLS is similar to regression analysis; however, it permits the utilization of latent constructs. As per predictive testing, PLS is more suitable than covariance-based tools, for example, LISREL for models examining theory development conceptualizations [10]. On the other hand, covariance-based methods are more suitable for testing established conceptualizations [10]. PLS recognizes two components of a casual model: the measurement and the structural models.

The measurement model provides information about the psychometric properties of the model like internal consistency, convergent, and discriminant validities. Composite reliability (COR) and Cronbach's alpha (CRA) values above 0.7 are considered adequate for assessing the internal consistency of variables [10]. The COR and CRA entries in Table 2 show that the study's data is consistently above 0.7. Fornell and Larcker [15] recommended that the average variance extracted (AVE) criterion be followed in assessing convergent validity. An AVE value of 0.50 is ideal. This study's AVEs, as seen in Table 2, were adequate. Among other considerations, discriminant validity is assured when the following two conditions are met: (a) the value of the AVE is above the threshold value of 0.50; and (b) the square root of the AVEs is larger than all other cross-correlations. Table 2 shows that the AVE ranged from 0.72 to 0.82, and in no case was any correlation between the constructs greater than the squared root of AVE (the principal diagonal element). Thus, the results indicated that the study's measures were psychometrically adequate.

Table 2. Composite reliabilities, Cronbach alphas, AVEs, and inter-construct correlations

	AVE	COR	CRA	BEHI	EMBE	EMBR	PENJ	PERC	SUBN
BEHI	0.82	0.93	0.89	0.91					
EMBE	0.69	0.90	0.85	0.46	0.95				
EMBR	0.72	0.91	0.87	0.56	0.63	0.95			
PENJ	0.74	0.92	0.88	0.62	0.54	0.56	0.86		
PERC	0.74	0.89	0.82	0.59	0.38	0.48	0.53	0.86	
SUBN	0.73	0.89	0.82	0.28	0.40	0.32	0.39	0.28	0.85

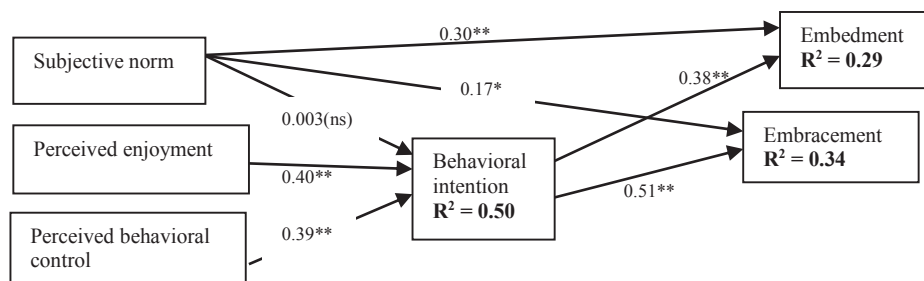
Notes: a) Composite reliability (COR), Cronbach alpha (CRA), Average variance extracted (AVE);

b) The bold fonts in the leading diagonals are the square root of AVEs; c) Off-diagonal elements are correlations among latent constructs; d) EMBE = Embedment; EMBR = Embracement; BEHI = Behavior Intention; PENJ = Perceived Enjoyment; PERC = Perceived Behavioral Control; SUBN = Subjective Norm.

The structural model provides information on hypothesized relationships using the path coefficients (β) and the squared R (R^2). Path significance levels (t-values) are estimated by the bootstrapping method with a sample of 1000 cases. The SmartPLS 2.0 results for the β s and the R^2 are shown in Figure 2. Six (6) out of the seven (7) hypotheses were supported. The data did not support H1 ($\beta = 0.003$), meaning that the subjective norm was not found to positively

influence students' behavioral intention. The result lent credence to findings [5, 9, 22] suggesting that subjective norm mattered less in shaping students' behavioral intention for SNS. Put differently, subjective norm may be of little value where other relevant group-related roles such as embedment of and embracement with specific technologies are being examined. Perceived enjoyment positively influenced behavioral intention to support H2 ($\beta = 0.40$). The hypothesis (H3) indicating that perceived behavioral control would positively influence behavioral intention was confirmed ($\beta = 0.39$).

Both H4 and H5 were affirmed to show that subjective norm positively influenced students' embedment with ($\beta = 0.30$) and embracement of SNS ($\beta = 0.17$). The data supported H6 and H7, confirming that behavioral intention positively influenced students' embedment with ($\beta = 0.38$), and embracement of ($\beta = 0.51$) SNS. The constructs of subjective norm, perceived enjoyment, and perceived behavioral control jointly explained 50% of the variance in the behavioral intention construct. Both subjective norm and behavioral intention interpreted 29% of the variance in embedment. Subjective norm and behavioral intention explained 34% of the variance in embracement. This information suggests that the amount of variance explained by the study's variables is meaningful [10].



Path significance: * $p < 0.05$, ** $p < 0.001$, ns = not significant

Fig. 2. The PLS results

6. Discussions and Conclusion

This study is designed to examine psychological factors influencing students' embedment with, and embracement of SNS. An appropriate theoretical perspective, i.e. TPB, which was modified to include such variables as enjoyment, embedment, and embracement, was used. To some degree, the study's results provided support for the original TPB framework [4]. The relationship between subjective norm and behavioral intention was however unconfirmed as others had previously indicated to suggest that, beyond pre-acceptance of SNS and other technologies in social computing contexts, the opinions of others may not be as important as ensuing behavioral roles such as the embedment with, and embracement of such tools. The relationships between students' behavioral intention regarding SNS acceptance and behavior, i.e. embedment and embracement, in this instance, were found to be significant.

The data supported the view suggesting that students who believe they derive some amount of enjoyment from SNS tend to have positive behavioral intentions toward such technologies [12, 21, 22, 23, 28]. The foregoing insight may help shed light on the overwhelming positive perceptions that students from around the world have for SNS. It is not surprising that students who do not find SNS difficult to use are the ones that develop positive intentions toward such use. It is safe to note that SNS that are difficult to use will not garner students' patronage [18, 24, 29, 35]. For example, a once-popular social-based tool, Digg, lost followers in the virtual community when users discovered that its newly released version was unstable and poorly designed, i.e. not easy to use [20]. Increased positive intention to engage with SNS boded well for students' embedment with, and embracement of SNS. That is, students' willingness to accept SNS may be dependent on the opinions of others in their social lives.

This study showed that little or no meaningful insight emerged regarding the direct influence of subjective norm on SNS' behavioral intention for reasons already espoused; however, reasonable interpretations surfaced when subjective norm was designed to directly impact the constructs of embedment and embracement. These results mean that the opinions of others in a student's group may matter in determining the extent to which they continue to accept SNS willingly and/or attach enhanced value to such technologies. This study's findings mirror observations related to peoples' embedment with, and embracement of technological innovations such as the Internet, mobile phones, and technologies elsewhere [6, 16]. To sum, students' acceptance of SNS will continue to be high if they continue to value the normative influences of others in their group.

This study has implication for research. First, it has responded to the call made by researchers [7, 8, 9, 33] for researchers investigating the acceptance/adoption of technologies in social computing contexts to consider employing appropriate theoretical frameworks that do not diminish the place of social influence. Second, this research has extended TPB's applicability to the investigation of users' (i.e. students') acceptance of SNS. Third, it is among the first to propose variables for the constructs of embedment and embracement, which others can build upon. Fourth, the findings of the study generally add to the growing body of work investigating psychological factors influencing students' use of SNS. There are also implications for practitioners (e.g. SNS developers, educators, business managers) as well. Developers of SNS should constantly develop features that an average user can relate to and enjoy. Developers should continue to enhance features such as newsfeeds that foster a sense of community among users; with such, the roles and values placed on such technologies will increase further. Given that online learning environments are promoting group-oriented learning approaches [3, 19], educators could encourage university students to form close associations with peers having similar values or interests as themselves so as to bolster group embedment and embracement of online learning technologies. The marketing discipline has also suggested that reference group influence has a bearing on an individual's purchasing decisions [30]. To that end, business organizations and marketers should continue to target groups - students and professionals - on SNS in order to promote their products and services to group members.

This study has some limitations: a) the data came from a cross-sectional field survey; longitudinal data may facilitate more insight, b) participants might have provided socially desirable responses to some of the questions to negatively impact the results, and c) the study's results should be interpreted in the light of its noted limitations. Future study should endeavor to overcome the shortcomings in this study. Other relevant theories such as social cognitive theory (SCT) could be incorporated into the proposed research model.

References

1. Ajzen, I.: The Theory of Planned Behaviour. *Org. Beh. and Hum. Decis. Proc.* 50 (2),179-211 (1991)
2. Al-Debei M.M., Al-Lozi, E., Papazafeiropoulou, A. Why People Keep Coming Back to Facebook: Explaining and Predicting Continuance Participation from an Extended Theory of Planned Behaviour Perspective. *Decis. Support Syst.* 55, 43–54 (2013)
3. Arbaugh, J.B., Benbunan-Finch, R.: An Investigation of Epistemological and Social Dimensions of Teaching in Online Learning Environments. *Acad. of Mgt.: Learning and Educ.* 5 (4), 435-447 (2006)
4. Armitage, C.J., Conner, M.: Efficacy of the Theory of Planned Behaviour: A Meta-Analytic Review. *Brit. J. of Soc. Psych.* 40, 471–499 (2001)
5. Baker, R.K., White, K.M.: Predicting Adolescents' Use of Social Networking Sites from an Extended Theory of Planned Behaviour Perspective. *Comp. in Hum. Beh.* 26 (6), 1591-1597 (2010)
6. Baron, S., Patterson, A., Harris, K.: Beyond Technology Acceptance: Understanding Consumer Practice. *Internl. J. of Serv. Indus. Mgt.* 17 (2), 111–135 (2006)

7. Benbasat, I., Barki, H.: Quo Vadis, TAM? *J. of the Assoc. for Inform. Syst.* 8 (4), 212-218 (2007)
8. Cheung, C.M.K., Lee, M.K.O.: A Theoretical Model of Intentional Social Action in Online Social Networks. *Decis. Supp. Syst.* 49, 24–30 (2010)
9. Cheung, C.M.K., Chiu, P-Y, Lee, M.K.O.: Online Social Networks: Why Do Students Use Facebook? *Comp. in Hum. Beh.* 27 (4), 1337–1343 (2011)
10. Chin, W.: Issues and Opinion on Structural Equation Modelling. *MISQ.* 22 (1): vii-xvi (1998)
11. Davis, F.D.: Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MISQ.* 13 (3), 318-39 (1989)
12. Ellison, N., Steinfield, C., Lampe, C.: The Benefits of Facebook “Friends”: Exploring the Relationship between College Students’ Use of Online Social Networks and Social Capital. *J. of Comp.-Mediated Communic.* 12 (4), 1143-1168 (2007)
13. EMarketer (2014), Social Networking Reaches Nearly One in Four around the World, <http://www.emarketer.com/Article/Social-Networking-Reaches-Nearly-One-Four-Around-World/1009976>. Accessed July 10, 2014
14. Fishbein, M., Ajzen, I.: Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research. Addison-Wesley, Reading, MA (1975)
15. Fornell, C., Larcker, D.F.: Evaluating Structural Equations Models with Unobservable Variables and Measurement Error. *J. of Mark. Res.* 8 (1), 39-50 (1981)
16. Geser, H. (2004), Towards a Sociological Theory of the Mobile Phone. In: *Sociology in Switzerland: Sociology of the Mobile Phone*. Online Publications, Zurich, March 2004 (Release 3.0). http://socio.ch/mobile/t_geser1.htm. Accessed February 18, 2014
17. Hofstede, G.: *Culture’s Consequences*. Sage Publications, Thousand Oaks, CA (2001)
18. Huang, A.H., Yen, D.C.: Usefulness of Instant Messaging among Young Users: Social Vs. Work Perspective. *Hum. Syst. Mgt.* 22 (2), 63-72 (2003)
19. Ifinedo, P.: Investigating the Antecedents of Continuance Intention of Course Management Systems Use among Estonian Undergraduates. *Internl. J. of Inform. and Communic. Tech. Educ.* 3 (4), 76-92 (2007)
20. Ingram, M. (2010), Digg Redesign Met With a Thumbs Down, <http://gigaom.com/2010/08/26/digg-redesign-met-with-a-thumbs-down/>. Accessed February 16, 2014
21. Lai, H-M., Chen, C-P.: Factors Influencing Secondary School Teachers’ Adoption of Teaching Blogs. *Comp. & Educ.* 56, 948–960 (2011)
22. Leng, G.S., Lada, S., Muhammad, M.Z.: An Exploration of Social Networking Sites (SNS) Adoption in Malaysia Using Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB) and Intrinsic Motivation. *J. of Internet Bank. and Commer.* 16 (2), 1-27 (2011)
23. Lenhart, A., Purcell, L., Smith, A., Zickuhr, K.: (2010), Social Media and Young Adults. Pew Internet and American Life Project, http://pewinternet.org/~media/Files/Reports/2010/PIP_Social_Media_and_Young_Adults_Report_Final_with_toplevels.pdf. Accessed February 5, 2014
24. Lu, H.P., Hsiao, K.L.: Understanding Intention to Continuously Share Information on Weblogs. *Internet Res.* 17 (4),345–361 (2007)
25. Maclean’s (2013), Facebook Releases Stats about Canadian Usage; 14 Million Daily Users, <http://www2.macleans.ca/2013/08/13/facebook-releases-stats-about-canadian-usage-14-million-daily-users/>. Accessed February 16, 2014
26. NextUpAsia (2014), 22 Facts that You Must Know about Social Media in Malaysia, <http://www.nextupasia.com/22-facts-that-you-must-know-about-social-media-in-malaysia/>. Accessed July 12, 2014
27. Pelling, E.L., White, K.M.: The Theory of Planned Behaviour Applied to Young People's Use of Social Networking Websites. *Cyberpsych. & Beh.* 12 (6), 755-759 (2009)
28. Pempek, T.A., Yermolayeva, Y.A., Calvert, S.L.: College Students' Social Networking Experiences on Facebook. *J. of Appl. Develop. Psych.* 30 (3), 227-238 (2009)

29. Pinho, J.C.M.R., Soares, A.M.: Examining the Technology Acceptance Model in the Adoption of Social Networks. *J. of Res. in Interactive Mark.* 5 (2/3), 116-129 (2011)
30. TechinAsia. (2014), Check out the Numbers on China's Top 10 Social Media Sites (Infographic), <http://www.techinasia.com/2013-china-top-10-social-sites-infographic/>. Accessed January 10, 2014
31. Techloy (2012), Nigeria Crosses 6 Million Facebook Users, Overtakes South Africa, <http://techloy.com/2012/10/21/nigeria-crosses-6-million-facebook-users-overtakes-south-africa-stats/> Accessed February 19, 2014
32. UNPAN (2013), Learner's Submission: Social Media - Its Use and Importance in Nigerian Government, <http://unpanelearning.wordpress.com/2013/10/21/learners-submission-social-media-its-use-and-importance-in-nigerian-government/>. Accessed February 20, 2014
33. Vannoy, S.A., Palvia, P.: The Social Influence Model of Technology Adoption. *Communic. of the ACM.* 53 (6), 149-153 (2010)
34. Venkatesh, V, Bala, H. Technology Acceptance Model 3 and a Research Agenda on Interventions. *Decis. Sci.* 39 (2), 273–315 (2008)
35. Wadie, N., Lanouar, C.: An Exploration of Facebook.com Adoption in Tunisia Using Technology Acceptance Model (TAM) and Theory of Reasoned Action (TRA). *Interdisciplinary J. of Contemp. Res. in Bus.* 4 (5), 948-968 (2012)
36. WebFuel (2013), Canadian Social Media Statistics 2013, <http://www.webfuel.ca/canadian-social-media-statistics-2013/>. Accessed February 5, 2014
37. Zhang L, Pentina I.: Motivations and Usage Patterns of Weibo. *Cyberpsych, Beh., and Soc. Networ.* 15 (6), 312-317 (2012)

Increasing Retention in First-Year Systems Analysis through Student Collaboration Using Real World Examples

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Abstract

It is important in teaching Systems Analysis to maintain currency with industry trends, and for teachers of these subjects to maintain close relationships with students' potential employers. This study presents a qualitative analysis of text responses from IS/IT students to open-ended questions concerning the introduction of a scaffolded small group problem based learning (PBL) task and the introduction of guest lectures. The results indicate that both of these enhancements to the subject have improved the learning experiences of students. These methods can be applied in other ISD subjects; and it is envisaged that enhanced student experiences will also be obtained through such applications.

Keywords: Guest Lectures, Problem Based Learning, Higher Education, Group Work, Systems Analysis Subject.

1. Introduction

Adjusting to the university environment can be a difficult process for students, with the first year of any degree a time when students assess whether they can be successful in their chosen field of studies. It is a time when some students will conclude that they are not equipped for the stressors of higher education or will find that personal issues are impinging on their ability to remain focused on the task at hand. In recent years the range of difficulties students experience has increased as the university cohort has become less homogenous with the increased recruitment of mature age, international and low socio-economic (LSE) background students to the university campus. The traditional university teaching structures of the lecture and tutorial are foreign to students entering the university for the first time – whether they are traditional or mature age, domestic or international or LSE students – and some find it difficult to adjust to this style of teaching and learning [16]. Many universities have recognized that the traditional lecture, though efficient, is not the most effective learning and teaching technique.

One method that has been identified in prior research is the use of small group learning, informed through the use of Problem Based Learning (PBL) tasks, in tutorials as a way to moderate students' potential disconnection from the pursuit of their degree that may result from impersonal experiences associated with lectures. Small group learning can be one of the few points of personal contact between the student and the university and it is considered an influential factor in relation to student integration, progression and retention [6], [8]. This may be particularly pertinent to Information Systems and Information

Technology degrees (IS/IT), where some subjects are taught as an individual endeavor and working with other students is viewed as cheating. This establishes a false impression in their first year that IS/IT employees work alone, when in reality projects in industry require teamwork and collaboration [28]. Small group learning also provides an environment that supports the development of communication, problem solving and the sharing of ideas. Studies have indicated that students identify social contact as a valuable component of the learning experience [22], [31]. By providing opportunities for collaboration in small groups, a junction in the otherwise fragmented experience that many non-traditional and mature students have with university life can be achieved. These opportunities also impart valuable skills which traditional students need in the modern workplace.

A second method of improving the student experience, as argued by Koppi et al. [21], is that IS/IT students receive more industry related learning; this was recommended in surveys of graduates in the workplace. Weng et al. [34] also called for an increased focus on solving 'real-world' business problems. Roberts et al. [29,30] found that university IS/IT subjects lacked input from, or insight into, business and the workplace. Thus the engagement of industry-based professionals to provide a series of guest lectures could facilitate the discussion of 'real-world' business problems, allow students to understand why they are presented certain material, and consider how their learning relates to the modern workplace.

To increase the learning experience of IS/IT students, a first year core subject *Systems Analysis* was modified by: integrating 'real-world' business problems into scaffolded small group learning experiences (through a PBL approach) and engaging with Alumni, as contributors of guest lectures. These changes allowed students to be exposed to 'real-world' business problems that highlight the significance of collaboration, international perspectives and leadership skills. The scaffolded development of assessment tasks ensured continual engagement of all students while the Alumni guest lectures provided examples of the value of on-going graduate learning. These modifications were made with the expectation that both the small group learning assessment items, and the opportunity to hear about real life experiences in the workplace, were likely to improve student retention and future job-readiness, and to increase the overall student experience.

2. A Problem Based Learning (PBL) Approach

Problem Based Learning (PBL) is an increasingly popular method for encouraging higher education learners to engage with content beyond traditional examples and rehearsed case studies. Effective use of the PBL approach leads to the achievement of better learning outcomes, with research showing it can result in an increased level of learning by learners and an enhanced classroom experience [1]. PBL is an instructional model where learning arises from the students' ability to fully consider and take ownership of the problem, typically through the use of small group learning exercise. It differs from the traditional case-based approach [32] that has been popular in IS/IT higher education, where learning is evaluated based on each learner's understanding of the case. While the structure and content of PBL approaches will vary across IS/IT educational environments, there are a general set of principles and guidelines that are common. The initial premise of all PBL approaches is that learning needs to be actively influenced by 'real-world' factors or business problems. With IS/IT subjects starting to use such PBL approaches [25], the next area of focus is how to enhance these experiences to further increase learner outcomes and their overall learning experience. Thus the use of Alumni guest lecturers allowed for greater 'real-world' experiences and current practices to be discussed during the subject.

PBL approaches are classified as constructivist theories of learning. Constructivism is characterized by three propositions: "Understanding is in our interactions with the environment; Cognitive conflict or puzzlement is the stimulus for learning and determines the organization and nature of what is learned; and Knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings" [32 pp. 135-136].

PBL approaches are self-directed and also must be student-centered, with the educator acting as a facilitator rather than a teacher. One typical way to implement a PBL approach

within an IS/IT subject is to give learners open problems for which they must find a potential solution [15]. This type of activity is supported by previous research in the IS/IT higher education space, which has identified the benefits (including creating value and increased student motivation) of exposing learners to ‘real-world’ problems [2], [9], [24]. Small group based activities are commonly used to engage students as they have been found to encourage students to develop deeper knowledge and problem solving skills [14]. Thus students have greater engagement and are more likely to continue their studies.

3. The Subject

The subject under evaluation in this research aims to introduce students to the use of techniques and technologies for performing structured *Systems Analysis*. It examines the roles of systems analysts, clients and users throughout the systems development life cycle (SDLC). The main objectives of the subject are that students should be able to: demonstrate an understanding of systems analysis methods; demonstrate an appreciation of the relationship between information strategy and organizational structure; understand the complementary roles of clients, users and analysts in the development of computer based information systems and demonstrate an ability to analyze a system and present a system description.

The first subject innovation was changing the major small group based assessment. This was originally a small component of the subject that was due as a single piece of work in the last week of session. The assessment was a scaffolded assessment consisting of the following tasks: an initial highlight report; a progress check interview; a narrative and use case analysis; and system description and requirements analysis.

The second subject innovation was to have Alumni who are working in the industry deliver interactive lectures. These industry-based lectures balanced the typical theory-based lectures of the subject discussing *Systems Analysis* methods. The industry-based lectures presented to students discussed the following topics:

- The skills that they learnt at university and how they now apply them;
- Their personal and business background;
- Their businesses approach to systems analysis or the role that they play in the process;
- Current trends and experiences with projects in their organisations; and
- A general Question and Answer session with the class.

Each of the lectures lasted approximately one hour during a typical two-hour lecture. There were three presentations throughout the session. The Alumni came from a medium sized ICT solutions company (consultancy, professional services and managed services); the internal university Project Management Office (PMO); and a small sized local web-based development company.

4. Method

This study employed the use of an online survey for students in the first year *Systems Analysis* subject. The survey was designed to elicit responses regarding students’ perceptions of: the subject; the small-group learning assessment items; and the introduction of Alumni guest lecturers to promote increased university engagement. A survey was chosen as it allows individual analysis of the issues identified in the research [4]. This paper reviews the quantitative data collected from students and provides an analysis of the new strategies that were implemented in the subject. Prior research has used similar approaches when reviewing retention surveys by students [21]. The survey gathered demographic details including the participants’ age, gender, enrolment status (part-time or full-time), background (domestic or international) as well as the degree in which they were enrolled (Bachelor of Information Technology - BIT, Bachelor of Business Information Systems - BBIS, Bachelor of Computer Science - BCS). The four open ended questions asked to students were:

- What was your highlight of the Systems Analysis subject? Why?
- What change would you like to see in this subject? Why?
- Which industry guest lecture(s) did you enjoy most? Why?
- Do you have any additional comments about this subject?

The questions were based on modifications by Koppi et al. [21] to Scott [33]. The purpose of this paper is to critically analyze responses to these four open-ended questions and identify the benefits and limitations of employing this approach. The findings of this experience have the potential to be applied in the future delivery of similar subjects.

5. Student Demographics

The completion of the survey was voluntary, with responses received from 43 of the 89 enrolled students in the undergraduate subject (48.3% response rate). Table 1 shows the demographics of the respondents. Students had an average age of 20.7 years (S.D. 3.4) with the youngest student 18 years and the eldest 36 years. This age range demonstrates that some of the students in the subject have not come from traditional backgrounds into their degree, highlighting the need for ensuring that the first year experience provides effective learning and teaching techniques to capture the cohort. The majority of the students were male 83.7%. With regard to their background, 74.4% of the students were domestic and enrolled in their degree fulltime (90.7%).

Table 1. Demographics of participants

Demographic		Number
Gender	Male	36
	Female	7
Background	Domestic	32
	International	11
Degree	BIT	34
	BBIS	7
	BCS	2
Study Pattern	Full-time	39
	Part-time	4

6. Analysis of the Responses

6.1. What was your highlight of the Systems Analysis subject? Why?

As the majority of the students taking this subject were expected to be first year students (although some students could be studying the subject after a previous failed attempt) this question was designed to allow students to identify whatever aspect they thought had been the stand out in their experience. Responses to this question fell into three distinct categories:

The first category of responses was about the group assessment. The following four students made explicit comments that the group report was a highlight in the subject:

- *“Group project was fun, challenging and helped learn the content.” Male, 19, BIT*
- *“The group assignment, as it allowed me to have more of a challenge.” Male, 20, BIT*
- *“The highlight report” Male, 20, BIT*
- *“The pretend client meeting in week 4” Male, 22, BIT*

The last two comments explicitly mentioned that the scaffolded nature of the assessment was a highlight of the subject; this was one of the changes introduced. However, while some

students stated that they wanted a greater amount of group work in the subject there were explicit statements that there should be less focus on group work.

The second category of responses identified by students was the guest Alumni lecturers with an industry focus.

- *“Discovering how and what system analysts do.” Male, 20, BIT*
- *“Learning content related to the job.” Female, 18, BBIS*
- *“Guest lecturers” Male, 19, BBIS*
- *“Industry Guest Lectures” Female, 18, BBIS*

The third category of responses identified by students was the staff teaching the subject and the way that they interacted with the material.

- *“Interesting lectures, concepts, learning MS Visio.” Female, 19, BBIS*
- *“Other than lectures, there were resources made available and the lecturer actually tried to give us useful information to learn.” Male, 19, BIT*
- *“Talking to [names removed] in the tutorials and this was good because they had a lot of knowledge to give and they gave it freely” Male, 19, BIT*

This is a positive result for the subject redesign as two of the three categories were focused on the newly introduced aspects of the subject. The responses demonstrate that the changes have had a positive effect on the students’ learning experience.

6.2. What change would you like to see in this subject? Why?

Unsurprisingly, some students did not have positive experiences with group work (e.g. *“less group work” Male, 23, BIT*), while a number wanted the guidelines for assignments and marking to be more specific. This may have been due to the nature of PBL assessments being open and having no actual answer. Rather, each student group developed a solution based on their understanding of the problem and the materials given.

Students commented on the need for more activities in tutorials and in the traditional lectures. Some students were critical of the lecturer’s performance; this had the potential to reduce their perceived benefits of the subject. It should be noted that for this subject the lecturer was changed prior to session commencement with only a few week’s notice due to unforeseen circumstances.

- *“Less reading off the slides please.” Male, 20, BIT*
- *“Shorter more condensed lectures with more visual and practical aspects.” Male, 19, BIT*
- *“The lectures should be more interesting.” Male, 19, BIT*

6.3. Which industry guest lecture(s) did you enjoy most? Why?

Approximately one third (34.9%, 15/43) of the students nominated the first guest lecturer who worked at a medium sized ICT solutions company (consultancy, professional services and managed services) as their most enjoyed. Comments were associated with the technical focus of his presentation (e.g. *“he provided insight to the tech industry” Male, 19, BIT*).

Four students indicated that the university staff member who worked for the PMO had been the best:

- *“The gentleman from the uni who has a tech background and now is more higher management level.” Male, 27, BIT*

Five students indicated that they thought all the lecturers were enjoyable, with comments such as *“All of them because they really provide me with their experience that I could benefit from.” Female, 20, BIT*

This is an encouraging result with approximately half the students commenting specifically about one or more of the guest lecturers and indicating that they had benefitted from this new aspect of the subject. It must be acknowledged, however, that several students directly indicated that they had not attended the lectures, for example:

- *“Didn't go to any.” Male, 20, BIT*
- *“Did not get to watch the guest lecture (sic) speak.” Female, 18, BBIS*
- *“Don't attend lectures.” Male, 19, BIT*

It is of concern that a major aspect of the newly modified subject was not experienced by all students. One of the students who had not attended the lectures was enrolled part-time; this may explain this student's absence from the lectures, which were held during the day. All other students who had been absent were enrolled full-time.

6.4. Do you have any additional comments about this subject?

Some students were not in favor of group work at all:

- *“Less group work, I think relying on others is a burden.” Male, 19, BBIS*

Other students commented that they had enjoyed the subject:

- *“Subject was better than I expected.” Male, 19, BCS*

One student appreciated that the group project had been designed to accurately reflect workplace reality (i.e. the introduced PBL nature of the assessment):

- *“The group project didn't have any real scope or boundaries and that scared some people, however I personally enjoyed the open nature of it. Perhaps if it was blatantly stated that it was meant to be very open and that was one of the points of the assignment, be creative in your development.” Male, 27, BIT*

Overall 18.6% of students identified that no changes were required to the subject and that the subject met its objectives. Some of the responses given in the open-ended questions have provided opportunities for reflection on the changes to the subject during this delivery, and informed consideration of where further changes are required to continue to increase the student experience associated with the teaching of *Systems Analysis*.

7. Discussion

A key component of teaching university students is assessing the effectiveness of the teaching and learning interactions, particularly when redevelopment and innovation has been introduced into a subject. The literature has argued that assessment of learning is best undertaken through the exploration of ill-defined problems [11] to challenge and engage learners; however some of the survey answers given by students contradict this notion. The literature argues that assessments as experiential learning activities play a key role in the learning process [18,19,20]. A well-structured PBL activity can allow learning and assessment to occur simultaneously. The results of this study indicate that successful implementation of PBL requires that the motivation for and potential benefits of PBL be explicitly stated upfront; effective implementation of PBL requires understanding of PBL by both educators and students.

For changes to the designated assessment approach within IS/IT subjects to be effective, educators (particularly those who have traditionally focused on using summative assessment) must be involved in the process of change. While previous research has noted resistance to change in the higher education space [5], explanation of the benefits of the new approach and a resulting ability for IS/IT educators to embrace such an approach can negate this resistance, as each educator assumes the role of a change agent [17]. Learners can be engaged through demonstration of the skills that they could develop as a result of full participation in the

assessment task, a clearly specified relationship between the task and subject objectives and graduate qualities, and understanding the value placed on these skills by employers [3, 13]. Learners can be encouraged to negotiate these outcomes using the PBL approach outlined above. To maximize the effectiveness of these methods of learner engagement, the role of educators must shift from lecturer to learning facilitator [7]; this places responsibility for learning in the control of the student. Some students highlighted this as an issue in their responses; it was a new experience for these students to respond to a problem with no established correct answer(s) and they recognized the need to be creative.

In prior research, small group work based assessment has been shown to provide students with motivational, social and cognitive benefits whilst increasing learning outcomes. Other benefits include increased problem solving skills and enhanced ability to deal with group dynamics including conflict and inter-group problems [12]. If groups are left on their own without instruction they can be unfocused [10] and can have unresolved conflict [23]. The issue of a ‘free-rider’ in group tasks has previously been identified in the literature [26, 27] – use of a *scaffolded learning environment* can automatically record contributions to minimize such problems. If these problems are not rectified then students could lose motivation on the project and not achieve the desired learning outcomes.

8. Conclusion

The changes to this Systems Analysis subject were made with the aim of enhancing the student experience. By providing variety in the lecture content and delivery and by providing PBL scaffolded small group learning experiences, students were able to connect with a ‘real-world’ approach to learning. Overall, an analysis of the open-ended responses to the survey data indicated that the majority of students enjoyed the small group learning assessment items, believed they had gained valuable information and insights into future careers from the Alumni, and intended to continue with their degree in light of their positive experiences within the subject.

Directions for future work include systematic inclusion of scaffolded small group PBL assessments and the use of Alumni guest lectures throughout relevant subjects. As a tool to enhance student engagement, further development of these techniques will contribute to a prolonged experience of student integration, progression and retention.

References

1. Ahlfeldt, S., Mehta, S., Sellnow, T.: Measurement and analysis of student engagement in university classes where varying levels of PBL methods of instruction are in use. *High. Educ. Res. Dev.* 24 (1), 5-20 (2005)
2. Armarego, J.: Advanced software design: a case in problem-based learning. In: *Proceedings of the 15th Software Engineering Education and Training*, pp. 44-54. IEEE, Covington (2002)
3. Barrie, S.C.: A research-based approach to generic graduate attributes policy. *Higher Educ. Res. Dev.* 23 (3), 261-275 (2004)
4. Bhattacharjee, A.: *Social Science Research: Principles, Methods, and Practices*. USF Tampa Bay Open Access Textbooks Collection. Book 3. http://scholarcommons.usf.edu/oa_textbooks/3. (2012)
5. Blin, F., Munro, M.: Why hasn't technology disrupted academics' teaching practices? Understanding resistance to change through the lens of activity theory. *Comput. Edu.* 50 (2), 475-490 (2008)
6. Cartney, P., Rouse, A.: The Emotional Impact of Learning in Small Groups: Highlighting the Impact on Student Progression and Retention. *Teach. High. Edu.* 11 (1), 79-91 (2006)
7. Collins, J., Blot, R.: *Literacy and Literacies*. Cambridge University Press (2003)

8. Connolly, C., Murphy, E.: Retention Initiatives for ICT Based Courses, In: Proceedings of Frontiers in Education, pp. 10-14. Indianapolis (2005)
9. Connor, A.M., Buchan, J., Petrova, K.: Bridging the Research-Practice Gap in Requirements Engineering through Effective Teaching and Peer Learning. In: Proceedings of the 6th Information Technology: New Generations, pp. 678-683. IEEE, Las Vegas (2009)
10. Dennis, A.R., Garfield, M., Reinicke, B.: Towards an Integrative Model of Group Development. In Sprouts: Working Papers on Information Systems, Indiana University 8 (3), (2008)
11. Gallagher, S.A.: Problem-based learning: Where did it come from, what does it do, and where is it going? *J. Edu. Gifted* 20 (4), 332-362 (1997)
12. Hammar Chiriac, E.: A scheme for understanding group processes in problem-based learning. *High. Edu.* 55 (5), 505-518 (2008)
13. Harwood, A.: Life Transitions: Overseas study, work and career for young Singaporeans. *Int. J. Pac. Stud.* 4 (1), 1-19 (2008)
14. Hauer, A., Daniels, M.: A Learning Theory Perspective on Running Open Ended Group Projects (OEGPs). In Proceedings of the 10th Australasian Computing Education Conference, pp. 85-92. Wollongong (2008)
15. Hoic-Bozic, N., Mornar, V., Boticki, I.: A Blended Learning Approach to Course Design and Implementation. *IEEE Trans. on Educ.* 52 (1), 19-30 (2009)
16. Jones, S.E.: Reflections on the Lecture: Outmoded Medium or Instrument of Inspiration? *J. Furth. High. Educ.* 31 (4), 397-406 (2007)
17. Kenny, J.: Work-based research in a large organisation: the transformation from change agent to researcher. *Res. Post-Compuls. Educ.* 14 (4), 369-385 (2009)
18. Kolb, A.Y., Kolb, D.A.: Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education. *Acad. Manag. Learn. Educ.* 4 (2), 193-212 (2005)
19. Kolb, D.A.: *Experiential Learning: experience as the source of learning and development.* Prentice-Hall, New Jersey (1984)
20. Kolb, D.A., Boyatzis, R.E., Mainemelis, C.: Experiential learning theory: Previous research and new directions. In, Sternberg R.J., Zhang, L.F. (eds.) *Perspectives on Thinking, Learning, and Cognitive Styles*, pp. 227-247. Lawrence Erlbaum, New Jersey (2000)
21. Koppi, T., Edwards, S.L., Sheard, J., Naghdy, F., Brookes, W.: The Case for ICT Work-Integrated Learning from Graduates in the Workplace, in 12th Australasian Conference on Computing Education, pp. 107-116. ACS, Brisbane (2010)
22. Longhurst, R.J.: Why Aren't They Here? Student Absenteeism in a Further Education College. *J. Furth. High. Educ.* 23 (1), 61-80 (1999)
23. Lubna, S.A., Collins, P.: Engaging our overseas graduate IT coursework community: Developing communication and critical thinking skills, In: Proceedings ASCILITE 2005: Balance, Fidelity, Mobility: maintaining the momentum? pp. 5-9. Brisbane (2005)
24. Lynch, K., Heinze, A., Scott, E.: Information Technology Team Projects in Higher Education: An International Viewpoint. *J. Inf. Technol. Educ.* 6 (Annual), 181-198 (2007)
25. Macklin, A.S.: A PBL Approach for Teaching Complex Information and Communication Technology (ICT) Skills in Higher Education. *Community Jr College Libr.* 14 (4), 233-249 (2008)
26. Maiden, B., Perry, B.: Dealing with free-riders in assessed group work: results from a study at a UK university. *Assess. Eval. High. Educ.* 36 (4), 451-464 (2011)
27. Nixon, H.: Towards a (Cyber)pedagogy for Multimedia Multiliteracies. *Teach. Educ.* 10 (2), 87-102 (1999)
28. Powell, R.M.: Improving the Persistence of First-Year Undergraduate Women in Computer Science. *SIGCSE Bulletin* 40 (1), 518-522 (2008)

29. Roberts, M.R.H., McGill, T.J., Hyland, P.N.: Why Students Leave Their ICT Degrees: A Gender Comparison. In: Proceedings of the 22nd Australasian Conference on Information Systems, Sydney (2011)
30. Roberts, M.R.H., McGill, T.J., Hyland, P.N., Attrition from Australian ICT Degrees – Why Women Leave. In Proceedings of the 14th Australian Computer Education Conference, pp. 15-24. Melbourne (2012)
31. Sander, P., Stevenson, K., King M., Coates D.: University Students' Expectations of Teaching. *Stud. in High. Educ.* 25 (3), 309-323 (2000)
32. Savery, J.R., Duffy, T.M.: Problem Based Learning: An instructional model and its constructivist framework. *Educ. Technol.* 35 (5), 31-38 (1995)
33. Scott, G.: Using successful graduates to improve the quality of curriculum and assessment in nurse education. In: Proceedings of the Australasian Nurse Educators Conference. Rotarua (2003)
34. Weng, F., Cheong, F., Cheong, C.: Modelling IS Student Retention in Taiwan: Extending Tinto and Bean's Model with Self-Efficacy. *Innov. Teach. Learn. Inf. Comput. Sci.* 9 (2), 97-108 (2010)

Predicting Students' Continuance Intention Related to the Use of Collaborative Web 2.0 Applications

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Abstract

One of the main prerequisites for the implementation of collaborative Web 2.0 applications in higher education is their acceptance by students. With the objective to identify the predictors of students' satisfaction and their intentions related to further use of collaborative Web 2.0 applications, a two-part research was conducted. After completing the collaborative educational activities by means of Google Docs, students were asked to fill out a post-use questionnaire. The aim of this paper is to examine the psychometric characteristics of the research framework which reflects the interplay among relevant aspects of Technology Acceptance Model (TAM) and Expectation-Confirmation Theory (ECT). Empirical findings and practical implications are presented and discussed.

Keywords: Technology Acceptance Model, Expectation Confirmation Theory, Collaborative Web 2.0 Applications, Higher Education, Empirical Findings.

1. Introduction

In the field of e-learning, a special emphasis is placed on constructivist teaching methods. They allow placing the student 'in the centre' of the educational process, while the teacher assumes the role of a facilitator and mediator. Influenced by various trends, these methods have evolved [6]. Among more contemporary theories of learning, socio-constructivism, i.e. collaborative learning, has earned a prominent place. Socio-constructivism combines elements of constructivism with elements of social learning such as discussion, exchange of experiences and building of knowledge [18]. Alongside their learning value, collaborative activities in higher education contribute to the development of teamwork skills that are beneficial in both education and business environments. Putro et al. [33] stated that collaborative experience is immensely useful as students prepare for future work. A significant progress in the development and implementation of different collaborative educational strategies was made possible by Web 2.0 applications such as wikis, blogs, social bookmarking sites, and media sharing tools, among others (for more details see [26]). The reasoning behind the aforementioned is based on the fact that features of Web 2.0 applications (e.g. user-centeredness, participative architecture, openness, interaction, collaboration, etc.) are in agreement with the characteristics of the socio-constructivist theory of learning and teaching [32]. Bubaš et al. [2] discovered that encouragement of collaboration and peer-to-peer learning, enrichment of learning experience, and development of ICT competencies are major advantages of the employment of Web 2.0 applications in the on-line educational settings. According to Hartshorne and Ajjan [14], the use of Web 2.0 applications enhances students' satisfaction, influences learning processes, and increases students' interaction with other participants in the educational ecosystem.

With the aid of collaborative Web 2.0 applications, students can, regardless of space and time, collaborate, learn from each other, exchange ideas and different digital resources, and

build knowledge within set educational goals. Today's market offers a large number of Web 2.0 applications which can be used for collaborative task execution. A representative example of such applications is Google Docs. Being a part of Google Drive cloud computing service, Google Docs allows synchronous work with online documents, including creating, editing, saving, publishing, sharing, etc. (for more information see [3], [31], [37]).

Integration of collaborative Web 2.0 applications into educational processes requires specific considerations such as different aspects within various educational environments. One of the key components in successful implementation of collaborative Web 2.0 applications and services in higher education processes proved to be students' adoption of new technologies. According to White et al. [40], the adoption of an application intended for collaborative work by every student is essential for successful completion of a team task in a virtual environment, as well as for achieving a higher level of the final product quality. Acceptance of collaborative Web 2.0 applications represents a 'process of involving social groups into the innovation process where learning takes place on the learners' experiences, knowledge, habits and preferences'[17] and is therefore particularly specific.

Orehovački et al. [25] found that personal characteristics of students, their motives, and types of online activities they carry out are associated with the use of Web 2.0 applications. However, according to Bhattacharjee [1], acceptance of any information system (IS) is only the beginning of its successful implementation, while 'long-term viability of an IS and its eventual success depend on its continued use rather than first time use'. Building on [1], White et al. [40] emphasize the importance of understanding students' satisfaction in working with collaborative applications, which contributes to their persistence in team work and greater engagement in achieving high quality of the final result.

Considering all the set forth, our research is focused on determining the factors related to students' intentions for continued use of collaborative Web 2.0 applications. The identified set of factors that affect the adoption of collaborative applications may be useful to students, teachers who consider implementation of collaborative Web 2.0 application, higher education institutions targeting the higher quality of e-learning, software companies, etc.

The remainder of the paper is structured as follows. Literature review related to relevant models and theories on technology acceptance and confirmation of expectations together with the proposed model and hypotheses are offered in the following section. The employed research methodology is described in the third section. Empirical findings are presented and discussed in the fourth section. Concluding remarks and future research directions are contained in the last section.

2. Background to the Research

2.1. Literature Review

More recently, the effort of researchers in the field was focused on explaining factors influencing the acceptance of collaborative Web 2.0 applications. This section provides an overview of relevant models and theories that represent a theoretical foundation of our research.

In the Theory of Reasoned Action (TRA), Fishbein and Ajzen [9] postulated that behavioural intention can predict a person's individual behaviour towards an action or object. It should be noted that, according to TRA, a person's behaviour can also be predicted by his or hers attitude towards certain behaviour. With an aim to predict the behaviour of users in the field of information systems use, Davis [5] developed Technology Acceptance Model (TAM). His initial assumption was that users' motivation is influenced by a system's features in an organisation. In TAM, users' motivation is defined with two basic constructs: perceived usefulness (PU), defined as 'the degree to which a person believes that using a particular system would enhance his or her job performance' and perceived ease of use (PEOU), defined as 'the degree to which a person believes that using a particular system would be free from effort' [5]. Perceived usefulness and attitude towards using determine behavioural intention to use,

perceived usefulness and perceived ease of use are predictors of attitude towards using, while perceived ease of use affects perceived usefulness.

However, practice showed that after the initial acceptance of applications, users refrain from further use. For this reason, Bhattacharjee [1] stressed the importance of determining the factors that influence continuance intention of a new information system after the initial acceptance, i.e. experience of working with the IS. According to the Expectation-confirmation theory (ECT), the continuance intention related to the use of a product or service is determined by satisfaction with prior use [19]. Consumer satisfaction describes an individual's positive feeling (affect) towards using the technology. Affect is an emotion which had partial influence on consumers' attitudes. The model predicts that consumer satisfaction is directly affected by expectation and confirmation. Drawing on ECT [19] and TAM [5], Bhattacharjee [1] developed Expectation-Confirmation Model of IS Continuance (ECT-IS), according to which intention to continuously use an IS can be explained by users' satisfaction and perceived usefulness stemming from a perception of expected benefits of using an application, which, in turn, is based on real-life experience with the application. In addition, ECT-IS [1] postulates that the level of confirmation and perceived usefulness contribute to users' satisfaction, while perceived usefulness is affected by confirmation.

Recent research related to the prediction of students' acceptance and continuance intention in the context of using collaborative Web 2.0 applications has associated TAM with different theories and models. For instance, by combining TAM and TPB, Cheung and Vogel [3] confirmed a significant effect of compatibility with existing tools and practices, perception of resources, self-efficiency and subjective norms on the intentions and behaviour when using Google applications. They also found that the ability to share information significantly influences the intention to use applications and stressed that perceived ease of use is more significant predictor of students' intentions than perceived usefulness. By employing the TPB in an analysis of students' acceptance and use of the Web 2.0 application Google Docs, Taylor and Hunsinger [37] confirmed significant positive correlations among attitude, subjective norms, control of behaviour and affect. Aiming to explore differences between collaborative applications, White et al. [40] used ECT and thereby confirmed the influence of students' satisfaction and perceived usefulness on continuance intention in the context of both traditional collaborative applications and Google Docs. In order to determine the predictors of continuance intention related to blogs, Shiau and Chau [35] compared three models: TAM, ECT-IS and an integrated model. The results of testing the psychometric features showed that ECT-IS and the integrated model (ECT-IS and TAM) have greater power in explaining continuance intention related to the use of blogs than TAM itself. They also found that perceived ease of use in TAM model significantly affects continuance intention while this relation in the integrated model was not statistically significant.

As a part of a comprehensive methodology aimed for evaluating all relevant facets of the quality in use of Web 2.0 applications [20], Orehovački proposed a set of attributes that contribute to the success of Web 2.0 applications [23], developed subjective and objective measuring instruments, and examined their psychometric properties on the representative sample of Web 2.0 applications meant for collaborative writing [22], mind mapping [28], and diagramming [27]. More recently, both post-use questionnaire and conceptual model were revised and validated on the sample of Web 2.0 applications with educational potential [24]. According to the results of an empirical study on the assessment of mashup tools [29], ease of use, satisfaction, usefulness, and loyalty significantly contribute to the quality in use of this specific breed of Web 2.0 applications. Finally, Orehovački and Žajdela Hrustek [30] found that learnability, satisfaction, and usefulness are important determinants of the usability of educational artefacts created by means of Web 2.0 applications.

2.2. Research Model and Hypotheses

The aim of the research presented in this paper was to identify constructs that contribute to students' satisfaction and continuance intention related to the collaborative Web 2.0 application Google Docs in educational settings. For this purpose, we developed the research framework

(presented in Figure 1) which illustrate an interplay between all relevant constructs originally introduced in TAM [5] and ECT-IS [1]. The reason why we have selected the integration of these two models is that TAM proved to be the most relevant model in explaining the acceptance of a vast diverse technologies, including particular types of Web 2.0 applications, while ECT-IS is able to explain users' behaviour after their interaction with specific technology. In that respect, following eight hypotheses that constitute the proposed research framework was defined:

- H1. Confirmation will positively influence perceived usefulness.
- H2. Confirmation will positively influence satisfaction.
- H3. Perceived ease of use will positively influence continuance intention.
- H4. Perceived ease of use will positively influence perceived usefulness.
- H5. Perceived ease of use will positively influence satisfaction.
- H6. Perceived usefulness will positively influence continuance intention.
- H7. Perceived usefulness will positively influence satisfaction.
- H8. Satisfaction will positively influence continuance intention.

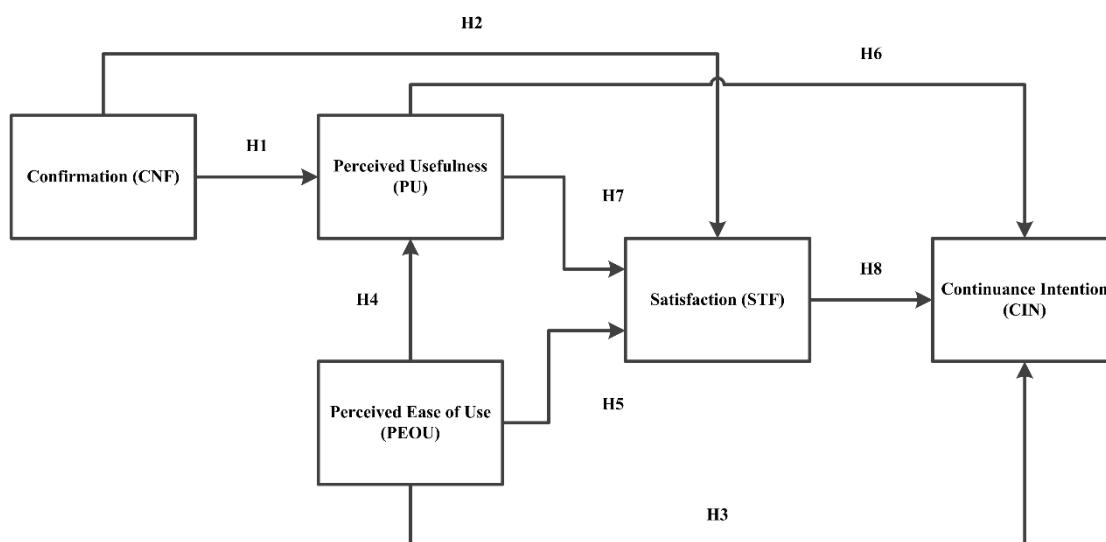


Fig. 1. Research framework.

3. Methodology

With the aim to identify factors that influence students' acceptance and continuance intentions regarding the use of collaborative Web 2.0 applications, an empirical study was carried out. Participants in the study were students from Polytechnic of Rijeka. After having completed educational activities by means of the collaborative Web 2.0 application Google Docs, the students were asked via e-mail and in the classrooms to fill out an online questionnaire that was created using the Kwiksurveys application. Collaborative e-learning activities were part of the hybrid educational process within the course 'Foundations of Informatics'. The students' task was to create a syllabus based on a selected topic using the Google Docs application. It should be noted that students were free to choose the topic and team members. The research was conducted at the beginning of the summer semester of the academic year 2013/2014.

Demographic data about students were gathered in the first part of the questionnaire. The second part contained 21 statements related to the following five constructs: perceived usefulness (PU; six items), perceived ease of use (PEOU; six items), confirmation (CNF; three items), satisfaction (STF; three items) and continuance intention (CIN; three items). Items assigned to constructs were adopted from existing models and tailored to the context of the research. Satisfaction and confirmation were measured by items adopted from Bhattacharjee [1], perceived usefulness and perceived ease of use were measured by items adopted from Davis

[5] and Venkateshet al. [39] while continuance intention was measured by items adopted from Bhattacharjee [1] and Davis [5]. The answers were modulated on a Likert scale ranging from (1) 'strongly disagree' to (4) 'strongly agree'.

The validity and reliability of the proposed research framework and associated hypotheses were examined by means of the partial least squares (PLS) structural equation modelling (SEM) technique. There are several reasons why we have chosen PLS path analysis (PLS-SEM) over its covariance-based counterpart (CB-SEM): (1) PLS-SEM does not require sound theoretical foundations and is therefore employable in exploratory studies [15]; (2) when the sample size is relatively small, PLS-SEM achieves higher level of statistical power than CB-SEM does [38]; (3) if data significantly deviate from normal distribution, PLS-SEM algorithm transforms them in accordance with the central limit theorem which makes parameter estimates highly robust [13]. Data analysis was carried out using SmartPLS 2.0 M3 [34] software.

The research was conducted on a voluntary basis and included 190 students of which 66.84% completed the questionnaire correctly. Majority (53.54%) of participants in the study were male while 46.46 % of them were female. The sample was comprised of full-time (74.02%) and part-time (25.98%) first year undergraduate students enrolled in various departments at Polytechnic of Rijeka: Transport (51.97%), Computer Science (27.56%) and Entrepreneurship (20.47%). The age of students ranged from 18 to 49 years where 74.02% of them had between 18 and 20 years. After having completed collaborative e-learning activities with Google Docs, 90% of students reported that their level of knowledge related to the use of application is at least good. For the purposes of e-learning, 87% of students had used different Web 2.0 applications (blog, wiki, Google Docs or other) for at least one year. The most commonly used Web 2.0 application employed by majority of students (94%) was Facebook. Finally, the participants use mobile devices (59.84%) and desktop computers (50.39%) for more than three hours a day.

4. Results

PLS-SEM path analysis is based on the algorithm which during its first step iteratively approximates the parameters of the measurement model while in its second step estimates standardized partial regression coefficients in the structural model [7]. In that respect, the assessment of the psychometric characteristics of the research framework was carried out in two stages. The quality of the measurement model was evaluated by examining the reliability of manifest variables (items), reliability of latent variables (constructs), convergent validity, and discriminant validity.

Reliability of manifest variables was assessed by exploring the standardized loadings of manifest variables with their respective latent variable. The purification guidelines proposed by Hulland [16] suggest that manifest variables should be retained in measurement model only if their standardized loadings are greater than 0.707. Results of the confirmatory factor analysis (CFA) presented in Table 1 indicate that standardized loadings of all manifest variables were over the recommended acceptable cut-off level, except for CIN3 which was consequently dropped from the measurement model. More specifically, standardized loadings of retained manifest variables were in the range from 0.7851 to 0.9194 which means that latent variables accounted for between 61.64% and 84.53% of their manifest variables' variance.

Reliability of latent variables was tested using two indices: the composite reliability (CR), and Cronbach's alpha (α). Drawing on assumption of equal weightings of items, Cronbach's α represents a lower bound estimate of construct reliability. On the other hand, the CR includes the actual item loadings and therefore offers better estimate of internal consistency. As can be seen in Table 2, estimated values were above the recommended thresholds of 0.707 for both CR and Cronbach's α [13].

Convergent validity was examined using the average variance extracted (AVE). An AVE value of 0.50 and higher means that the shared variance between a latent variable and its manifest variables is larger than the variance of the measurement error and is therefore considered acceptable [10]. Data provided in Table 2 imply that all latent variables have met this criterion.

Discriminant validity is defined as an extent of dissimilarity among latent variables in measurement model. It was evaluated with two measures: the cross loadings and the Fornell-Larcker criterion. The first measure postulates that manifest variables should load higher on their respective latent variable than on the other latent variables in the model. Table 1 clearly illustrates that loadings of all manifest variables with their associated latent variables are higher than their loadings with all remaining latent variables which indicates that the model has met the first measure of discriminant validity. According to the Fornell-Larcker criterion [10], the square root of the AVE of each latent variable should be greater than its highest correlation with any other latent variable in the model. As depicted in Table 3, each latent variable shares more variance with its assigned manifest variables than with other latent variables in the model which confirms the discriminant validity of the model. All the aforementioned confirms the sound reliability and validity of the measurement model.

Table 1. Standardized factor loadings and cross loadings of manifest variables.

Manifest Variables (MVs)	Latent Variables (LVs)				
	Continuance Intention (CIN)	Confirmation (CNF)	Perceived Ease of Use (PEOU)	Perceived Usefulness (PU)	Satisfaction (STF)
CIN1	0.8519	0.4493	0.4551	0.4809	0.4900
CIN2	0.8842	0.4958	0.4336	0.5031	0.4964
CIN3*	0.5356	0.3358	0.3874	0.2924	0.3576
CNF1	0.4602	0.8826	0.5669	0.6321	0.6741
CNF2	0.5205	0.9194	0.5752	0.7042	0.7011
CNF3	0.5059	0.8535	0.5584	0.6223	0.6222
PEOU1	0.3551	0.4700	0.7968	0.4492	0.5591
PEOU2	0.5003	0.4765	0.8658	0.5873	0.5142
PEOU3	0.4938	0.5252	0.8772	0.5976	0.6537
PEOU4	0.5189	0.6424	0.7851	0.7353	0.6382
PEOU5	0.4017	0.4970	0.8583	0.6329	0.5607
PEOU6	0.4706	0.5770	0.8469	0.5618	0.6352
PU1	0.5025	0.7060	0.6144	0.8356	0.6593
PU2	0.4738	0.5749	0.5336	0.8132	0.6192
PU3	0.4615	0.6024	0.6315	0.8304	0.6221
PU4	0.4022	0.5898	0.5341	0.7884	0.6159
PU5	0.4633	0.4815	0.5777	0.8007	0.5782
PU6	0.4745	0.6741	0.6464	0.8707	0.6630
STF1	0.5266	0.6956	0.5898	0.6886	0.8721
STF2	0.4803	0.5866	0.6302	0.6519	0.8555
STF3	0.5318	0.6910	0.6518	0.6602	0.8993

* omitted from measurement model because standardized factor loading was below the cut-off value

Table 2. Convergent validity and internal consistency of latent variables.

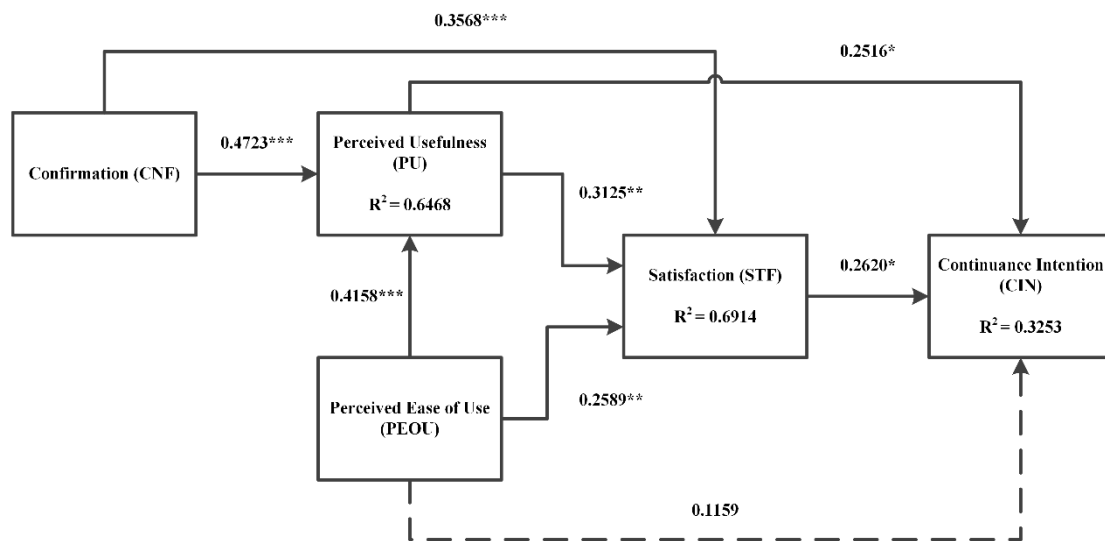
Latent Variables (LVs)	Average Variance Extracted (AVE)	Composite Reliability (CR)	Cronbach's Alpha (α)
Continuance Intention (CIN)	0.8479	0.9177	0.8206
Confirmation (CNF)	0.7842	0.9159	0.8620
Perceived Ease of Use (PEOU)	0.7039	0.9344	0.9158
Perceived Usefulness (PU)	0.6783	0.9267	0.9050
Satisfaction (STF)	0.7670	0.9080	0.8480

Table 3. Discriminant validity of latent variables.

	CIN	CNF	PEOU	PU	STF
CIN	0.9208				
CNF	0.5134	0.8856			
PEOU	0.4830	0.6400	0.8390		
PU	0.5344	0.7384	0.7181	0.8236	
STF	0.5362	0.7532	0.7116	0.7619	0.8758

After having determined the adequacy of the measurement model, the quality of structural model was explored by means of endogenous latent variables' determination coefficient, path coefficients' significance level, exogenous latent variables' effect size, and exogenous latent variables' predictive relevance.

The determination coefficient (R^2) reflects the proportion of endogenous latent variables' variance explained by the set of predictors. Götz et al. [12] emphasize that acceptable values of R^2 depend on the specific research discipline as well as on the individual study. As an outcome of the four models estimation, Orehovački [21] proposed that R^2 values of 0.15, 0.34, and 0.46 can be, as a rule of thumb in empirical studies related to information systems in general and Web 2.0 applications in particular, interpreted as weak, moderate, and substantial, respectively. As presented in Figure 2, 64.68% of variance in perceived usefulness was explained by confirmation and perceived ease of use, 69.14% of variance in satisfaction was accounted for by confirmation, perceived usefulness and perceived ease of use while 32.53% of variance in continuance intention was explained by perceived usefulness and satisfaction. Considering the set forth, predictors of both perceived usefulness and satisfaction have substantial explanatory power whereas predictors of continuance intention have moderate explanatory power.



* $p < 0.01$, ** $p < 0.001$, *** $p < 0.0001$

Fig. 2. PLS estimates for the structural model.

With an objective to examine the hypothesized associations among latent variables in the research framework, the evaluation of path coefficients' goodness was carried out. The significance of path coefficients was tested by means of asymptotic one-tailed t-statistics derived from a bootstrapping resampling procedure. The number of bootstrap samples was 5.000 while the number of cases was equal to the sample size. Results of hypotheses testing are shown in the first five columns of Table 4. It was found that both confirmation ($\beta = 0.4723$, $p < 0.001$) and perceived ease of use ($\beta = 0.4158$, $p < 0.001$) significantly contribute to the perceived usefulness thus providing support for H1 and H4. Data analysis also revealed that confirmation ($\beta = 0.3568$, $p < 0.001$), perceived usefulness ($\beta = 0.3125$, $p < 0.01$), and perceived

ease of use ($\beta = 0.2589$, $p < 0.01$) significantly affect satisfaction thereby supporting hypotheses H2, H7, and H5, respectively. Furthermore, satisfaction ($\beta = 0.2620$, $p < 0.05$) and perceived usefulness ($\beta = 0.2516$, $p < 0.05$) were found to have significant impact on continuance intention thus demonstrating support for H6 and H8. Finally, it appeared that perceived ease of use ($\beta = 0.1159$, ns) does not have significant effect on continuance intention and thus H3 was rejected.

The effect size (f^2) refers to the change in the endogenous latent variable's determination coefficient. Values for f^2 of 0.02, 0.15, or 0.35 indicate that exogenous latent variable has small, medium, or large influence on endogenous latent variable, respectively [4]. As reported in the sixth column of Table 4, confirmation strongly affects ($f^2 = 0.37$) the perceived usefulness whereas perceived ease of use has medium impact ($f^2 = 0.28$) on this endogenous latent variable. While confirmation has medium influence on satisfaction, perceived usefulness and perceived ease of use have small impact ($f^2 = 0.11$ and 0.10 , respectively) on this dependent latent variable. Finally, the effect of satisfaction and perceived usefulness on confirmation turned out to be weak ($f^2 = 0.06$).

The predictive validity of exogenous latent variables was explored by means of the non-parametric Stone's [36] and Geisser's [11] cross-validated redundancy measure Q^2 that employs the blindfolding reuse technique in order to predict the endogenous latent variable's indicators. Changes in Q^2 reflect the exogenous latent variables' relative impact (q^2) in predicting the observed measures of an endogenous latent variable. According to Henseler et al. [15], q^2 values of 0.02, 0.15, or 0.35 signify weak, moderate, or substantial predictive relevance of a certain exogenous latent variable. Considering the data presented in the last column of Table 4, confirmation has moderate relevance ($q^2 = 0.16$) while perceived ease of use has weak relevance ($q^2 = 0.12$) in predicting perceived usefulness. In addition, confirmation, perceived ease of use, and perceived usefulness have weak relevance ($q^2 = 0.12$, 0.12 , and 0.06 , respectively) in predicting satisfaction. Finally, the relevance of both perceived usefulness and satisfaction in predicting continuance intention is modest ($q^2 = 0.04$).

Table 4. Results of testing the hypotheses, effect size, and predictive validity.

Hypotheses	β	t-value	p-value	Supported	f^2	q^2
H1. CNF \rightarrow PU	0.4723	6.1977	***	Yes	0.37	0.16
H2. CNF \rightarrow STF	0.3568	3.8930	***	Yes	0.18	0.12
H3. PEOU \rightarrow CIN	0.1159	1.2577	ns	No	n/a	n/a
H4. PEOU \rightarrow PU	0.4158	4.7215	***	Yes	0.28	0.12
H5. PEOU \rightarrow STF	0.2589	2.8208	**	Yes	0.10	0.06
H6. PU \rightarrow CIN	0.2516	2.2303	*	Yes	0.06	0.04
H7. PU \rightarrow STF	0.3125	2.9849	**	Yes	0.11	0.06
H8. STF \rightarrow CIN	0.2620	2.3807	*	Yes	0.06	0.04

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5. Discussion and Concluding Remarks

The objective of this paper was to identify a set of factors that affect students' satisfaction and continuance intentions related to the use of Web 2.0 application Google Docs in the context of hybrid courses. For that purpose, a research framework which represents an integration of TAM [5] and ECT-IS [1] models was designed. The psychometric characteristics of the proposed research framework were examined by means of the partial least squares (PLS) structural equation modelling (SEM) technique. By exploring four criteria for testing reflective constructs, both validity and reliability of the measurement model were confirmed. Drawing on the outcomes of non-parametric tests for evaluating the structural model's quality, a strength of hypothesized relationships between constructs which constitute a research framework was determined.

Results of the empirical study confirmed the influence of perceived usefulness of Google Docs (H6) and students' satisfaction (H8) on their behavioural intentions related to future use of this Web 2.0 application. Both findings are in accordance with those reported in prior studies

(e.g. [1], [35] and [40]). Compared to the ECT-IS model [1], the proposed research framework includes perceived ease of use which does not have a direct influence on the continuance intention (H3). However, it was discovered that perceived ease of use significantly affects students' satisfaction after their interaction with Web 2.0 application meant for collaborative writing (H5). The aforementioned finding indicates that difficulties in use of Web 2.0 application result in students' dissatisfaction and as a consequence decrease their motivation to participate in a teamwork (for more information see [40]). It also appeared that in the context of Web 2.0 applications perceived ease of use significantly contributes to the perceived usefulness (H4) which is in conformity with the findings presented in TAM [5]. Moreover, it was found that the extent to which students' expectations related to use of Google Docs have been confirmed represents a significant determinant in explaining their satisfaction with this Web 2.0 application (H2). The set forth finding is in accordance with results reported in [1]. An analysis of the research framework revealed that perceived quality of teamwork activities which can be carried out by means of Web 2.0 application for collaborative writing is significantly affected by the degree to which interaction with it has confirmed students' expectations (H1). Finally, it was discovered that perceived usefulness of Google Docs plays an important role in predicting students' satisfaction with this Web 2.0 application (H7).

Considering the reported findings some sound conclusions can be drawn. To begin with, satisfaction of students who are novel users of Web 2.0 applications meant for collaborative writing can be enhanced with helpful guidelines and well-organized interface functionalities. In addition, students' efficiency and effectiveness in completing teamwork activities can be improved by means of various and high-quality forms of information on how to use the Web 2.0 application for collaborative writing. Finally, an extent to which Web 2.0 application aimed for collaborative writing is able to meet the aforementioned requirements and confirm students' expectation will determine the level of their loyal behaviour in terms of future interaction with this Web 2.0 application.

This paper provides implications for both researchers and practitioners. Higher education teachers can employ the post-use questionnaire in order to evaluate students' acceptance and continuance intention related to the use of collaborative Web 2.0 applications, software developers may use it in order to improve these applications while researchers can use the introduced framework as a background for future advances in the field. Taking into account that only one Web 2.0 application was used in the study and that results presented in this paper are part of an ongoing research, our future work will be focused on the use of the proposed model for the evaluation of various Web 2.0 applications in diverse educational contexts as well as on determining additional constructs that contribute to the students' satisfaction and loyal behaviour.

References

1. Bhattacharjee, A.: Understanding information systems continuance: An expectation confirmation model. *MIS Quarterly* 25(3), 351-370 (2001)
2. Bubaš, G., Čorić, A., Orehovački, T.: Strategies for implementation of Web 2.0 tools in academic education. In: 17th European University Information Systems International Congress. EUNIS, Dublin (2011), http://www.eunis.ie/papers/Strategies-For-Implementation-for-Web2.0_GoranBubasAnaCoricTihomirOrehovacki_Paper.pdf, Accessed April 15, 2014
3. Cheung, R., Vogel, D.: Predicting user acceptance of collaborative technologies: An extension of the technology acceptance model for e-learning. *Computers & Education*, 63, 160-175 (2013)
4. Cohen, J.: *Statistical power analysis for the behavioral sciences*. Lawrence Erlbaum Associates, Hillsdale (1988)
5. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly* 13(3), 319-340 (1989)

6. Ertmer, P.A., Newby, T.J.: Behaviorism, Cognitivism, Constructivism: Comparing Critical Features From an Instructional Design Perspective. *Performance Improvement Quarterly*, 26(2), 43-71 (2013)
7. Esposito Vinzi, V., Trinchera, L., Amato, S.: PLS Path Modeling: From Foundations to Recent Developments and Open Issues for Model Assessment and Improvement. In: Esposito Vinzi, V., Chin, W.W., Henseler, J., Wang, H. (eds.) *Handbook of Partial Least Squares*, pp. 47-82. Springer, Heidelberg (2010)
8. Fernández, M.A., Muñoz, M.J., Rivera, J.M., León, R., Escrig, E., Ferrero, I.: Using Web 2.0 Learning Tools: Two Virtual Experiences? In: 2013 International Conference on Advanced ICT and Education (ICAICTE-13), pp. 471-475. Atlantis Press, Paris (2013)
9. Fishbein, M., Ajzen, I.: *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. Addison-Wesley, Reading (1975)
10. Fornell, C.G., Larcker, D.F.: Structural equation models with unobservable variables and measurement error: Algebra and statistics. *Journal of Marketing Research* 18(3), 328-388 (1981)
11. Geisser, S.: The predictive sample reuse method with applications. *Journal of the American Statistical Association* 70(350), 320-328 (1975)
12. Götz, O., Liehr-Gobbers, K., Krafft, M.: Evaluation of Structural Equation Models Using the Partial Least Squares (PLS) Approach. In: Esposito Vinzi, V., Chin, W.W., Henseler, J., Wang, H. (eds.) *Handbook of Partial Least Squares*, pp. 691-711. Springer, Heidelberg (2010)
13. Hair, J.F., Ringle, C.M., Sarstedt, M.: PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice* 19(2), 139-151 (2011)
14. Hartshorne, R., Ajjan, H.: Examining student decisions to adopt Web 2.0 technologies: theory and empirical tests. *Journal of Computing in Higher Education* 21(3), 183-198 (2009)
15. Henseler, J., Ringle, C.M., Sinkovics, R.R.: The use of partial least squares path modeling in international marketing. *Advances in International Marketing* 20, 277-319 (2009)
16. Hulland, J.: Use of partial least squares (PLS) in strategic management research: a review of four recent studies. *Strategic Management Journal* 20(2), 195-204 (1999)
17. Kundi, G.M., Nawaz, A.: From objectivism to social constructivism: The impacts of information and communication technologies (ICTs) on higher education. *Journal of Science and Technology Education Research* 1(2), 30-36 (2010)
18. Laurillard, D.: The pedagogical challenges to collaborative technologies. *International Journal of Computer-Supported Collaborative Learning* 4(1), 5-20 (2009)
19. Oliver, R.L.: A cognitive model for the antecedents and consequences of satisfaction. *Journal of Marketing Research* 17, 460-469(1980)
20. Orehovački, T.: Development of a Methodology for Evaluating the Quality in Use of Web 2.0 Applications. In: Campos, P., Graham, N., Jorge, J., Nunes, N., Palanque, P., Winckler, M. (eds.) *INTERACT 2011, Part IV*. LNCS, vol. 6949, pp. 382-385. Springer, Heidelberg (2011)
21. Orehovački, T.: Methodology for Evaluating the Quality in Use of Web 2.0 Applications (In Croatian: Metodologija vrjednovanja kvalitete u korištenju aplikacijama Web 2.0), Ph.D. thesis. University of Zagreb, Faculty of Organization and Informatics, Varaždin (2013)
22. Orehovački, T.: Perceived Quality of Cloud Based Applications for Collaborative Writing. In: Pokorny, J., et al. (eds.) *Information Systems Development – Business Systems and Services: Modeling and Development*, pp. 575-586. Springer, Heidelberg (2011)
23. Orehovački, T.: Proposal for a Set of Quality Attributes Relevant for Web 2.0 Application Success. In: *Proceedings of the 32nd International Conference on Information Technology Interfaces*, pp.319-326. IEEE Press, Cavtat (2010)

24. Orehovački, T., Babić, S., Jadrić, M.: Exploring the Validity of an Instrument to Measure the Perceived Quality in Use of Web 2.0 Applications with Educational Potential. In: Zaphiris, P., Ioannou, A. (eds.) LCT 2014, Part I. LNCS, vol. 8523, pp. 192-203. Springer, Heidelberg (2014)
25. Orehovački, T., Bubaš, G., Konecki, M.: Web 2.0 in Education and Potential Factors of Web 2.0 Use by Students of Information Systems. In: Proceedings of the 31st International Conference on Information Technology Interfaces, pp. 443-448. IEEE Press, Cavtat (2009)
26. Orehovački, T., Bubaš, G., Kovačić, A.: Taxonomy of Web 2.0 Applications with Educational Potential. In: Cheal, C., Coughlin, J., Moore, S. (eds.) Transformation in Teaching: Social Media Strategies in Higher Education, pp. 43-72. Informing Science Press, Santa Rosa (2012)
27. Orehovački, T., Granić, A., Kermek, D.: Evaluating the Perceived and Estimated Quality in Use of Web 2.0 Applications. *Journal of Systems and Software* 86 (12), 3039-3059 (2013)
28. Orehovački, T., Granić, A., Kermek, D.: Exploring the Quality in Use of Web 2.0 Applications: The Case of Mind Mapping Services. In: Harth, A., Koch, N. (eds.) ICWE 2011 Workshops. LNCS, vol. 7059, pp. 266-277. Springer, Heidelberg (2012)
29. Orehovački, T., Granollers, T.: Subjective and Objective Assessment of Mashup Tools. In: Marcus, A. (ed.) DUXU 2014, Part I. LNCS, vol. 8517, pp. 340-351. Springer, Heidelberg (2014)
30. Orehovački, T., Žajdela Hrustek, N.: Development and Validation of an Instrument to Measure the Usability of Educational Artifacts Created with Web 2.0 Applications. In: Marcus, A. (ed.) DUXU 2013, Part I. LNCS, vol. 8012, pp. 369-378. Springer, Heidelberg (2013)
31. Pitner, T., Derntl, M., Hampel, T., Motschnig-Pitrik, R.: Web 2.0 as platform for inclusive universal access in cooperative learning and knowledge sharing. In: Proceedings of 14th International Conference on Knowledge Technologies and Data-driven Business, pp. 49-56. Graz University of Technology, Knowledge Technologies Institute, Graz (2007)
32. Popescu, E.: Students' acceptance of web 2.0 technologies in higher education: findings from a survey in a Romanian University. In: Proceedings of the Workshop on Database and Expert Systems Applications (DEXA), pp. 92-96. IEEE, Bilbao (2010)
33. Putro, I.H., Carbone, A., Sheard, J.: Developing a Framework to Assess Students' Contributions during Wiki Construction. In: Proceedings of the 16th Australasian Computing Education Conference (ACE2014), pp. 123-131. Australian Computer Society, Auckland (2014)
34. Ringle, C.M., Wende, S., Will, A.: SmartPLS 2.0 M3 (2005)
35. Shiau, W.L., Chau, P.Y.: Understanding blog continuance: a model comparison approach. *Industrial Management & Data Systems* 112(4), 663-682 (2012)
36. Stone, M.: Cross-validatory choice and assessment of statistical predictions. *Journal of the Royal Statistical Society Series B* 36(2), 111-133 (1974)
37. Taylor, C., Hunsinger, D. S.: A study of student use of cloud computing applications. *Journal of Information Technology Management* 22(3), 36-50 (2011)
38. Tenenhaus, M., Esposito Vinzi, V., Chatelin, Y-M., Lauro, C.: PLS path modeling. *Computational Statistics & Data Analysis* 48 (1), 159-205 (2005)
39. Venkatesh, V., Morris, M.G., Davis, G.B. Davis, F.D.: User acceptance of information technology: Toward a unified view. *MIS Quarterly* 27(3), 425-478 (2003)
40. White, B.J., Brown, J.A.E., Deale, C.S., Hardin, A.T.: Collaboration using cloud computing and traditional systems. *Issues in Information Systems* 10 (2), 27-32 (2009)

Evidence Based Management for Bologna Process Support

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Abstract

In the paper, author explains the evidence based management approach application for university education process audit and accreditation. The Bologna Process encourages universities to implement the National Qualification Framework, and student learning outcomes development. Author shares her own experiences and argues that learning outcomes provide the evidence of quality of educational processes. The paper aims to present that evidence based approach results in university education ontology development. The paper supports the methodology for evidence gathering at universities.

Keywords: Evidence Based Management, Learning Outcomes, University Audit, Accreditation, Protégé Ontology.

1. Introduction

For years, evidence based (EB) approach has been developed in medicine, dentistry and public health. According to Trinder and Reynolds, this approach has been adopted in other fields, i.e., social work, education, social politics and human resources management [11]. EB practice proponents claim that the approach results in the resource usage controlling. They add that EB practice is developed, because otherwise the professionals would rely on a range of less reliable indicators, i.e., knowledge gained during trainings, prejudice and opinions, outcomes of previous cases, fashions, advices of senior and other colleagues, observations done in other countries or in other social environments. The opponents have argued that EB practice is overly simplistic and constraints professional autonomy. The article consists of three parts. Firstly, the author provides discussion on EB approach and on the characteristics of evidence. Next, the author considers student learning outcomes according to the Bologna Process and the National Qualification Framework ideas, particularly focusing on the situation in Poland. This part of the paper covers the ontology models. The third part includes discussion on learning outcomes evidence as useful for university education stakeholders, i.e., students, academic staff, potential employers, and university accreditation institutions. This part concerns the audit evidence procedures for further improvement of university education methods and outcomes.

2. Evidence Based Practice

Evidence based practice is considered as a scientific approach, which is justified in terms of sound evidence based upon a process of methodical research, evaluation and utilisation of the research findings in decision making. Evidence is factual knowledge that supports or casts doubts on the hypothesis. Evidence is facts that allow people to justify their opinions or explain their attitudes, their proposed solutions and answers to questions. Evidence is the object or substance of what is advanced to support a hypothesis that something is true. That is why an evidence is different from information, data or facts [1]. In law, evidence is identified with a proof of a fact or condition. It is collected to support a claim that something is true. It is intentional and purposeful, but evidence is never waiting to be found by the researcher. There is always the question for whom is the evidence, according to which criteria and in which context the evidence is analysed.

Evidence based management at university means making decisions about the management of university courses, learning outcomes, teaching staff efforts, and administrative staff and students' work through conscientious and explicit use of four sources of evidence: scientific evidence, organizational evidence, experiential evidence, learning outcomes evidence as well as organizational values and stakeholders' concerns. Generally, evidence should always be located within a dialogue among those who seek to reach agreed-upon conclusions [1]. The meaning of evidence should be recognized in the overall context, in which the evidence is presented. The individual pieces of evidence should be interconnected and mutually reinforce one another. At the university, the evidence-based management is an iterative and incremental improvement process. The decision on what is or what is not an evidence requires iterative approach. Using the education consultancy and university operational audit as a basis raises the problems of selectivity of knowledge and expertise. The auditors' and consultants' expertise must be up to date and well grounded in the most recent research evidence. Therefore, in the process of evidence selection, an action research approach seems to be the most suitable. According to Kemmis and McTaggart, the action research involves the use of qualitative, interpretative modes of inquiry and data collection by teachers [6]. The research is oriented towards improvement of the teaching practices. Primacy should be given to teachers' self-understandings and judgements. The emphasis is on practice and on the sense of practical reasoning about how to act rightly and properly in a situation with which one is confronted. If university researchers are involved as consultants, their role is a service role to the teachers. Such university consultants are often advocates for teachers' knowledge and they seek to diminish the relevance of more theoretical discourses [6].

3. Evidence in Educational Process

Discussions on applicability of evidence-based approach for university management should include the requirements of the Bologna Process. Therefore, each university ought to implement European Credit Transfer System (ECTS), European Qualification Framework (EQF) and National Qualifications Framework (NQF). NQF is an instrument for the classification of qualifications according to a set of criteria for specified levels of learning achieved, which is developed to integrate and coordinate national qualifications subsystems and improve the transparency, access, progress and quality of qualifications in relation to the demand on the labour market [5].

The traditional emphasis on factual knowledge provided by universities no longer meets the requirements of a changing society. The word "competence" is more attractive for both educators and employers, because it is easily identified with value capabilities, qualifications and expertise. Competence is defined as knowledge, skills and attitudes. It is the proven ability to use knowledge, skills and personal, social and methodological abilities, in studies and in professional and personal development. In the context of EQF, competence should be described in terms of responsibility and autonomy. Simultaneously, universities defined the learning outcomes, which are also expressed in terms of knowledge, skills and attitudes (KSAs). Beyond KSAs model, there are some other similar models, e.g., Knowledge, Attitude, Skills and Habits (KASH) model [3], and Knowledge, Experience, Skills, Aptitude and Attitude (KESAA) model [10].

Generally, universities in Poland have implemented the KSAs model. In this model, knowledge should not be identified only with understanding. Understanding represents the intellectual capability to use information in a sensible and meaningful way. The information from observations, personal experiences, beliefs and prejudices in everyday life are also referred to as knowledge. Skills are associated with activities like problem solving, reasoning, assessing, concluding and they include the mental process of analysis, synthesis and evaluation. The cognitive skills are observable in practice, but social competences, i.e., attitudes, are revealed in student behaviour. In EB approach to the university education management, the learning outcomes are the most important drivers of the educational process and as such they require evidence. The KSAs learning outcomes are specified in university

program of studies as well as in the individual course description cards. The concepts in the course description and the relationships among them are presented in Fig. 1.

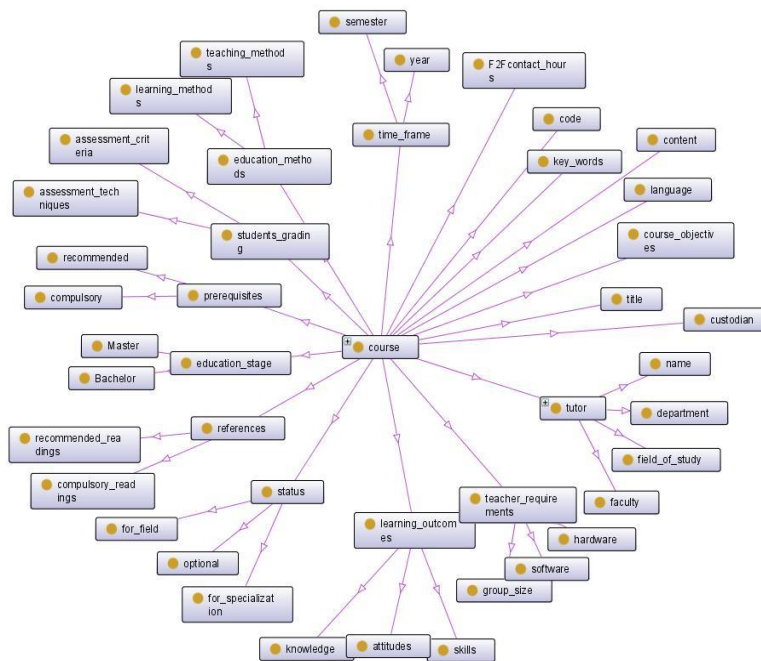


Fig. 1. Protégé ontology model of the course.

According to Fensel [4], ontologies are developed to provide a shared understanding of certain domains that can be communicated between people and application systems. Ontology of the university course is applied to represent the semantics of structured information for further automatic support of acquisition, maintaining and accessing information. The ontology is to facilitate the construction of a domain model. The ontology covers a vocabulary of terms and relations in the university education domain. The ontology is visualised with Protégé tool, which is to assist in the construction of large knowledge bases [8]. The key concepts of a university course (i.e., sub-classes in the ontology model) are as follows: code, title, keywords, content, language, objectives, custodian, tutor, prerequisites, learning outcomes, status, references, education level, teacher's requirements, students' grading, didactic methods. Course tutor is characterized by name, department, field of study, projects, publications, faculty to which they are affiliated. The teacher requirements concerns hardware, software, and group size. Learning outcomes are divided into three groups, i.e., knowledge, skills and attitudes. Course status means that the course can be mandatory for field, mandatory for specialization, or just optional. Course references can be treated as recommended or optional. The courses are provided to students on Bachelor or on Master level. Course prerequisites established by course tutor are usually accepted as recommended or compulsory. Student grading requires the establishing of assessment techniques and assessment criteria. The applied educational methods are divided into learning methods and teaching methods. Student learning outcome (SLO) describes what a student is expected to learn as a result of participating in academic activities or experiences [2]. Sometimes, beyond SLO, student progress outcome (SPO) is developed to reflect student progress in course sequences and in degree programs. Examples of direct assessment techniques usually applied at universities comprise the use of written communications, project work, portfolios, grading system with rubrics, theses, reflective essays, and performance assessment. Examples of indirect assessment methods are surveys of employers, comparison with peer institutions, surveys of past graduates, retention rates, analysis of curriculum. The challenge for teachers is to ensure the alignment among teaching methods, assessment techniques, assessment criteria and learning outcomes. Taking into account the requirements of the Bologna Process, course mentors develop formative and summative assessments. Formative assessment is described as

an assessment for learning. It helps to inform the teacher and the student as to how the students are progressing. Formative assessment is usually introduced at the beginning of a programme and it is a part of the teaching process. Summative assessment is to summarise student learning at a point in time. The use of summative assessment enables a grade to be generated that reflects the student's performance.

The science learning outcomes determine the discipline, i.e., field of study, learning outcomes, which are the premise to further specification of the student learning outcomes (SLOs) that are included in the course description card. Taking into account the SLOs, the teacher formulates the course objectives, course contents, references and methods of student work assessment. Course contents determine teaching hours and student individual work, i.e., learning hours. Beyond the SLOs and data provided by the teacher for the course, the evidence concerns the student work assessment.

Student learning outcomes must be monitored, registered, evaluated and stored in a documentation computerized system. The student learning outcomes are an evidence of education process realization. The simplified process of student learning outcomes realization includes the following phases:

- defining the program and plan of studies, and simultaneously defining the student learning outcomes,
- aligning course components with learning outcomes,
- selection and implementation of assessment methods,
- evaluation of evidence gathered in the assessment activities.

The student learning outcomes are defined as specific, observable behaviours evidenced by students who have achieved the educational objectives. Student learning outcomes are established operationally by teacher and they describe the observable evidence of student's knowledge, skills and social competence. The student learning outcomes are evidencing educational objectives. The course curricula and programs of studies should be designed to meet university strategy, program goals, and educational objectives. Course assessment methods and instruments are selected by teachers and university administrative staff for gathering evidence to show whether students have achieved the expected learning outcomes related to program objectives. Assessment methods should be meaningful, manageable and sustainable. They are selected to show whether students have achieved the expected learning outcomes related to educational objectives and goals.

Development of an appropriate typology of KSAs is important in promoting student mobility as well as labour mobility in three senses: vertical as in career progression, horizontal as in movement between sectors or among university specializations, and spatial, as in mobility in the extended European Union [12]. Generally, the acceptance of qualifications and competences is realized at universities in two ways:

- social approval: acceptance of competences by organizers of socio-economic events,
- formal approval: acceptance of competences through diploma, certificates, ECTS points' transfers, and courses' validations.

Some examination processes are realized centrally, even on national levels, but the most of the examination process is realized offline. University e-learning platform, i.e., Moodle is applied as compulsory communication tool for teachers and students. Always, because of the university audit requirements, the teachers responsible for the exams should collect examination results, student portfolios and benchmark assignments embedded in regular classes and scores by teams of faculty teachers employing specially designed scoring guides [1].

The universities should ensure the necessary technical tools and consultancy to simplify assembling different items of assignment works and to enable the integration of student works into a coherent personal portfolio. Students usually complete and submit their portfolios during their studies, particularly during their Master studies. Evaluation and scoring of the portfolio can be done by a team of faculty teachers working as a commission. Simultaneously, they participate in faculty strategy development and campus discussion. A portfolio includes works demonstrating: 1) critical thinking and writing, 2) interdisciplinary thinking, 3)

historical analysis, 4) creative work and reflection. Students can be requested to present the most personally satisfying works and add the cover letter to the portfolio as well as the learning experience questionnaire [9]. Student competence portfolio is developed as a certain portrait of student capabilities. It makes it possible to check what has learnt to date and what needs to be improved. Portfolio encourages teachers to focus on student outcomes, provide potential employers and the community with credible evidence of student achievement, and inform governmental institution about the university education system.

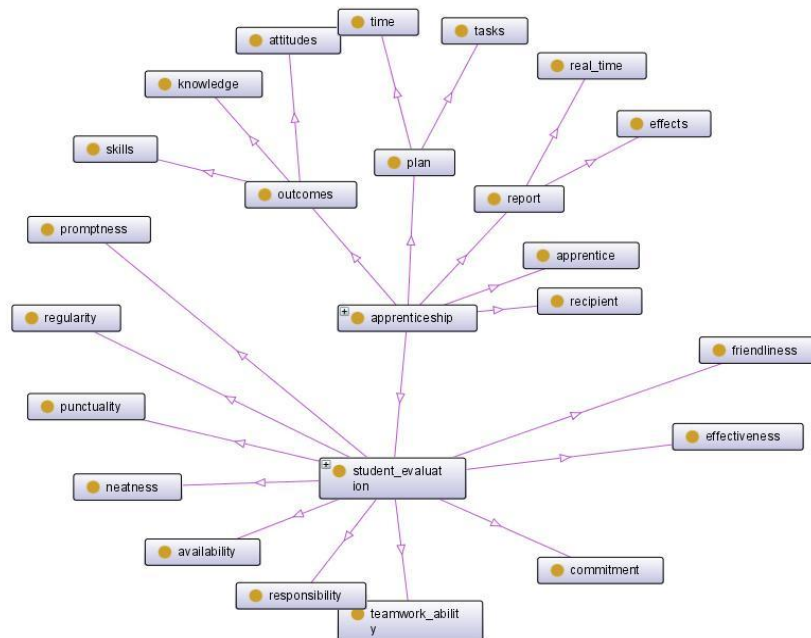


Fig. 2. Protégé ontology model of the apprenticeship.

Student's portfolio can be enriched by the results achieved during apprenticeships and internships. The learning outcomes achieved in apprenticeship process have to be cohesive with the learning outcomes in university educational process. Student-apprentice is responsible for the specification of learning outcomes, apprentices' recipient, apprenticeship plan and report (see Fig. 2). During the apprenticeship, student is evaluated in the following aspects: promptness, regularity, punctuality, neatness, availability, responsibility, team work ability, independence of work, commitment, orderliness, effectiveness and friendliness (see Fig. 2). The presented above ontology models are topic maps, which are solutions enabling the representation of complex structure of knowledge and delivering useful models of a knowledge representation. Topic map is a semantic graph that contains definitions of a set of topics and a set of associations between topics. Topic map permits to reveal hidden knowledge concerning hierarchical and semantic dependencies. Visualization in the topic map permits interactive retrieval of information, taking into account semantic dependencies among different topics [7].

4. Recipients of University Education Evidence

According to the Bologna Process, student learning outcomes (SLOs) present what a student is expected to learn as a result of participating in academic activities and apprenticeships. Beyond SLOs development process, universities focus on student progress outcomes (SPOs), which reflect student progress in a given course sequence. SPOs provide indirect measures of student learning, as well as describe the outcomes of the programs that students themselves may consider to be most important [3]. The SLOs assessment process is to directly involve all faculty staff who teach courses being assessed in the accreditation process itself. The course

outcomes should be assessed using the same methods regardless of where or how the course is taught. The faculty teachers give grades to students, but the works selected for assessment in the accreditation process are evaluated basing on student learning outcomes. Therefore, it may be required to analyse and compare the student learning outcomes (SLOs) with student progress outcomes (SPOs). The student learning outcomes are the subject of interest of different groups of stakeholders (see Fig. 3). For students, the SLOs will:

- communicate clear expectations and form an evidence about what is important in a course or program of studies,
- inform them that they will be evaluated in a consistent and transparent way in the aspect of pre-specified learning outcomes,
- allow them to choose courses taking into account their outcomes [3].

According to Fig. 3, learning outcomes evidence has impact on students, teachers and administrative staff at universities as well as on relations among these stakeholders and their attitudes towards SLOs development. For faculty teachers, participating in student learning outcomes development process, SLOs will:

- help them to determine what is and what is not important in their courses and programs,
- facilitate valuable interdisciplinary and multidisciplinary considerations and inter-institutional discussions among academicians,
- provide evidence to justify needed resources to maintain or improve course syllabus and program of studies,
- allow teachers to recommend the course for other students and to explain the value of the course to the Faculty Boards, University Rectors, other institutions, potential employers, university administration and sponsors,
- ensure that all faculty teaching staff providing any courses agree to address certain content specified in course syllabus, and they will work to distribute the defined knowledge and take care to receive the pre-specified outcomes.

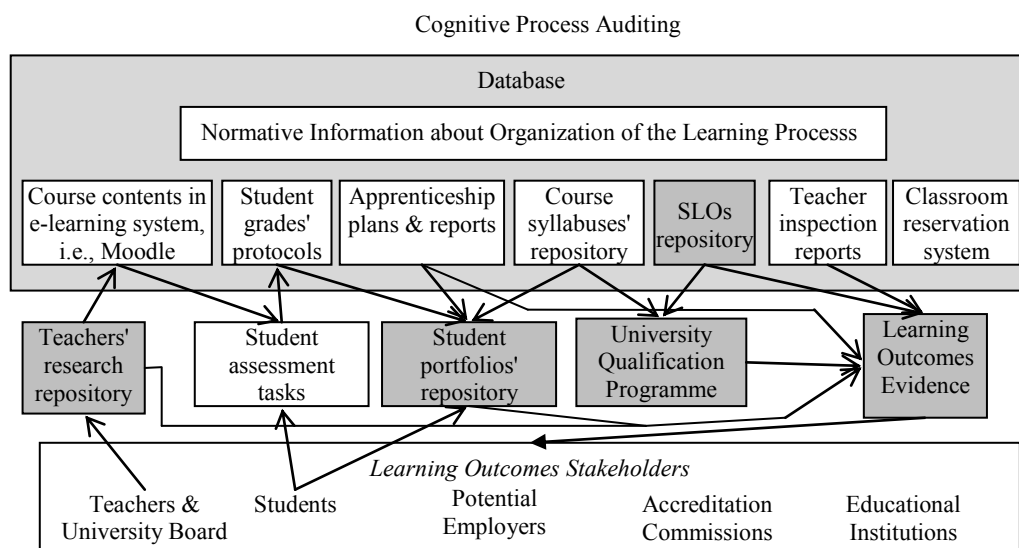


Fig. 3. Student Learning Outcomes' recipients

For university administrative staff, collecting the evidence of student learning outcomes and outcomes assessment will permit to:

- demonstrate an institutional commitment to continually improving the university programs and services offered by the university,
- provide valuable evidence to support requests for funds from state government and private donors,
- demonstrate responsibility and accountability for the courses provided by the university,

- provide valuable evidence for university planning and decision-making on educational processes and university procedures,
- enable administrative staff to inform elected officials, local businesses and potential donors about the impact of SLOs on university students and on academic staff in a very compelling and convincing way.

Financial support and scientific development of universities strongly depend on the evaluation provided by the central national accreditation commission. Systematic outcomes assessment and gathering learning outcomes evidence are now required for accreditation by all higher education accrediting organizations. Through university evaluation, the accreditation commission has impact on educational processes at universities as well as on the further development of student learning outcomes. Less than satisfactory assessment results should lead to necessary improvements in programs, courses and services.

The necessary requirements for completing student learning outcomes assessment tasks at university are as follows:

- obtaining faculty consensus about the outcomes and the plan to assess them (the discipline custodians are asked to work with their faculty teachers to achieve consensus),
- establishing a committee responsible for defining the learning outcomes and informing the faculty teachers about the outcomes to ensure that they will be achieved, regardless of who teaches it or where,
- sharing outcomes with students, because they must be aware of the expected learning outcomes for the courses as well as of the courses' objectives, contents, and references,
- usage of the results of student learning outcomes assessment for the improvement and remedy of the weaknesses [3].

Student learning outcomes regular assessment permits to systematically review the alignment between student learning, instructional or institutional expectations and instructional activities. The learning outcomes should focus on what students can do instead of the effort the teacher can put into teaching. The learning outcomes ought to be aligned with the course's and program's mission. Some people argue that the outcomes specified in the program of studies are very general, however outcomes that are idiosyncratic or tied to a particular teacher's approach to a course should be avoided as incomparable. The student learning outcomes present ways of thinking, from low level identification, i.e., on Bachelor level, to higher level application of knowledge and skill, i.e., on the doctorate level. Beyond student learning outcomes, the accreditation commission should review student progress outcomes. SPOs can be evidenced in student portfolio. Evaluation and scoring of the student portfolios are done by faculty staff, who also participate in faculty development and in preparation of the faculty self-evaluation reports for accreditation commissions.

Accreditation commissions' inspections are realized once every three years. In the meantime, the faculty audit commissions evaluate the educational processes at universities. Educational resources and processes auditors are appointed by the faculty dean. Mostly, they are interested in gathering appropriate evidence, which covers physical examinations (i.e., teachers' inspections), confirmations, documentations, inquiries of students, and auditor's observations. Confirmations cover written or oral responses from an independent party, e.g., faculty commission for teaching quality management or student representatives. Documentations include reviews and examination protocols, apprenticeship reports and plans, courses syllabuses, plagiarism reports, and teachers' inspection reports, seminar and lecture lists of participants, examination and diploma works. The systematic documentation of teaching skills is needed. The documented skills are confronted with the taught courses' contents and teacher inspection reports to evaluate cohesion among them.

5. Conclusion

Nowadays, gathering student learning evidence is crucial for effective educational assessment. In the paper, the learning outcomes were presented as necessary for university audit and accreditation process. The learning outcomes, analysed in the paper, concern the

knowledge, skills and social competences that are developed throughout the programs' curricula. The traditional approach to educational assessment have relied on indirect evidence pertaining to student's self-perceptions of their learning and their perspectives on program structure and curricular contents. Nowadays, the student learning outcomes, student portfolio, departmental evaluations of students' projects and diploma theses, apprenticeship reports, and institutional and individual certificates are accepted as university identity constructive evidence. Gathering evidence should be supported by university management information systems and knowledge systems. Visualization in topic maps reveals the complex structure of knowledge sub-classes and would allow the navigation from topic to topic in a highly interactive manner.

References

1. A Guide to using evidence in the accreditation process: a resource to support institutions and evaluation teams. Accrediting Commission for Senior Colleges and Universities, Western Association of Schools and Colleges, January (2002), <http://www.wascenior.org/search/site/Evidence%20Guide%20Jan%2002%20>. Accessed January 2, 2013
2. Cartwright, R., Weiner, K., Streamer-Veneruso, S.: Student Learning Outcomes (SLO) Assessment Handbook. Montgomery College, Montgomery County, Maryland (2009), http://cms.montgomerycollege.edu/uploadedFiles/EDU/Departments_-_Academic/Outcomes_Assessment/sloa_handbook.pdf . Accessed December 20, 2013
3. Czarnecki, H.: KASH - Knowledge, Attitude, Skills & Habits, Auburn Works. Auburn Technical Assistance Center (ATAC), March (2013), <http://virtual.auburnworks.org/profiles/blogs/kash-knowledge-attitude-skills-habits>. Accessed December 20, 2013
4. Fensel D.: Ontologies: A Silver Bullet for Knowledge Management and Electronic Commerce, Springer, Berlin (2004)
5. FIRST Glossary, KNOWLEDGE SKILLS AND ATTITUDES (KSA) EFFECTS (2010), http://www.firstbtn.eu/files/FIRST_Glossary.pdf. Accessed January 2, 2010
6. Kemmis, S., McTaggart, R.: Participatory Action Research. In: Denzin, N.K., Lincoln, Y.S (eds.) Handbook of qualitative research, pp.567-606. Sage Publications, Thousand Oaks (2000)
7. Le Grand B., Soto M.: Information Management - Topic Maps visualization , 2000, http://www.researchgate.net/publication/2396100_Information_management_-_Topic_Maps_visualization. Accessed June 28, 2014
8. Narzedzia do budowy ontologii i narzedzia wnioskujace, Laboratorium technik semantycznych, LTS, 2012, <http://library.lts-portal.org/handle/123456789/19>. Accessed June 28, 2014
9. Pfeffer, T.: Virtualization of Universities, Digital Media and the Organization of Higher Education Institutions. Springer, New York (2012)
10. Service Quality Division, Knowledge, Experience, Skills, Aptitude, Attitude (KESAA) (2010), <http://asq.org/service/body-of-knowledge/framework-KESAA.html>. Accessed December 20, 2013
11. Trinder, L., Reynolds, S.: Evidence-based practice: a critical appraisal. J.Wiley and Sons, Chichester (2000)
12. Winterton, J., Delamare-Le Deist, F., Stringfellow, E.: Typology of knowledge, skills and competences: clarification of the concept and prototype. CEDEFOP, Luxembourg, Office for Official Publications of the European Communities (2006), <http://europa.eu/>. Accessed December 20, 2013

Academic Literacies: A Critical Review of a Core Information Systems Postgraduate Subject

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Abstract

This paper presents a case study review of a major assessment task in a core postgraduate-level subject in the Information Systems (IS) discipline. Through a critical analysis, the review identified three types of literacies that the subject aims to distil in students: critical, academic and digital literacies. The critical analysis was used to identify whether, and how, students were taught these literacies through the completion of a major assessment, which asked students to review an existing information system. Three opportunities for improvement were identified, these were: greater use of scaffolding in the development of literacy skills; involving experts from across the institution and industry to develop student skills; and embedding technology within assessments. Validation of the case study findings to determine their generalizability is underway. It is envisaged that these three methods can be applied in any information systems subject to improve students' literacies. Through their application, it is expected that students will be better equipped to deal with the continual changes they will face in their careers.

Keywords: Higher Education, Literacies, IS Education, Case Study, Assessment.

1. Introduction

Recently, there has been increased discussion about appropriate approaches for engaging students with information to ensure that students have the literacies needed to operate appropriately in a higher education environment and to then transfer these skills into the workplace. This discussion is of particular importance considering the global context of the information society in which these students will operate after graduation. Initially, this paper outlines the issues surrounding literacy in the context of higher education in the Information Systems (IS) discipline. A discussion situating this research within the current discourse of literacy considering the culture of learning within the IS higher educational context is provided.

By presenting a transformative learning approach as a method to aid teaching literacy education, it is argued that there is potential for greater learning outcomes to occur. An analysis of this approach, considering benefits and limitations, is conducted, followed by consideration of how this approach can be used to improve academic skills for increasing literacy outcomes. Assessments need to be flexible and adaptive, have the ability to allow students to be collaborative and facilitate students becoming problem solvers within the context of their learning environment. After consideration of these issues, guidelines along with concrete examples of how this approach can be applied to achieve greater literacy learning outcomes are presented.

2. Literacy Literature

As the subject under consideration is a postgraduate subject, the traditional definition of literacy encompassing reading, writing and basic assessment of a student as literate or illiterate is not comprehensive [7], both in terms of the cohort and the modern issues facing

these students after graduation. The complexities of literacy have led to the introduction of the term multiliteracies [26]. Assessment of literacies has also developed, from an individual being considered literate or illiterate to an ordinal scale demonstrating literacy functioning [33]. The complexities of literacies have recently been identified in society, leading to the topic becoming an area of intense research and to the introduction of the term multiliteracies. This is an area of intense research with its meaning being embedded in context, economics and within different cultural norms and practices [11]. Students need to be aware that if they are not in ‘possession’ of a particular literacy [13], their learning challenges become “complex, cumulative and interactive” [28] and this influences their chances of future employment [5]. With the change in focus from ‘literacy’ to ‘multiliteracies’, it is important to consider literacy within both the general higher education context and within IS education specifically. This is of particular importance for ISD subjects at each stage of the Systems Development Lifecycle (SDLC).

Lonsdale and McCurry [18] argue that literacy consists of a range of skills and understandings held by an individual and that almost every new domain has its own ‘literacy’. Within academic contexts, terms including academic literacies [10, 15] and critical literacies [18, 39] are commonly used to pigeon hole student literacy skills. Academic literacy is concerned with the cultural and contextual practice of learning particularly “writing, reading, knowledge and meaning making” [13 p. 107]. Having an understanding of the complexities of teaching students with varying literacy abilities requires consideration of why literacy education is important. Luke and Freebody [20] identified four stages of critical literacy practice: (i) Break the code of texts; (ii) Participate in the meanings of text; (iii) Use texts functionally; and (iv) Critically analyze and transform texts. As a student enhances their literacy skills, they are able to move through the four stages of literacy. Further to the discussion on the broadening term of literacy, critical literacy theorists agree on the following points with regard to literacy [40]:

- There are numerous types of literacy.
- Literacy is specific to social contexts.
- Literacies exist on a continuum, with a student reaching a certain level of literacy in an area.
- Having literacy in a particular area brings no direct benefit; a student must engage with the literacy to gain benefit from their learning.
- Acquisition of a literacy is not solely an issue of education. It is about a student having a level of power in the social context for which that literacy is relevant.

Understanding this viewpoint of multiliteracies, in the ICT and IS domains the development of new literacy terms [9] such as digital literacies [3, 4], [37], information literacies [18, 19] and computer literacies [32] has occurred.

Gilster defined ‘digital literacy’ as “the ability to understand and use information in multiple formats from a wide variety of sources when it is presented via computers. The concept of literacy goes beyond simply being able to read; it has always meant the ability to read with meaning, and to understand. It is the fundamental act of cognition” [8 p. 1-2]. Where Martin and Grudziecki argued that “digital literacy is the awareness, attitude and ability of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyze and synthesize digital resources, construct new knowledge, create media expressions, and communicate with others, in the context of specific life situations, in order to enable constructive social action; and to reflect upon this process” [21].

While constant in their reference to the understanding of use of information when presented through technology, the definitions above show that research concerning digital literacy is responsive to the constant development of technology and its capabilities. The focus of this research is to understand how a student can increase their digital and critical literacies whilst engaging with digital and information literacy issues.

A student in the IS discipline must grasp both literacy and numeracy skills to be able to function effectively in the classroom environment and their future workplace. Considering the digital era [17], also referred to as the 'information age' [16], in which students operate, new literacies that focus on digital concepts have been identified [12]. A student studying IS in higher education at the postgraduate level needs to initially understand that if they do not have a high level of literacy in a number of different areas of focus within the subject then this can create problems for their learning, meaning that they will not be able to fully address the subject's objectives and learning outcomes.

In the subject under review, these issues are complex in nature and they build on each other throughout the session [28]. Scaffolding is therefore potentially an appropriate method for increasing the literacy levels of students in this subject. One of the major benefits of increasing the literacy levels is to increase students' employability [5]; this is particularly true for this subject. Having an understanding of the concepts of literacy, it is important to contextualize literacy within ICT and IS education in higher education. The following section provides an overview of the subject under evaluation and the complex nature of what is taught to students.

3. Increasing Literacy: The Transformative Learning Approach

The goal of any educator is to foster change within a student; one approach that considers this issue at its core is the theory of transformative learning developed by Mezirow [35]. Transformative learning has three common themes designed to allow personal growth: individual experience, critical reflection and dialogue [34]. Since identification of these initial themes, new themes have emerged within this approach. These include holistic orientation, context awareness and authentic practice [35]. Theorists orientate transformative learning between different frameworks: individualistic or social and personal transformation. For the purposes of this paper a social and personal transformation view of transformative learning will be considered as a means of best developing student literacies in ICT higher education.

Considering transformative learning as a method for the development of adult learning skills, Tisdell [36] utilized popular culture as a means to engage students. By employing this technique Tisdell was able to situate the student within a context that they already understood before applying academic literacies within it. However, it has been argued that using popular culture in higher education can detract from the high culture typically used for teaching purposes in higher education [1]. However, by students understanding information within a social context (i.e. social literacy practices), they can then transfer this understanding to an academic literacy perspective [17]. To increase literacy skills, educators should develop materials for teaching students literacy skills using blended approaches from both traditional academic literature and more contemporary means, thereby increasing student engagement. In the literacy literature Lea [13] and Lea and Jones [14] identified a number of contemporary means that students are using to develop their 'digital literacies'. This assists students to become aware of the context of their learning, which is a core principle of transformative learning.

One major criticism of the transformative approach is that it is fraught with difficulties when utilizing the underlying principles within a classroom environment [35]. Another criticism is that the approach is seen to embody the western value of individualism [23]. However, by implementing the practices of transformative learning and considering the socio-cultural focus, the core themes can be applied in many different ways. In order to consider socio-cultural impacts, it is necessary to conduct research within a real life context. This paper presents a case study of a real assessment task designed to develop and evaluate students' digital literacies. The subject used for the case study is described in the following section.

4. Subject Background

As a core subject for all postgraduate students in the IS discipline and an option for students studying other postgraduate degrees in several other disciplines, the content covered is very broad. The student cohort, particularly in relation to educational background, is also diverse. The load for the subject is equivalent to a quarter of full-time study in a single academic session. The key points identified from the subject description and objectives are provided below. These are subsequently reviewed to determine the different types of literacies needed by a student to demonstrate that the requirements of this subject have been fully met.

The subject description states that the overall aim of the subject is to develop students' academic skills at the postgraduate level, with an initial focus on writing for the ICT and IS discipline. This process will occur with students being expected to develop skills in critical listening, reading and the analysis of both text and data. These skills should be able to be communicated in both written and oral form. For the development of digital and information literacies students are required to develop skills in the location of information (through academic databases and the Internet), evaluate this information for their needs and the suitability of the information for their needs and use the information appropriately [38]. Based on the subject description the subject is primarily concerned with improving students' critical, academic, digital and information literacies. Students' critical and academic skills (critical and academic literacies) are developed through their understanding of information and their written and oral work.

A task involving use of the software application EndNote was the major assessment for the subject. To complete the assessment, students were required to learn to use the EndNote application (developing digital literacy skills) and then critically evaluate its abilities against other applications (academic and critical literacy skills). The assessment was designed to evaluate students' critical and digital literacies through the selection of appropriate reference materials, and the selection and evaluation of other systems designed for the same specific purpose. The assessment task completed by students as follows:

1. Students were given five references in an EndNote library. All references were on a specified topic. The references contained errors, which students were required to correct.
2. Students searched library databases to find the five articles and correct the errors in the EndNote library.
3. Students searched library databases to find five more references on the specified topic. Students entered all of the reference details into their EndNote library.
4. Students used the Internet to identify, download and use two other applications that were similar to EndNote (i.e. other reference management packages). Based on usage of these other applications, students wrote a critical review and usability evaluation of EndNote compared with its competitors.

The ability to perform this assessment demonstrates that students have digital literacies in being able to use the software program effectively; and academic and critical literacies in being able to find other references on the same topic. Conducting the critical review of the three applications (EndNote, plus two others e.g. Mendeley, Papers, Zotero) demonstrates that students are able to critically review a software product based on its goals and then compare the products features and functionality. From a literacy perspective this assessment encompasses Luke and Freebody's [20] 'four stages of critical literacy'.

Having established an understanding of the different types of literacy education required to meet the objectives of the subject, the next issue to consider is the complexity of teaching students with varying literacy abilities. This requires consideration of why literacy education is important. Previous research has identified that there are a number of different types of literacy, that literacy is specific to social contexts, that a literacy has no direct benefit unless it is engaged with, and that literacy is more than just education – it is about power [40]. These

complexities will be discussed when examining the different literacies being evaluated as part of the critical review of the major individual assessment in the subject using EndNote.

5. Critical Review of Literacy Literature: A Review of the Assessment

From the subject's perspective, the concept of scaffolding the information provided to students is an attempt to increase critical literacies (i.e. the four stages of the assessment). When students are studying, they are involved in a subject that is designed to adapt their ways of interpreting and understanding knowledge [15]. The processes of writing and reading are central to students being able to develop knowledge (*students needed to identify the metadata needed to create an appropriate reference for the articles*). If a student is able to demonstrate academic literacy skills he will have the abilities to operate within the theoretical and written environments of his subjects [25]. It is also important that the practices that students are engaged in are situated in cultural and contextual situations. Lea and Street [15] argue that teaching should be on the premise that, for a student to understand academic literacies, these literacies must be embedded in cultural and social practice (*this draws in further discussion on why it is important to give credit to others work, and how the program under evaluation improves efficiencies*).

One major issue within the academic literacy arena is that it is diluted with teaching critical thinking rather than critical literacies [9]; critical thinking alone does not adequately address issues of culture and politics. However, critical literacy in the ICT and IS domain has been argued to identify how "students might be encouraged to recognize and question the politics of computers" [31 p. 75]. An alternate view is that of Lonsdale and McCurry [18], who argue that the concept of critical thinking is an integral component for all literacies today. They raise questions about whether critical thinking is separate to other literacy practices such as information literacies. The role of literacy education has great value within ICT and IS courses in higher education, particularly when students are taught to critically reflect on its use. For students in this subject this is a particularly challenging task for the assessment being evaluated. The EndNote assessment requires students to use digital literacy skills to critically evaluate the different applications forming understanding to make appropriate technology decisions. The skill of critically assessing software is vital relevance in any ISD career.

The assessment also provided the opportunity for students to link their technical skills with digital and academic literacies. Lea and Jones [14] state that the complex relationship between academic literacies and technologies have the potential to disrupt conventional academic practices. The continual innovation in technologies means that digital literacies of students need to be continually redefined [16]. While educators need to be constantly aware of developing technologies [29], the effective management of changes in technology as part of the learning environment [27] needs to be given careful consideration. *Digital literacies require a student to have more than the ability to use a software application or device*. Digital literacies require a student to be able to fully engage as they employ a range of complex skills to be able to use the application effectively [4]. The use of technologies needs to be pedagogically sound and have relevance to the material being taught. In higher education, particularly in the ISD domain, students must be equipped with transferable digital literacies rather than providing students with step-by-step instructions on how to perform certain tasks within an application. This is one trap that should be actively avoided when employing technologies in a subject.

6. Recommendations

If students have an awareness of the educational values and approaches used in their studies then they are able to become "critical managers of their own learning and international communication practices with the teacher as cultural and educational mediator in this process" [22 p. 200]. The following section identifies three opportunities for IS educators involved in teaching subjects to increase students' literacy skills. It is believed that each of these opportunities can be applied to any ISD subject. These three opportunities are: greater

use of scaffolding in the development of literacy skills; involving experts from across the institution to develop student skills; and embedding technology within assessments.

6.1. Scaffolding as a Process to Increase Literacy

One approach that could be developed further in the subject to increase literacy outcomes is that of scaffolding. Scaffolding is concerned with “developing the more complex skills associated with constructing academic argument through engagement with a range of texts” [30]. The process of scaffolding can be mapped to the EndNote assessment. Students are first exposed to the EndNote application with data already entered into the application. Students are then required to conduct their own information research to identify the accuracy of the data. By extending the scaffolding technique, focus should be given to the competencies obtained by students rather than just the digital literacy practices [9]. This could be conducted by giving students the option to critically reflect on the literacy skills obtained [35] and become self-aware about how they use their developed digital literacies.

Scaffolding also has the potential to allow for initial development of low-stakes tasks [6]. For example the use of the EndNote application to ensure that students have an understanding of its functionality before being required to critically assess it compared with competing applications.

6.2. Involve Experts where Appropriate to Ensure the Latest Techniques

Historically there has been much debate about the *best* location for teaching students literacy skills in higher education. While some researchers argue that literacy education should be moving towards reconstructing the importance of writing within a discipline area (and hence should be taught within that discipline) [2], [24], [41] most higher education providers deliver these services through centralized departments. When developing students’ literacy skills it is important to situate the learning with the discipline area. This allows support to be embedded within formal programs [17]. However, experts within the institution should be identified and called upon when appropriate for advice and best practice [2]. For the EndNote assessment, this could involve discussions with the library (the providers of the application) and staff delivering training to academics and researchers about how best to use the application. In the past this type of training was conducted, however, the focus of the training was importing references from journal databases but not critically reviewing the application from a technical and systems development perspective. This was a skill that the library staff stated that they were uncomfortable teaching due to their skill-set.

6.3. Embedding Technology from a Digital Literacy Perspective

The final recommendation for the assessment being evaluated is to embed appropriate technologies within the assessments. Prior research has demonstrated that there is a need to pay critical attention to the ways that students are accessing information when completing assessments, with students placing a great deal of attention on the digital information freely available on the Internet (i.e. Google) rather than on peer-reviewed academic literature [14]. Lea and Jones [14] argue that there are increased complexities for students in the digital era; where they need to use a range of different technologies and applications integrating the content for the purposes of their assessments. Initial analysis indicated that this was achieved effectively in the EndNote assessment, with students finding appropriate references for the development of their library in the first part of the assessment. However, further critical reflection showed that when students complete the evaluation of EndNote compared with competing packages they revert back to only referencing Internet sources rather than consulting peer-reviewed information; a practice identified in prior literature [13]. Clearly more work is needed to develop academic literacies concerning the appropriate selection of sources; this is an area for future research.

7. Concluding Remarks

When developing students' literacy skills in a higher education environment it is important to situate the learning with their discipline area. This allows support to be embedded within formal programs. This approach has two benefits for students: they are more likely to be engaged in an area of interest, and students are provided with the ability to articulate the information clearly which has the potential to improve overall communication skills. These concepts are supported in a transformative learning approach as it focuses on the student's experience, with the student having an awareness of the context of their work. This follows the common themes of the theory of transformative learning where individual experience, critical reflection and dialogue allow for a student's growth and learning.

This paper has presented a review of a major assessment in a core postgraduate subject in the IS discipline and how the subject has attempted to increase students' critical and digital literacies. Through a critical analysis of the EndNote application, several initiatives have been identified. The three opportunities that were identified for increasing literacies were: greater use of scaffolding in the development of literacy skills; involving experts from across the institution to develop student skills; and embedding technology within assessments. The implementation of these initiatives in future deliveries of the subject is recommended in an attempt to increase these literacies. Further research is being conducted to establish whether and how these digital literacies skills can be applied in other subjects. By future educators implementing these recommendations, in other courses and subjects, it is expected that students will achieve greater literacy outcomes.

References

1. Bloland, H.G.: Postmodernism and Higher Education. *J. High. Educ.* 66 (5), 521-559 (1995)
2. Buzzi, O., Grimes, S., Rolls, A.: Writing for the Discipline in the Discipline? *Teach. High. Educ.* 17 (4), 479-484 (2012)
3. Erstad, O., Gilje, Ø., de Lange, T.: Re-mixing Multimodal Resources: Multiliteracies and Digital Production in Norwegian Media Education. *Learn. Media Technol.* 32 (2), 183-198 (2007)
4. Eshet-Alkali, Y., Amichai-Hamberger, Y.: Experiments in Digital Literacy. *CyberPsychol. Behav.* 7 (4), 421-429 (2004)
5. Farrell, L.: New Literacies in the New Workplace. *Literacy Link: Newsl.Aust. Counc. Adult Lit.* 28 (2), 4-5, 14 (2008)
6. Fernsten, L.A., Reda, M.: Helping Students Meet the Challenges of Academic Writing. *Teach. High. Educ.* 16 (2), 171-182 (2011)
7. Gee, J.P.: *Social Linguistics and Literacies: Ideology in Discourses*. Routledge, Abingdon (2012)
8. Gilster, P.: *Digital Literacy*. Wiley, New York (1997)
9. Goodfellow, R.: Literacy, Literacies and the Digital in Higher Education. *Teach.High. Educ.* 16 (1), 131-144 (2011)
10. Jacobs, C.: On Being an Insider on the Outside: New Spaces for Integrating Academic Literacies. *Teach. High. Educ.* 10 (4), 475-487 (2005)
11. Johnson, M.E.: An Investigation into Pedagogical Challenges Facing International Tertiary-Level Students in New Zealand. *High. Educ. Res. Dev.* 27 (3), 231-243 (2008)
12. Jones, C., Healing, G.: Net Generation Students: Agency and Choice and the New Technologies. *J. Comput. Assist. Learn.* 26 (5), 344-356 (2010)
13. Lea, M.: Reclaiming Literacies: Competing Textual Practices in a Digital Higher Education. *Teach. High. Educ.* 18 (1), 106-118 (2013)
14. Lea, M., Jones, S.: Digital Literacies in Higher Education: Exploring Textual and Technological Practice. *Stud. High. Educ.* 36 (4), 377-393 (2011)

15. Lea, M., Street, B.: *Student Writing in Higher Education: An Academic Literacies Approach*. *Stud. High. Educ.* 23 (2), 157-172 (1998)
16. Leu, D.J., *Literacy and Technology: Deictic Consequences for Literacy Education in an Information Age*. In: Kamil, M.L., Mosenthal, P.B., Pearson P.D., Barr, R. (eds.) *Handbook of Reading Research*. Volume III, pp. 743-770. Lawrence Erlbaum Associates, Mahwah (2000)
17. Littlejohn, A., Beetham, H., McGill, L.: *Learning at the Digital Frontier: A Review of Digital Literacies in Theory and Practice*. *J. Comput. Assist. Learn.* 28 (6), 547-556 (2012)
18. Lonsdale, M., McCurry, D.: *Literacy in the New Millennium*. NCVER, Adelaide (2004)
19. Loveless, A., Longman, D.: *Information Literacy: Innuendo or Insight?* *Educ. Inf. Technol.* 3 (1), 27-40 (1998)
20. Luke, A., Freebody, P.: *A Map of Possible Practices: Further Notes on the Four Resources Model*. *Pract. Prim.* 4 (2), 5-8 (1999)
21. Martin, A., Grudziecki, J.: *DigEuLit: Concepts and Tools for Digital Literacy Development*. *Innov. Teach. Learn. Inf. Comput. Sci.* 5 (4), (2007)
22. Mavor, S.: *Socio-Culturally Appropriate Methodologies for Teaching and Learning in a Portuguese University*. *Teach. High. Educ.* 6 (2), 183-201 (2001)
23. McCaffery, J.: *Using Transformative Models of Adult Literacy in Conflict Resolution and Peacebuilding Processes at Community Level: Examples from Guinea, Sierra Leone and Sudan*. *Comp.: J. Comp. Int. Educ.* 35 (4), 443-462 (2005)
24. Monroe, J.: *Writing, Assessment and the Authority of the Disciplines*. *Educ. Stud. Lang. Literature* 8 (2), 59-88 (2008)
25. NCVER. *Building the Foundations: Outcomes from the Adult Language, Literacy and Numeracy Search Conference*, Australian Department of Education, Employment and Workplace Relations (ed.), NCVER, Adelaide (2011)
26. New London Group: *A Pedagogy of Multiliteracies: Designing Social Futures*. *Harvard Educ. Rev.* 66 (1), 60-92 (1996)
27. Nixon, H.: *Towards a (Cyber)pedagogy for Multimedia Multiliteracies*. *Teach. Educ.* 10 (2), 87-102 (1999)
28. O'Maley, P.: *Literacy Beyond the Classroom: ACAL's Approach to Literacy as Both Lifelong and Lifewide*. *Literacy Link: Newsl.Aust. Counc. Adult Lit.* 28 (2), 1-3 (2008)
29. Rasmusson, M., Eklund, M.: "It's Easier to Read on the Internet—You Just Click on What You Want to Read...". *Educ. Inf. Technol.*, 18, 401-419 (2013)
30. Saltmarsh, D., Saltmarsh, S.: *Has Anyone Read the Reading? Using Assessment to Promote Academic Literacies and Learning Cultures*. *Teach. High. Educ.* 13 (6), 621-632 (2008)
31. Selber, S.A.: *Multiliteracies for a Digital Age*. Southern Illinois Univ. Press, Carbondale (2004)
32. Selber, S.A.: *Reimagining the Functional Side of Computer Literacy*. *College Composition and Communication* 55 (3), 470-503 (2004)
33. Shore, S.: *Adult Literacy in Australia Today - A Commentary*. *Quest* 3 (Spring), 18-19 (2008)
34. Taylor, E.W.: *The Theory and Practice of Transformative Learning: A Critical Review*. ERIC/ACVE Information Series No. 374 (1998)
35. Taylor, E.W., *Fostering Transformative Learning*. In: Mezirow J., Taylor, E.W. (eds.) *Transformative Learning in Practice Insights from Community, Workplace, and Higher Education*, pp. 3-17. Wiley, San Francisco (2009)
36. Tisdell, E.J.: *Critical Media Literacy and Transformative Learning Drawing on Pop Culture and Entertainment Media in Teaching for Diversity in Adult Higher Education*. *J. Transform. Educ.* 6 (1), 48-67 (2008)
37. Tyner, K.: *Literacy in a Digital World: Teaching and Learning in the Age of Information*. Lawrence Erlbaum, Mahwah (1998)

38. University of Wollongong. (2014)
https://solss.uow.edu.au/owa/sid/CAL.USER_SUBJECTINFO_SCREEN?p_faccode=24&p_subcode=ISIT900&p_depabb=ISAT&p_cal_subject_id=149845&p_year=2014&p_cal_type=P&p_cal_types=UP&p_display=NO. Accessed July 5, 2014
39. Unsworth, L.: *Teaching Multiliteracies Across the Curriculum : Changing Contexts of Text and Image in Classroom Practice*. Open University Press, Buckingham (2001)
40. Warschauer, M.: Dissecting the "Digital Divide": A Case Study in Egypt. *Inf. Soc.: Int. J.* 19 (4), 297-304 (2003)
41. Wingate, U., Andon, N., Cogo, A.: Embedding academic writing instruction into subject teaching: A case study. *Act. Learn. High. Educ.* 12 (1), 69-81 (2011)

The Effects of Multimedia Learning Materials Quality on Knowledge Acquisition

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Abstract

Different learning environments offer learners various kinds of multimedia learning materials (MLMs). Although the usage of multimedia has proven to foster meaningful learning, a multimedia resource will not necessarily contribute to the teaching-learning process unless proper attention is paid to its quality. This paper explores issues regarding the assessment of multimedia learning materials (MLMs) quality as well as the relationship between MLM quality and knowledge acquisition.

We present a research experiment that involves low-quality and high-quality MLMs implemented in the learning management system (LMS) Moodle of a polytechnic school course. The quality of MLMs was evaluated by means of the LORI assessment tool adapted for the purpose of this research. The analysis of research data shows that MLMs developed according to the principles of multimedia learning and principles for reducing cognitive load were perceived as being of higher quality than those not developed using multimedia principles. Furthermore, students' usage of high-quality MLMs during treatment resulted in better knowledge acquisition indicated by significantly higher scores in knowledge assessment.

Keywords: Multimedia Learning Materials, Quality Assessment Tool, LORI, Knowledge Acquisition.

1. Introduction

Multimedia is seen as one of the most valuable teaching media as it offers a combination of text, still graphics, animation, audio and video within a single technology that enables the representation of knowledge in a variety of ways [3]. These days teachers can use many forms of technologies (e.g. TV, computers, tablets, smart phones) and media (books, audio, video, multimedia) to enhance their classroom teaching. A positive influence of a combination of several digital media on learning outcomes has been proven in a number of studies, e.g. [1, 2, 15]. However, the production of multimedia learning materials (MLMs) does not necessarily contribute to the teaching-learning process since hardly any attention is paid to the quality of educational materials and pedagogical standards [6].

High-quality of multimedia learning materials entails that they are produced using design principles or guidelines established in appropriate theories and that they serve their intended purpose, i.e. facilitate knowledge acquisition. Nevertheless, a lot of developers of multimedia learning materials are not familiar with relevant research in psychology and education [19].

Also, it seems that insufficient focus is placed on quality assurance of MLMs, which results in materials that are not assessed by appropriate assessment tools. Leacock and Nesbit [12] suggested that instruments used to evaluate educational software packages may not be suitable for evaluating small learning objects. The problem of different definitions and scope of MLMs therefore needs to be addressed first: they can be regarded as smaller digital learning resources that combine different media and are intended for re-use [12], meaning that those learning objects do not depend on technical and educational settings. Alternatively, they can be a part of an e-learning setting and should thus be evaluated using a broader e-learning quality framework [6].

The study in this paper explores issues regarding the quality of multimedia learning materials and focuses on two goals: 1) assessing the quality of MLMs and 2) exploring the effects of using MLMs of different quality on knowledge acquisition. To achieve these goals, we first reviewed theoretical and empirical research on the influence of multimedia on learning, then examined the tools for quality assessment of MLMs and finally conducted an experiment with low- and high-quality MLMs. In the final section of this paper, we discuss research results and implications of MLM quality on the e-learning systems design.

2. Review of Previous Research

2.1. The Influence of Multimedia on Learning

There is a vast body of research that explores the usage of multimedia to foster meaningful learning. One of the most elaborate studies about the impact of multimedia on learning was conducted by Richard E. Mayer and his associates. They performed a series of experiments to confirm Mayer's cognitive theory of multimedia learning and to show benefits of using the twelve principles of multimedia design when developing learning materials [13]. In one of the experiments Mayer [14] established the importance of convergence of individual types of media such as auditory narration with visual animation to promote meaningful learning. Along with that, Mayer and Moreno proposed nine ways for reducing cognitive load in multimedia learning [16].

Other researchers also explored the influence of digital media representation on learning. For example, Alty et al. [1] showed that the sound-and-diagram media combination significantly outperformed text-and-diagram and text-only presentations. Similarly, Arguel and Jamet [2] experimented with static pictures and video presentations to investigate their influence on learning outcomes. They found that students who had learned from a combination of video and static pictures performed better in the assessment than those learning only from video presentations.

On the other hand, there are studies in which no significant evidence on the impact of different media modalities in the e-learning environment was obtained. The experimental study by Jenkinson et al. [11] was comprised of respondents' time-limited exposure to one of two treatments: e-learning modules with static graphics vs. animated graphics, preceded by a pre-test and followed by a post-test. Although in their study no significant difference between treatments was found in the quantitative data, significant differences regarding students' perception of the effectiveness of the media were identified in the qualitative data.

2.2. Evaluating the Quality of Multimedia Learning Materials

Evaluating the quality of digital multimedia learning resources is important for a number of reasons:

- design of multimedia learning resources is often not in accordance with relevant research in psychology and education [19], resulting in a large amount of multimedia materials of questionable quality that are stored in repositories or on the Web,
- searching for high-quality MLMs may be impractical or time-consuming [12],

- choosing MLMs for re-use does not have to be objective [13] since search engines implemented in some MLM repositories use certain quality metrics in order to get specific (ordered) search results [22] and thus depend on the validity of the evaluation tool used to generate quality ratings,
- criteria used to evaluate the quality of MLM can serve as guidelines for improving the design of multimedia learning materials [5], [18].

While there are numerous studies that deal with effects of multimedia learning, the quality of multimedia learning materials has hardly been investigated.

One of the rare empirical studies is that by Chen et al. [8], who explored the relationship between students' cognitive styles, quality of multimedia service access by the Internet (QoS) and quality perceptions of participants (QoP) of multimedia content. In their research, the quality of multimedia learning content was limited to the service of Internet access, which is only one of the attributes that should be considered within the quality of multimedia learning materials in general. This technological approach to MLM quality is also common in a number of other studies, e.g. [4], [6], [9], where technological standards were used for MLM development and assessment of their quality, without focusing on its pedagogical aspects.

Another issue in the evaluation of multimedia learning materials is that their quality is usually considered within the overall online course quality, as in the study by Sung et al. [20]. In their investigation of e-learning quality assurance, sixty-seven e-learning courseware applications were analyzed and evaluated for the purpose of e-learning courseware certification.

Bubaš et al. [5] describe such an approach as *course providers' perspective* in the process of e-learning quality assurance, which emphasizes transparency, quality control and standardization. Other aspects of quality assurance are *students' standpoint*, with a focus on effective presentation of content, promotion of interaction and greater achievement in learning [5], or *suppliers' aspect*, where market-boosting and cost/benefit issues are considered [11].

The aforementioned examples illustrate different approaches to researching the quality of multimedia teaching materials and their use in the teaching process. However, the relationship between the MLM quality and achievement of learning process outcomes are scarce.

2.3. Tools for Measuring the Quality of Multimedia Learning Materials

The quality of multimedia learning materials is usually measured by using evaluation tools like questionnaires or checklists, many of which are of questionable reliability and validity [19]. In selecting a tool for assessing MLM quality the scope of multimedia learning materials should be taken into account as an additional criterion so as to differentiate smaller independent digital learning resources ('narrower scope') from multimedia learning materials that are an integral part of an e-learning course ('broader scope').

In this paper, we consider multimedia learning materials (MLMs) as computer-based learning materials intended to be used for teaching or learning that are not dependent on the learning environment and can be presented online or offline. Thus, for the purpose of this research, we reviewed two available instruments for measuring the quality of multimedia learning materials with similar definitions of MLM: LORI [12], [17], [19], and QAMLM [6], [7].

Leacock and Nesbit [12] define MLMs as digital learning resources that combine text, images and other media intended to be reused in different learning contexts. They created an instrument to measure the quality of multimedia learning resources named *LORI (Learning Object Review Instrument)*. LORI includes nine indicators or items for evaluation of multimedia learning resources. Every item is described with several dimensions pertaining to that item rated on a 5-point scale, where 1 means the lowest grade and 5 means the highest grade, and can be further described with reviewers' comments. The final score for MLM quality is calculated by averaging the ratings.

The other instrument for measuring the quality of multimedia learning materials is the assessment guide entitled *Quality Assurance in Multimedia Learning Materials (QAMLM)* developed by the Commonwealth Educational Media Centre for Asia. Two versions of the

guide exist: QAMLM 1.0 [6] and the revised QAMLM 1.5 [7]. In the latter version, the guide provides quality assurance rating tools for developers of MLM (e.g. designers, technical specialists, subject matter experts), individuals who will perform the evaluation of MLM quality (e.g. teachers, parents, administrators and librarians) and end-users of MLM (learners), respectively. The revised version also incorporates some parameters that enable evaluation of e-learning courses like reusability or information validity and updating, among others [7]. The assessment guide for evaluators of MLMs (Part B) in the v1.0 version contains 19 quality indicators which are scored on a five-point scale. QAMLM is more suitable for qualitative assessment of MLM quality [6] and should be adapted according to the context of evaluation [7].

3. Empirical Research

3.1. Research Design

The main goal of our research was to determine the quality of multimedia learning materials and to examine the relationship between MLM quality and knowledge acquisition. In order to explore these issues, we defined the following sub-goals:

- developing low-quality and high-quality multimedia learning materials,
- selecting and adapting the MLM quality assessment tool,
- conducting the experiment to measure the quality of MLMs and its effects on knowledge acquisition during a longer period of time.

Our main research question was: *(RQ) What are the effects of high-quality multimedia learning material on knowledge acquisition?*

3.1.1. Development of Multimedia Learning Materials

In this study, multimedia learning materials are regarded as independent learning resources. This means that they can be implemented as part of a learning unit on a CD-ROM or used in online learning that is not facilitated by a teacher. In our case, MLMs were implemented within a blended learning environment in LMS Moodle v.1.9 for the course 'Graphics, text and multimedia' which was delivered to 1st year students at the Polytechnic of Rijeka, Croatia.

All multimedia learning materials were developed according to the guidelines for developing interactive multimedia learning modules by Stanford University [10] and by following the *Quality Assurance Framework* based on the ADDIE model of instructional design [6]. MLMs were developed for two topics: 'Colors and the Use of Colors on the Internet' (MLM C) and 'The Use of Graphics on the Internet' (MLM G).

Two versions of each topic were developed: the low-quality version (LQ) and the high-quality version (HQ). Low-quality multimedia learning materials (MLM G-LQ and MLM C-LQ) contained only texts and static images. In addition, in MLMs LQ learning goals were not indicated, navigation was available only through the breadcrumbs determined by the Moodle, pages did not have a title, important parts of the content were not emphasized with formatted text or a different font, multimedia was not properly used for the presentation of the content, and self-assessment was not available, to mention only some of their features. On the other hand, high-quality multimedia learning materials (MLM G-HQ and MLM C-HQ) presented the same learning content as MLMs LQ but with additional multimedia types: audio, video, animations and interactive simulations. Those were developed by applying Mayer's principles of multimedia learning [13] as well as principles for reducing cognitive load [16]. Processes and changing parameters, e.g. how a change in the *brightness* parameter affects the picture, were presented with video or animation as well as additional text. The latter was placed in the proximity of the animation to reduce cognitive overload, according to the spatial contiguity principle [16].

3.1.2. Selection and Adaptation of the MLM Quality Assessment Tool

Before conducting experimental research, we analyzed two available instruments for measuring the quality of multimedia learning materials, LORI and QAMLM 1.0. While the QAMLM assessment guide was still under revision when this research was performed, the LORI tool had already been validated in several studies [17, 21] and proven to be easy to use and time-effective [12]. The advantage of the latter lies in the quantitative measures, which allows for easier interpretation of results. Furthermore, it had been used by many educational institutions to teach learning resource evaluation as well as to perform evaluations within different educational models (e.g. in a collaborative environment) [12]. Thus, we decided to use LORI for assessing the quality of the developed MLMs.

LORI's dimensions are described by the following nine items [12, 17]: *Content quality* (veracity, accuracy, balanced presentation of ideas, appropriate level of detail), *Learning goal alignment* (alignment among learning goals, activities, assessments, learner characteristics), *Feedback and adaptation* (feedback or adaptive content driven by differential learner input or learner modeling), *Motivation* (ability to motivate and interest a population of learners), *Presentation design* (design of visual and auditory information for enhanced learning and efficient cognitive processing), *Interaction usability* (ease of navigation, predictability of the user interface, quality of the interface help features), *Accessibility* (design of controls and presentation formats to accommodate disabled and mobile learners), *Reusability* (ability to use the tool in varying learning contexts and with learners from different backgrounds), and *Standards compliance* (adherence to international standards and specifications).

We extended and adapted the original LORI after the pilot research conducted among fifteen teachers at the Polytechnic of Rijeka concerning their usage of MLMs in the classroom and issues concerning MLM quality. Based on their answers in a semi-structured interview three LORI items were extended with new statements. The reliability of the adapted LORI was tested during the analysis of experimental data indicating high internal consistency, as reported in Section 4.2.

3.1.3. Experimental Method Plan

The experiment was primarily aimed to collect data for achieving the objective of the research: to determine the quality of MLMs and the effect of using MLMs of different quality on knowledge acquisition.

It was comprised of: a) usage of multimedia learning materials in a blended learning environment and repeated knowledge assessment on selected topics and b) evaluation of multimedia learning materials quality.

In the first part of the experiment students enrolled in the first year of a professional study programme in Information Science used multimedia learning materials during regular classes in a computer laboratory. Since our intention was for every student to use both low-quality and high-quality multimedia learning materials, a within-subjects research design was chosen. In order to eliminate a possible effect of the preferred learning topic on knowledge acquisition, students were randomly distributed into two groups and assigned MLM C-LQ and MLM G-HQ (Group 1) or MLM C-HQ and MLM G-LQ (Group 2). The procedure lasted for eight weeks, during which three knowledge tests were administered for each of the two topics. In the first week a diagnostic test was performed with each group of students to identify their prior knowledge of the topics from the course syllabus, including the two topics of our research interest. Students were briefly introduced to the research study but were not acquainted with the objective of the experiment. They were also introduced to LMS Moodle. In the second week they used MLM C-LQ (Group 1) or MLM C-HQ (Group 2) in class for 45 minutes, with a knowledge test administered 10 minutes afterwards. The tests were comprised of 15 questions (MLM C) and 21 questions (MLM G), respectively, and evaluated both recall and comprehension of the given topic. Grades were assigned according to the following percentages of points acquired in the test, as defined by the Assessment Regulations of the Polytechnic of Rijeka: 1 – failing grade (less than 40% of acquired points), 2 – satisfactory

(40-59.9% of acquired points), 3 – good (60-69.9% of acquired points), 4 – very good (70-79.9% of acquired points), and 5 – excellent (80-100% of acquired points). In the third week, the knowledge assessment test was repeated. During the fourth week the groups studied the other topic, using MLM G-HQ (Group 1) or MLM G-LQ (Group 2), with a knowledge test administered as in the second week. In the fifth week they were re-tested on the second topic. During the sixth and eighth week, the third knowledge assessment was performed, on the first and second topic, respectively. In the seventh week there was no class activity but students were able to interact with MLMs from their home.

The second part of the experiment was comprised of evaluation of the multimedia learning materials quality with the adapted LORI instrument that contained 50 statements. Evaluation was performed by randomly chosen Croatian teachers of informatics who examined the MLMs and assessed them in an online survey.

4. Research Findings

4.1. Demographic Data of Participants

A total of 141 first-year students, 105 of them male (74.5%) and 36 female (25.5%) participated in the study. Among them, 102 (72.3%) had previously used multimedia in learning. A vast majority of respondents (133, or 94.3%) had attended a computer science course in high school.

In evaluating the quality of MLMs 19 teachers were involved, 13 (68.4%) of whom were female and 6 (31.6%) male. Most respondents had between 3 and 5 years of teaching experience, with 16 of them working at a higher education institution. All respondents had been using multimedia in their teaching practice, 3 (15.8%) of them sometimes, 14 (73.7%) of them often, and two (10.5%) of them constantly.

4.2. MLM Quality and Its Effect on Knowledge Acquisition

Due to page limitation, we provide only partial research results focusing on MLM quality and its effect on knowledge acquisition obtained after the first knowledge assessment.

The analysis of data gathered in the evaluation of MLM quality with the adapted LORI showed that teachers evaluated MLM LQ as low-quality and MLM HQ as high-quality materials, which was evident in the average grade given to a particular MLM type. Figure 1 represents the average grades for MLMs of different quality.

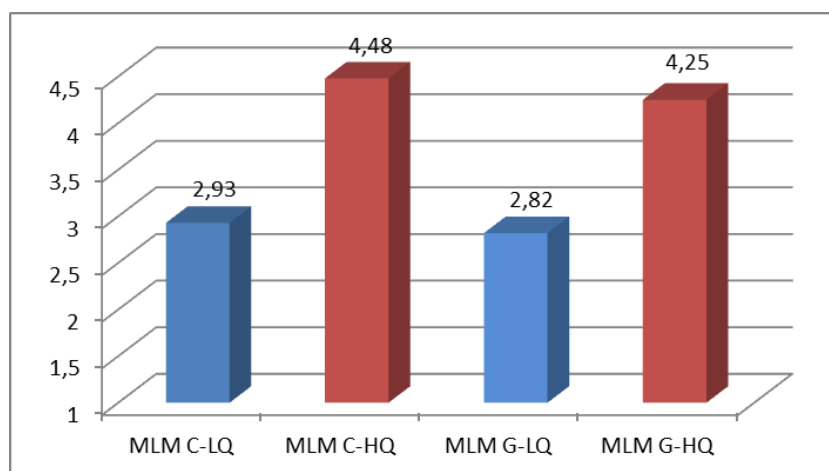


Fig 1. Average grades for MLMs of different quality

The reliability of the adapted LORI was determined by running the Cronbach's Alpha test in which all factors showed high internal consistency: 0.933 (MLM C-LQ), 0.947 (MLM C-HQ), 0.936 (MLM G-LQ) and 0.900 (MLM G-HQ).

Figure 2 represents the values for nine items of the LORI assessment tool for the topic 'Colors and the Use of Colors on the Internet' (MLM C). The smallest difference in the score (1.06) was identified for the *Content Quality* parameter, as both MLM C-LQ and MLM C-HQ contained the same factual knowledge related to the aforementioned topic. The biggest difference between scores (2.43) was found for the *Learning Goal Alignment* parameter, which, among other reasons, was due to the fact that in MLM C-LQ learning objectives were not defined while in MLM C-HQ they were clearly stated.

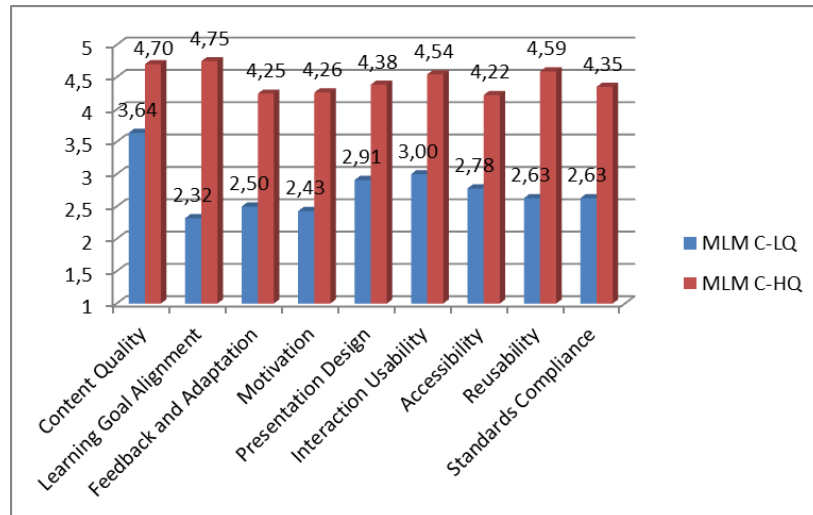


Fig 2. LORI values for MLM C

For the topic 'The Use of Graphics on the Internet' (MLM G), the biggest difference between the average scores (2.16) was identified for the *Standards Compliance* parameter (see Figure 3), since MLM G-LQ did not have embedded metadata and were not developed by using web technologies such as CSS or similar standards. The smallest difference between the average scores (0.87) was found for the *Accessibility* parameter since both types of MLMs were available via LMS Moodle which was accessed from computer labs equipped with a high-speed Internet connection.

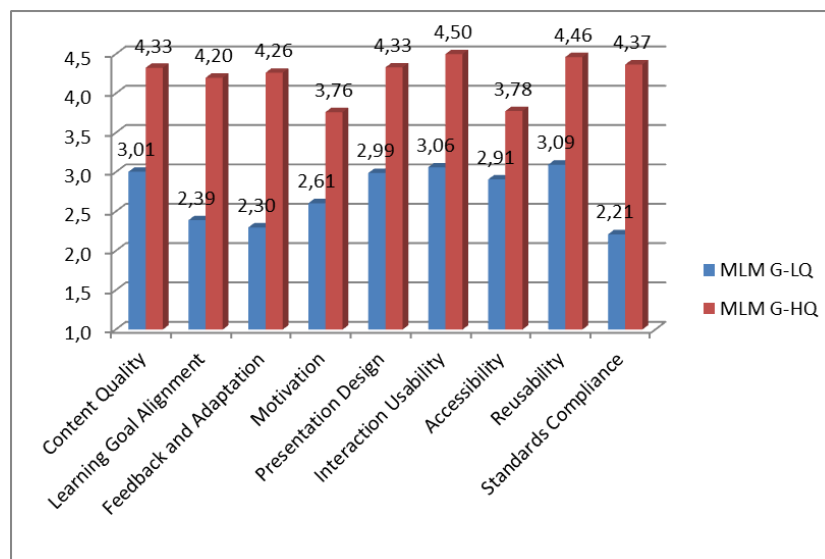


Fig 3. LORI values for MLM G

To determine the effects of MLMs on knowledge acquisition, we first calculated the average number of points and associated grades (ranging from 1 to 5) acquired after the use of MLMs and knowledge assessment. After that we verified whether there was a statistically significant difference in those parameters for MLMs of different quality for each topic (MLM C and MLM G).

Table 1 shows the results of the t-test for independent samples, where the number of points generated as a commemorative shape represents the amount of acquired knowledge. A statistically significant difference ($p < 0.01$) was found between LQ and HQ for both topics.

Table 1. Comparison of knowledge acquisition after the usage of MLMs of different quality and first knowledge assessment

Variable	N	Mean (max=32 points)	Std. Deviation	t	df	Sig. (2- tailed)	d
First knowledge assessment				-6.336	130.181	0.000	1.077
MLM C-LQ	70	21.43	4.292				
MLM C-HQ	71	25.54	3.337				

Variable	n	Mean (max=38 points)	Std. Deviation	t	df	Sig. (2- tailed)	d
First knowledge assessment				-7.475	139	0.000	1.262
MLM G-LQ	71	23.42	4.449				
MLM G-HQ	70	25.54	5.183				

Furthermore, Table 2 shows knowledge acquisition expressed as the average scores achieved, their percentages and the average rating for all MLMs. The percentage of acquired knowledge upon the use of higher-quality MLMs (C-HQ and G-HQ) was significantly higher (66.96% and 79.81%, respectively) than after the use of low-quality MLMs (C-LQ: 61.63%, G-LQ: 67.21%).

Table 2. Knowledge acquisition expressed by scores in points, percentage and average grade after the usage of MLMs of different quality

Variable	n	Score in points (average/max)	Percentage of acquired knowledge	Average grade (max. 5)
MLM C-LQ	70	21.43/32	66.96%	2.77
MLM C-HQ	71	25.54/32	79.81%	3.66
MLM G-LQ	71	23.42/28	61.63%	2.15
MLM G-HQ	70	25.54/28	67.21%	3.28

5. Conclusion

The design and development of high-quality MLMs is a challenging task, which explains why a lot of teachers are reluctant to invest their time and effort into them, especially considering that outcomes regarding MLM quality and knowledge gain are sometimes questionable. Moreover, most teachers are not sufficiently informed about recent research or guidelines for creating learning materials that foster meaningful learning.

The results of our research confirm that the usage of Mayer's principles of multimedia learning allow for creation of high-quality MLMs in a blended learning environment. In our experiment multimedia learning materials of different quality were created for the topics 'Colors and the Use of Colors on the Internet' (MLM C) and 'The Use of Graphics on the Internet' (MLM G) and were subsequently implemented in a polytechnic school course via LMS Moodle. The assessment of MLMs quality performed by teachers by means of the adapted LORI evaluation tool showed significant difference between the high-quality (MLM

C-HQ, MLM G-HQ) and low-quality materials (MLM C-LQ, MLM G-LQ) for every LORI item.

The adapted LORI assessment tool was validated as an effective evaluation tool with clear benchmarks for different quality items. It can be used to evaluate not only small learning resources, but also, as in our case, MLMs implemented in learning management systems. Items like *Feedback and adaptation*, *Interaction usability* or *Accessibility* evaluate dimensions that are part of LMS's functionality and as such can be used for evaluation of LMS as a product. However, the above assumption needs to be confirmed by additional research.

One of the limitations of the research in this paper regarding the assessment of MLM quality lies in a small number of teachers who evaluated MLMs, so additional research with a larger number of evaluators is needed in that respect as well. Also, evaluations performed by other stakeholders (e.g. students) might yield different quality estimation results since different stakeholders may emphasize different quality attributes, as suggested in [12]. Another potential problem involved in generalizing the results of our research might lie in different combinations of media types used in HQ and LQ MLMs with the same learning topic, which does not make those materials directly comparable. However, given that the learning content was the same in both MLM LQ and MLM HQ and that our goal was to assess the overall quality of multimedia learning materials presented within the online course and determine the effects of their quality on knowledge acquisition, we perceive this as a minor obstacle.

From the description of the experiment reported in this paper it is evident that students who used MLMs of higher quality acquired the average grade that was approximately one grade higher than that acquired by students who used lower-quality MLMs. This result was obtained in the knowledge assessment test taken shortly after the usage of MLMs in class. In our future papers we will show the results of knowledge assessments after a longer period of time during which students will also have had the opportunity to use and learn from MLMs in their spare time.

Positive effects of HQ MLMs on knowledge acquisition and achievement of learning outcomes as well as better grades for learners identified in our research indicate the necessity of investment in appropriate design of high-quality multimedia learning materials for use in the e-learning environment.

References

1. Alty, J.L., Al-Sharrah, a., Beacham, N.: When humans form media and media form humans: An experimental study examining the effects different digital media have on the learning outcomes of students who have different learning styles. *Interact. Comput.* 18 (5), 891–909 (2006)
2. Arguel, A., Jamet, E.: Using video and static pictures to improve learning of procedural contents. *Comput. Human Behav.* 25 (2), 354–359 (2009)
3. Bates, A.W., Poole, G.: *Effective Teaching with Technology in Higher Education*. John Wiley & Sons, Inc., San Francisco, USA (2003)
4. Batteram, H., Damm, G., Mukhopadhyay, A., Philippart, L., Odysseos, R., Urrutia-Valdés, C.: Delivering quality of experience in multimedia networks. *Bell Labs Tech. J.* 15 (1), 175–193 (2010)
5. Bubaš, G., Balaban, I., Begičević, N.: Evaluation of Online Courses as an Element of Instructional Design : The Case of Two Hybrid University Courses. In: Čičin-Šain, M., Turčić Prstačić, I., and Sluganović, I. (eds.) *Proceedings of the 30th MIPRO Jubilee International Convention on Computers in Education - MIPRO 2007*. pp. 216–221. MIPRO, Rijeka (2007)
6. CEMCA (Commonwealth Educational Media Centre for Asia): *Quality Assurance of MultiMedia Learning Materials (Version 1.0)*. , New Delhi (2009)

7. CEMCA (Commonwealth Educational Media Centre for Asia): *Quality Assurance of MultiMedia Learning Materials (Version 1.5)*. , New Delhi (2010)
8. Chen, S.Y., Ghinea, G., Macredie, R.D.: A cognitive approach to user perception of multimedia quality: An empirical investigation. *Int. J. Hum. Comput. Stud.* 64 (12), 1200–1213 (2006)
9. Hede, T., Hede, A.: Multimedia effects on learning: Design implications of an integrated model. In: *Proceedings ASET Conference 2002*. (2002)
10. Huang, C.: Designing high-quality interactive multimedia learning modules. *Comput. Med. Imaging Graph.* 29 (2-3), 223–33 (2005)
11. Kidney, G., Cummings, L., Boehm, A.: Toward a Quality Assurance Approach to E-Learning Courses. *Int. J. ELearning.* 6 17–30 (2007)
12. Leacock, T.L., Nesbit, J.C.: A Framework for Evaluating the Quality of Multimedia Learning Resources. *Educ. Technol. Soc.* 10 (2), 44–59 (2007)
13. Mayer, R.E.: *Cognitive Theory of Multimedia Learning*. In: *The Cambridge handbook of multimedia learning*. pp. 31–48. (2005)
14. Mayer, R.E.: *Multimedia learning: Are we asking the right questions?*, (1997)
15. Mayer, R.E., Moreno, R.: *Aids to computer-based multimedia learning*, (2002)
16. Mayer, R.E., Moreno, R.: Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educ. Psychol.* 38 (1), 43–52 (2003)
17. Nesbit, J., Belfer, K., Leacock, T.: *Learning Object Review Instrument (LORI): User Manual*, <http://www.transplantedgoose.net/gradstudies/educ892/LORI1.5.pdf>, (2004)
18. Nesbit, J., Belfer, K., Vargo, J.: A Convergent Participation Model for Evaluation of Learning Objects. *Can. J. Learn. Technol. / La Rev. Can. l'apprentissage la Technol.* 28 (3), (2002)
19. Nesbit, J.C., Leacock, T.L.: Web-Based Tools for Collaborative Evaluation of Learning Resources. *Syst. Cybern. Informatics.* 3 (5), 102–112 (2006)
20. Sung, Y.T., Chang, K.E., Yu, W.C.: Evaluating the reliability and impact of a quality assurance system for E-learning courseware. *Comput. Educ.* 57 (2), 1615–1627 (2011)
21. Vargo, J., Nesbit, J.C., Belfer, K., Archambault, A.: Learning object evaluation: Computer mediated collaboration and inter-rater reliability. *Int. J. Comput. Appl.* 25 (3), 198–205 (2003)

Considering Student Personal Needs and Preferences and Accessible Learning Objects to Adapt Moodle Learning Platform

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Abstract

This paper provides information about the standards that govern accessibility of learning objects, presents an example of an accessible learning object and shows the procedure to operate the Moodle learning platform which has been adapted by the authors to the preferences and needs of the students. The way to operate the Moodle adapted platform takes place in three phases. In the first phase, the platform asks the students and stores in their profile their sensory preferences to access the information. In the second stage the content authors or teachers are provided with the possibility to upload adapted learning objects to the platform. In the third stage, it searches for adapted learning objects that best suit the needs and preferences of the students, showing them how to view and use.

Keywords: E-learning, Accessibility, Metadata, Learning Object, Personal Needs and Preferences, Digital Resource Description.

1. Introduction

Accessibility is an unresolved subject in our society. Seale and Cooper [13] show the limited success of accessibility of some specific tools and mention the possibility of a mix approach in the use of specific accessibility tools and general pedagogical tools. Cooper [3], points out the need to consider the personal needs of the student, conducted by the Open University in order to provide access to information to students who possess some type of disability in higher education. Other authors such as Karampiperis and Sampson [12] also stress the need. Today there is still no clear solution.

An Accessible Learning Object (ALO) is one that consists of an original Learning Object (LO) and other adapted LOs presenting the same intellectual content but a different sensory form of access (sight, hearing or touch) to content, where each LO must have associated the accessibility metadata specified in the standards.

In section 2 we describe the developed projects related with accessibility in education. Section 3 shows both the standard in which it is based, and the example of ALO that we have chosen. Section 4 describes the three phases which must take place in order the students are able to access the information. Finally in section 5 we present the conclusions.

2. Related Works

Three projects are presented in this section, in which, in one way or another, it has worked on accessible learning: TILE (The Inclusive Learning Exchange) [14], EU4ALL (European Unified Approach for Accessible Lifelong Learning) [6] and Xerte [15].

TILE is a repository of accessible learning objects that provides authoring tools and allows the users to define their needs and preferences. The project was developed in 2004 to be implemented in a network of learning communities in different sectors in Canada.

In a comparative way with our application, the TILE project allows searching for ALOs in a specific repository and download, while the plug-in that we present is embedded in a learning platform where ALOs are part of an online training course in a particular area and where you can perform different activities with ALOs in order to get a high learning level and quality assessment.

The EU4ALL project was developed by 13 countries within the Sixth Framework Programme of the European Union. It lasted four years ending in 2011. Its objective was to improve the efficiency and effectiveness of learning strategies in the field of universities and institutions for people with disabilities. The project is based on accessibility standards such as ISO / IEC 24751-1-2-3 "Individualized adaptability and accessibility in e-learning in education and training" [9]. In the same way as in the previous project, the Personal Needs and Preferences (PNP) of users were taken into account for access to information. Boticario et al. [2] and Cooper & Heath [4] provide wide information of the followed process.

In order to start our work from the achievements of this project, we have been in touch with some of the people responsible for LOs and software architecture areas of the EU4ALL project. To solve possible problems of "bottlenecks" in the flow information that can be caused by complex software architecture, a simple structure has been designed. The IMS Global Access For All (AFA) 3.0 of 2012 [8] specification has been followed to facilitate the construction of ALOs and save the current obstacle posed by the lack of ALOs generation by content authors. The IMS Global AFA 3.0 specification makes the creating learning objects easier since it summarizes the ISO / IEC 24751 standard, which presents a difficult start-up for both content authors and programmers due to the complexity of data models presented.

Xerte is a free tool created by the University of Nottingham to develop accessible interactive LOs based on Flash and Internet Explorer and following the SCORM standard. The tool has been created in collaboration with JISC TechDis [11] a UK advisory service on technologies for the inclusion of working in the field of teaching and learning in higher education in the UK.

The plug-in, that we present, allows the teacher and the content authors to upload in the learning platform an original LO and the adapted LOs for use. Furthermore it allows them to upload a compressed file containing a previously created ALO (a file with the original LO, the adapted LOs and XML files with the metadata for each LO). Therefore within the plug-in functionality there is the uploading and use of those ALOs developed with Xerte tool.

Because of the above problems, so far we know of no adaptable learning platform, which is capable of uploading ALOs. To get this utility for the Moodle learning platform, a plug-in software (starting from zero) has been developed within the framework of ESVI-AL (Virtual Inclusive Higher Education in Latin America) [5] project, which allows the student ALOs use. The application is based on both the simplicity of design and the AFA IMS v3.0 specification. It consists of a basic application that runs efficiently and has been conceived and designed to facilitate their growth easily by including new accessibility metadata, that accommodate new types of functional diversity.

3. Accessible Learning Objects for Students

3.1. Standard on which is Based

There are numerous standards that seek to guide and direct accessibility in education [7], but there are two [8, 9] that emphasize the role model for adapting an educational platform, which will be shown in this section.

The ISO / IEC standard 24751, regulates how to develop an Accessible Learning Object (ALO). The procedure presented by the standard, to achieve an ALO consists of three phases.

In the first phase the student, at the time of signing up for the learning platform, introduces his or her sensory access preferences to the ALOs. These preferences may be due both to personal characteristics (information access through sight, hearing, etc.) or the characteristics of the environment (dimly lit or a noisy room). The actors in this phase are both the student, who select his or her preferences, and the learning platform which has been reprogrammed through the plug-in, so as to provide the student with the creation of a profile based on his or her preferences.

The second phase should be carried out by the authors of LOs, who, to make an ALO they should develop, in addition to the original LO, several adapted LOs to the original LO. The adapted LOs should contain all or part of the intellectual content, but different format to the original LO [1], to enable the access to information to people not using all the senses. For example the previously mentioned video as an original resource, can accept captions and audio-description as adapted LOs. The captions are an alternative to the hearing part of the video and they are aimed at people who use the sight and may not use the ear as access mode. The audio-description is an alternative to the visual part of the video and they are aimed at people whose access to information is performed through the ear. Furthermore, the authors of ALOs must enter, for each LO, the accessibility metadata established by the standard for this purpose. We highlight two important examples of accessibility metadata: the access mode of a resource (both original or adapted), which can take values as visual, auditory, textual, tactile, etc. and the type of adaptation of an adapted resource, which can take values as captions, audiodescription, alternativetext, signlanguage, transcript, etc. The actors in this second phase are the authors of ALOs, introducing resources and its metadata, and the learning platform which has been reprogrammed so as to allow the authors to enter all the referred data.

The third phase takes place after completion the previous two, when the student clicks on a LO. This phase is carried out only by the plug-in of the learning platform and involves the search and display of adapted learning resources, which best adapt the preferences the user has set in their profile.

Two data models have been defined by the ISO / IEC 24751 standard one for defining PNP students and another for Digital Resource Description (DRD), which includes all accessibility metadata of resources that will guide the most appropriate adapted LO search to the student profile. Due to the complexity of such data models and the difficulties encountered in previous projects for their implementation a draft of specifications, called IMS Global Access For All (AFA) 3.0, has been presented by IMS Global Learning Consortium. The draft of specifications includes the structure and organization of the process and summarizes data models proposed in the Standard ISO / IEC 24751.

3.2. An Example: Learning to Program with Pointers

The ALO that we show is composed by a video as original LO, which teaches how to allocate dynamic memory in C Language using pointers. Sign language is shown as an adaptation.

Original Learning Object

As an example, a video is presented demonstrating the debugging process of a coded program in C Language using the integrated development environment Microsoft Visual C ++. The portion of code displayed corresponds to one of the functions of the program, which is in

charge of dynamic memory allocation to add a new item in a dynamic array of structures. The image in Figure 1 shows a time of the debugging sequence, that it allows to display the value of local variables of the function, in order to detect an executing error of the program. The video as a teaching resource has been created in an easy and intuitive way with the free tool Jing [10]. To receive all of the information displayed by the LO, visual and auditory access is required. The students without any or none of the two types of access will be deprived of information.

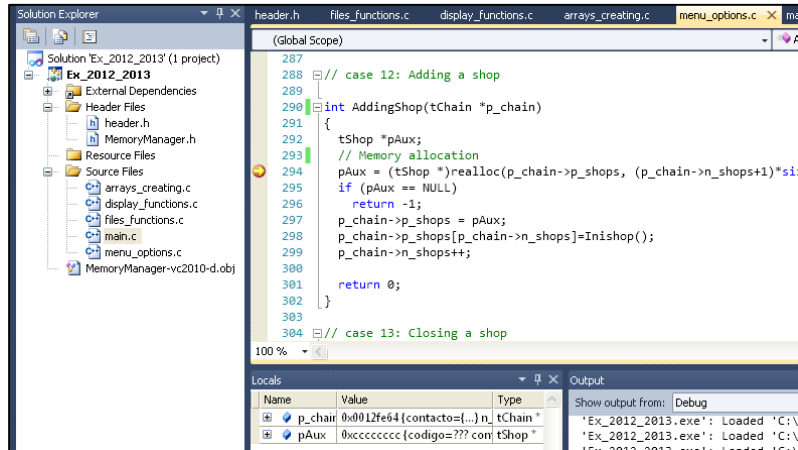


Fig. 1. Video as original learning object.

Adapted Learning Objects

In order to provide access to the resource to every student, adapted LOs to the original LO, are required. To adapt the audio content of the video, this may include alternatives such as captions, long description, alternative text or sign language. The visual content of the video can be adapted by audio description. Furthermore, for the latter case, if the student has technical aids such as a screen reader, he or she can use adapted LOs whose access mode is textual, such as long description or alternative text, as they are read by the screen reader and automatically converted to audio.

Figure 2 shows the original LO to which it was added the adapted LO sign language.

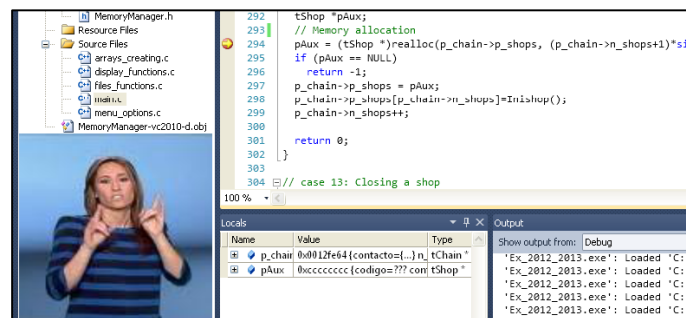


Fig. 2. Sig Language as adapted learning object.

4. Applying the Example to the Moodle Platform

To select an appropriate online learning platform an analysis of existing learning platforms to provide information about which one is most effective and has greater projection is required. In this regard, the work done in the ESVI-AL project during the process of elaboration of a methodological guide for the implementation of accessible virtual curricular developments [5] has been adopted. A comparative study of the different platforms in the market has been carried out in chapter 9 of the guide, taking into account a wide range of factors. The study

concludes by selecting the Moodle platform such as presenting a greater number of advantages. Considering the results of this study, a plug-in for the Moodle platform has been programmed by us, which performs all the tasks outlined above. Because of the lack of adaptable learning resources and applications in the field of accessibility, the plug-in, initially has focused on the efficient development and implementation of a basic application that serves as an impetus for new enlargement proposals, and new accessibility metadata covering a wider diversity of access to information.

The plug-in, programmed in PHP, relies on a database, programmed in MySQL, that stores both student PNPs and ALOs (which include the original and adapted resources and its DRDs). It is possible to communicate the database from the learning platform Moodle and also by Web from any LOs.

The next sections describe the three necessary stages to operate the adapted platform.

4.1. Phase 1: Configuring the Students PNPs

Figure 3 shows the Phase 1 which includes the introduction of the student PNPs at the time of first access to the platform. In the example the student has selected as sensory access modes, the textual and visual modes and as preferred or required adaptation types, at least selected, as shown in the picture, high contrast, long description, sign language and transcript; everything which corresponds to the profile of a person with hearing problems. In addition, the selection of English and Spanish languages indicates that LOs will be selected only in these languages. Finally, the student indicated a risk of convulsion with elements that produce flash on the screen. Furthermore, the system is capable of importing PNPs from other systems or learning platforms.

Fig. 3. 1 Student PNPs configuration.

4.2. Phase 2: Adding Access For All Resources

To perform phase 2, the plug-in allows upload in the learning platform the original LO and its adapted LOs, offering in the Add Resources menu a new option called AFA Resource (as shown in Figure 4) in order to add to the platform one new type of AFA resource.

Fig. 4. Window to add an AFA resource.

Furthermore it shows the necessary menus to add the essential accessibility metadata to search the adapted LO that meets the requirements of the student PNPs. A button allowing the teacher or contents author to enter the rest of accessibility metadata is also shown.

Once added the original AFA resource and its DRD, it is possible to upload the adapted LOs to the original LO and its DRDs (Figure 5). Those metadata that are not introduced by the author of content, they will be filled automatically by the plug-in following the logic that is appropriate based on the available information.

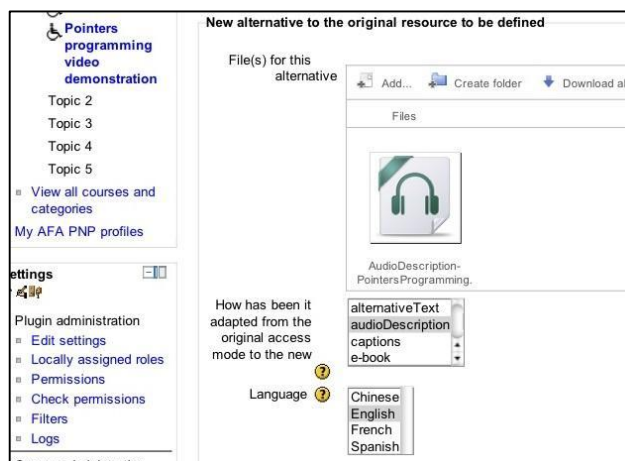


Fig. 5. Introducing metadata to the audio description.

Table 1 shows the accessibility metadata that have been configured for the original video and two of the adapted LOs example shown (sign language and long description).

Table 1. Accessibility metadata for shown ALO.

Metadata	Video	Sign Language	Long description
AccessMode	Visual, Auditory	Visual	Textual
HasAdaptation	ID_1.1, ID_1.2		
ControlFlexibility	FullMouseControl	FullMouseControl	FullMouseControl
DisplayTransformability	Layout	Layout	
Hazard			
AtInteroperable	False	False	False
ApiInteroperable			
IsAdaptationOf		ID_1	ID_1
IsPartialAdaptationOf		ID_1	ID_1
IsFullAdaptationOf			
AdaptationType		SignLanguage	LongDescription
AccessModeAdapted		Suditory	Visual
AdaptationDetail		RealTime	
AdaptationMediaType			PDF
LanguageOfAdaptation			English
EducationalComplexityOfAdaptation			
EducationalLevelOfAdaptation		4	4

After entering the metadata, they are stored in XML files. Figure 6 shows a part of the XML file of accessibility metadata for captions as adapted LO of the video. LOs can be downloaded from the platform in a zip package that includes the XML file with the metadata

resource (original or adapted), and the file containing the LO (pdf, video, etc), so they can be reused in other systems as repositories or other learning platforms.

```
<accessForAllResource xmlns="http://www.imslobal.org/xsd/accessibili
  <accessMode>afaterms-textual</accessMode>
  <accessModeAdapted>afaterms-auditory</accessModeAdapted>
  <adaptationType>afaterms-captions</adaptationType>
  <hazard>afaterms-flashing</hazard>
  <languageOfAdaptation>es</languageOfAdaptation>
  <controlFlexibility>afaterms-fullMouseControl</controlFlexibi
```

Fig. 6. XML file of accessibility metadata for captions.

4.3. Phase 3: Accessing to the Accessible Learning Objects

Phase 3 begins when the student clicks on the original LO, and involves the search by the plug-in, between existing adaptations to the original LO selected, of those adaptations that are appropriate to the student PNPs. Once found, they are displayed on the screen in order to be downloaded by students. In our example the introduced PNPs are textual and the visual access modes preferred. In addition to this, we have introduced three adapted LOs to the video: sign language, audio description and long description. Sign language is shown in figure 7 as the adapted resource found in the search, which meets the PNPs. At the end, the plug-in presents the rest of the adapted LOs that they not meet the student PNPs.

AFA Resource selected: Pointers prog. video

Here is the alternative(s) found based on your active personal needs & preferences

Pointers prog video - Download
 Access mode for these files: auditory
 Access mode for these files: visual
 Language: English

Pointers prog_SignLanguage - Download
 Access mode for these files: visual
 Access mode of the original resource that is adapted: auditory
 How has been it adapted from the original access mode to the new: signLanguage
 Language: English

Other alternatives to this resource found in the AFA central

Name	Language

Fig.7. Adapted LOs that meet the student PNPs.

5. Conclusions

Accessibility is an unsolved problem, which produces marginalization and social exclusion at all levels, especially at the level of education.

To solve the problem, we have developed a plug-in that runs on three phases: introduction of the student PNPs, ALOs creation by the authors of content and instructors, and search for the adapted LOs, which meet the student PNPs.

The simple design of the elaborated plug-in allows an efficient implementation of the adapted learning platform and an easy portability to other platforms for learning and storage of LOs.

The reduction of data models that we have followed, which is presented by the IMS AFA 3.0 specification, it facilitates both the programming of the application and the creation of ALOs by the content's authors and teachers.

The software structure of the plug-in allows for an easy extension at a later stage through the introduction of new accessibility metadata and based on the experience of its use.

Through this application the students with functional diversity will be able to access the learning material. Nevertheless there is a lack of adaptations of learning objects that must be solved by Public Institutions since funding is required for their development.

There is a wide range of degrees in functional diversity, which complicates the design of applications, building adaptations and difficult work since lacking specific data on which to rely.

Future Works

The plug-in will be installed in a virtual campus under the project ESVI-AL. It will be used in 6 online courses. Each course will house 150 students with physical and sensory disabilities and will last for 30 hours.

The project is scheduled to begin a second phase, that building on the experience of this first phase, it will be expanded the functionality of the adapted platform, including new types of functional diversity.

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References

1. Batanero, C., García, E., García, A. And Piedra, N.: Norma ISO/IEC 24751: Acceso para todos. III Congreso Iberoamericano sobre Calidad y Accesibilidad de la Formación Virtual (CAFVIR 2012). Alcalá de Henares. Págs. 105-112 (2012)
2. Boticario, J., Rodriguez-Ascaso, A., Santos, O., Raffenne, E., Montandon, L., Roldán, D. And Buendía, F.: Accessible Lifelong Learning at Higher Education: Outcomes and Lessons Learned at two Different Pilot Sites in the EU4ALL Project. *J. UCS*, 18(1), 62-85 (2012)
3. Cooper, M.: Making online learning accessible to disabled students: an institutional case study. Open University, U.K. In: *ALT-J: Research in Learning Technology*, 14(1) pp. 103–115 (2006)
4. Cooper, M., & Heath, A.: Access for all to eLearning. In A. Méndez-Vilas, A. solano Martín, J.A. Mesa González, J. Mesa González (Eds.), *Research, reflections and innovations in integrating ICT in education (Vol. 2, pp. 1139-1143)* (2009)
5. ES-VIAL: Mejora de la Accesibilidad en la Educación Superior Virtual en América Latina. Proyecto encuadrado en el programa ALFA III de la Unión Europea (2013)
6. EU4ALL: Accessible Lifelong Learning for Higher Education. Proyecto europeo encuadrado en el sexto programa marco sobre tecnologías de la sociedad de la información <http://www.eu4all-project.eu/> (2011)
7. Fabregat, R., Moreno, G. D., Alonso, F., Fuertes, J. L., González, A. L., Martínez, L.: Estándares para e-learning adaptativo y accesible. *Revista Iberoamerica de Educación Superior a Distancia*. V.13: 2. 45—71 (2010)
8. IMS. IMS Access For All. Version 3.0. IMS Global Learning Consortium, Inc. <http://imglobal.org/accessibility> (2012)
9. ISO/IEC 24751-1-2-3: Information technology -- Individualized adaptability and accessibility in e-learning education and training. International Standard Organization, Geneve, Switzerland (2008)
10. Jing. TechSmith Corporation. 2405 Woodlake Drive, Okemos, MI 48864-5910 USA
11. Jisc TechDis: Inclusion technology advice, C/O The Higher Education Academy Building, Innovation Way. York Science Park, YORK YO10 5 BR
12. Karampiperisand, P. and Sampson, D.: Designing Learning Systems to Provide Accessible Services. Informatics and Telematics Institute, Centre for Research and Technology and Department of Technology Education and Digital Systems, University of Piraeus. Greece (2005)

13. Seale, J. and Cooper, M.: E-learning and accessibility: An exploration of the potential role of generic pedagogical tools. In *Computers and Education*, Volume 54, Issue 4, May 2010, p. 1107-1116 (2010)
14. TILE. The Inclusive Learning Exchange. University of Toronto (2004)
15. The Xerte Project. University of Nottingham. Learning Technology. B158 King's Meadow Campus. Lenton Lane. Nottingham, NG7 2NR (2008)

A Gamification Platform for Inspiring Young Students to Take an Interest in Coding

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Abstract

Coding skills are widely considered an invaluable asset in today's and tomorrow's business landscape. However, universities in North America and Europe are expected to produce computer scientists at a rate that is well below the projected demand. This has called for initiatives like the Computer Science Education Week in the United States and the Europe Code Week in the European Union. This paper proposes a novel, engaging activity that aims at inspiring students to take an interest in Coding via a mobile phone-based treasure hunt. The main contributions of the paper are the description of the platform used to realize the treasure hunt, and the experience report of the event that evaluated its effectiveness.

Keywords: Education, Coding

1. Introduction

Coding skills are widely considered an invaluable asset in today's and tomorrow's business landscape [1]. By learning how to code, one not only improves their employability but also their potential of becoming a successful entrepreneur – even when their activity is not directly related to the software sector. At the same time, universities in North America and Europe are expected to produce computer scientists at a rate that is well below the projected demand [1]. This has called for initiatives like the Computer Science Education Week in the United States [2] and the Europe Code Week in the European Union [3].

This paper proposes a novel engaging activity that aims at inspiring students to take an interest in Computer Science in general, and Coding in particular. This is based on a mobile phone-based treasure hunt, implemented as an Android app communicating with an AppEngine server. This approach, combined with a one-hour motivation speech and training, was tested and evaluated in an event involving 65 high school students, aged 12 to 18. The two main contributions of this paper are the description of the open-source platform used to realize the treasure hunt activity, and the experience report of the event which evaluated its effectiveness.

The rest of this paper is organized as follows: Section 2 discusses gamification and its use in the education sector. Then, Section 3 introduces the Gamification Platform, and Section 4 presents the experience report. The paper closes with conclusions in Section 5.

2. Gamification and Education

While gamification has historically been used even before computer use became mainstream, its potential has seen wide acceptance after the success of location-based service *Foursquare* [12], which was followed by more, general-purpose gamification apps like *Funifi* [4]. A popular

definition of gamification is “*the use of game design elements in non-game contexts*” [8]. In its more recent incarnation, gamification is also viewed as a “*software service layer of reward and reputation systems with points, badges, levels and leader boards*” [8].

In education, technology has been blamed for burdening learning by distracting students [16]. At the same time, technology is used to engage students and enhance learning, largely based on game-like approaches. Particularly in teaching programming, gamification has been used with great success: While technically not a game, Scratch [15] has succeeded in engaging programming novices with its jigsaw puzzle-like interface to creating fun programming projects. Similar to Scratch, Tynker provides a jigsaw puzzle-like programming language, which is used to solve small puzzles and progress to the next one [5]. Other, more traditional games, such as the Lightbot educational game [9], aim at inspiring computational thinking. Beyond teaching programming, gamification has also become popular in general instructional lectures, in the form of digital *Game Based Learning* [17]. Extensive work has also been conducted in “*determining how to match instructional content to specific game design features*” [11].

In terms of inspiring students to take an interest in computer science, various attempts have been documented. For example, the most recent Computer Science Education Week (code named *Hour of Code*) utilized self-paced puzzle-like games. These were used to introduce students to new concepts first (like *loops* and *conditionals*) via recorded videos featuring popular figures, and then to guide them into applying the newly acquired knowledge in solving new stages of a puzzle game. To further entice students, popular themes such as *Angry Birds* [20] – and more recently *Flappy bird* [18] – were used as the background story. The *Hour of Code* event was able to attract millions of students, and was arguably successful in giving students “*a taste of programming and motivate some of them to continue onward*” [10].

Finally, besides inspiring young students to take an interest in coding, gamification has also been used to *engage existing computing students*. For example, Mitchell et al. [14, 13] describe a particular case, where Freshman students go through an intensive, *four week challenge* during which they build a mobile application in teams. The main goal of it is “*to lead students through a challenging (yet highly scaffolded) project to show them where their course could take them.*”. In this case, the target mobile application is a game, but the course itself is also organized and run as a game itself.

3. Gamification Platform

This paper describes an approach for inspiring high school students to take an interest in computer science in general, and coding in particular. The proposed approach is centered around events which aim at engaging high school students. The events include the standard motivational talks and programming tutorials, but also – importantly – a fun, game-like treasure hunt activity, designed to interest participants.

3.1. Computerized Treasure Hunt

The success of a motivational event is dependent on its inclusion of a fun, memorable activity. In this section, we describe the *Treasure Hunt Challenge*, an activity aiming to inspire and motivate students to take an interest in computing in general, and coding in particular.

The *Treasure Hunt Challenge* (THC) is a traditional treasure hunt in the sense that it provides a sequence of clues, which can lead the participants to the treasure. Finding the answer to the current clue opens up the next one. The process repeats until the final clue is uncovered, which leads to the treasure. In our implementation, users can also skip a step if they choose, which however results to a penalty.

In the THC, the clues are questions that are either directly related to computing-related facts or questions that require puzzle-solving and coding skills (see Figure 1). To further engage

participants, the challenge can include location-aware activities (such as requiring that you go to a specific place before answering a question) and task-oriented challenges (such as scanning a QR-code with the camera to reveal the answer).

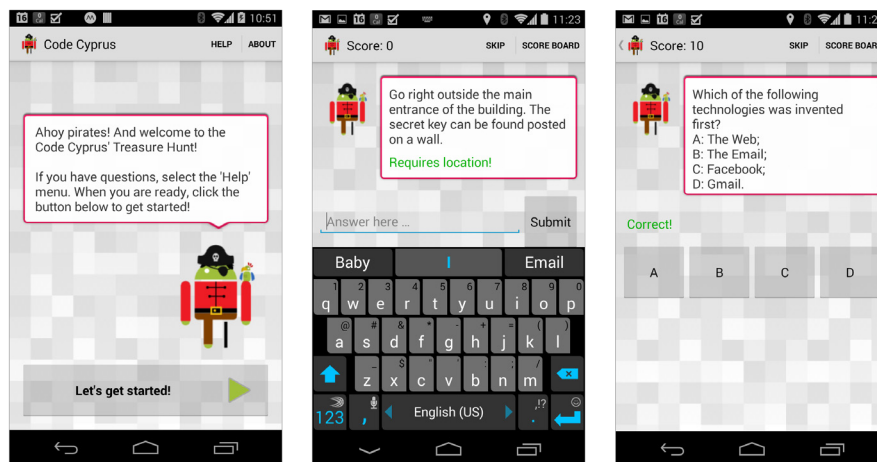


Figure 1. Screenshots from the Treasure Hunt app.

Unlike traditional treasure hunts, the THC is fully computerized and requires the use of a network-connected smartphone, which must be equipped with a location service (typically based on a GPS sensor) and a camera. Currently, only Android devices are supported, even though there are no technical limitations for extending support to other mobile platforms.

From a technical standpoint, the THC requires the continuous availability of a server-based system which provides the clues, and verifies the submitted answers. The same system is also responsible for keeping track of the score, which is a combination of how many questions were answered correctly and how many not, as well as of when was the treasure hunt completed (the time is used to break ties, in case two teams collect the exact same number of points).



Figure 2. The live scoreboard.

Adding to the participant's experience, and to the overall engagement achieved, is a live scoreboard. The scoreboard displays both the top teams with their corresponding score, as well as location of the teams on a map, both in real-time. As the live scoreboard is web-based, it can be easily projected to supported, network connected monitors. This is particularly useful when the facilities allow for a large display in the area where the treasure hunt takes place, as it engages the teams to compete with each other (see Figures 2 and 3).

3.2. System Architecture

The THC platform follows the client-server architecture. The core logic of the treasure hunt is implemented in the server side, and is made available to clients via a REST-ful [7] *Application Programming Interface* (API). The developed API is largely based on the one used in the *Four Week Challenge* [14] for realizing custom mobile apps using AppInventor [19]. It was designed to be simple, while enabling interested students to develop their own version of the client.



Figure 3. Students participating to the Treasure Hunt.

The API allows the client to query the available *categories* (i.e. competitions), and start a new *session* for a selected category. While in an active session, the client can query the server for the *current question* and the *score*. It can also use a similar query to *submit an answer* or *skip the current question*. Finally, while in a session, the client can also *update its current location* – which is required for location-aware questions – and also *request the full scoreboard*.

Passing arguments to the service is always done via HTTP GET requests with parameters. For instance, assuming that a session has been established (providing the client with a valid *Session UUID*), the current question can be requested as follows:

```
http://uclan-thc.appspot.com/api/csv/currentQuestion?
  session=agtzfnVjbGFuLXR0Y3IUCxIHU2Vzc2lwbhiAgICAgOe8CQw
```

Two variants of the API are supported, allowing for encoding the data in standard *Comma Separated Values* (CSV) or in *JavaScript Object Notation* (JSON) format. For instance, the above request could produce the following output (guiding the player to the clue from Figure 4):

```
OK,
This question is exactly at this location: (35.007584,\
  33.696870). Use a map to find it!
false
```

At the same time, using the JSON variant (i.e. by replacing CSV with JSON in the request URL), the output would be as follows:

```
{  "status": "OK",
   "question": "This question is exactly at this location:\
    (35.007584, 33.696870). Use a map to find it!",
   "isLocationRelevant": false
}
```

A detailed description of the API is available at: <https://uclan-thc.appspot.com/guide>.

3.3. Implementation

The implementation of the Computerized Treasure Hunt system includes two main apps, the mobile app, and the server.

A standard mobile app was developed and made available in Google's Play store. While the API allows for custom implementation, even using the App Inventor framework, our choice was to develop a native app that allows finer customization of the User Interface and the functionality (screenshots of the mobile app can be seen in Figure 1).

For the server side, we chose Google App Engine, which is a popular *Platform as a Service* (PaaS) framework. This provides a convenient platform as it is highly scalable: as minimal traffic is required in normal times, with high peaks during the competitions, serving a medium size treasure hunt can generally stay within the free quota limits, while providing extremely high reliability and performance when needed. Additionally, this platform provides many ready-made services, like user authentication, which minimize the required development effort.

The implementation of the server required the development of both a front-end – i.e. the services realizing the API calls – and a back-end – i.e. the system that can be used to create and edit a treasure hunt. The front-end was realized as Java Servlets, implementing all the API calls, such as those described in Subsection 3.2. The back-end was realized also via Java Servlets, but with the employment of *Java Servlet Pages* (JSP) to implement the graphical UI of the system.

The source code of both the mobile client and the server is available under the *Lesser General Public License* (LGPL) at: <https://github.com/nearchos/uclan-tch>.

4. Evaluation

Our approach was evaluated in a Treasure Hunt event where high school students were invited to attend the event and compete in the treasure hunt. There were no prior coding skills required, or any other requirements, besides the limit age of: students should be in high school and be age 12-18. This event received funding from the Cyprus Fulbright Commission, which allowed us to advertise it online, and also use some popular prizes to make it more appealing.

The event was organized in sessions, which included traditional elements like an inspiration talk, and a guided programming tutorial. It also included less traditional sessions such as the smartphone-based *treasure hunt* and a movie. However, this kind of events have been used widely already, and we have learned from them [10]. In our case we wanted to go a step further, and see how a game could add to effectiveness of the event, and in particular in its engagement and memorability. In this paper we focus on the treasure hunt, and the feedback it received from the participants.

The participants were not aware of the nature of the treasure hunt, or the Android app itself, before the event. They were only asked to bring along a compatible Android device (phone or tablet). The venue provided WiFi access to all the participants, at which point they were informed of the nature of the competition and were asked to install the app. During the launch of the app, the students were asked to enter their names and email, and were allowed to form single-person or two-person teams.

The treasure hunt questions were prepared in advance, and the competition was automatically set to start at a predefined time – with a countdown clock displayed on a large screen at the starting area (see Figure 3). At that point, the students were able to get the first question and start finding clues and answering the questions. The competition was programmed to last for one hour, after which the system automatically terminated the treasure hunt.

This particular competition was designed with 12 questions that included puzzles, observation tasks, and some programming tasks. For instance, we asked questions related to Scratch [15] programming language's *loop* and *conditional* mechanisms, which were presented in the talks before the Treasure Hunt (see Figure 4).

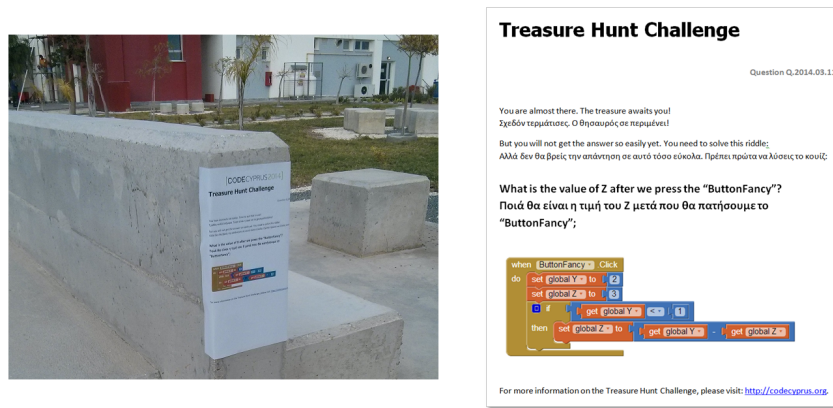


Figure 4. Sample clue which includes a Scratch-based puzzle.

4.1. Design Elements

The uttermost aim of the event was to engage high school students to take an interest in coding. In doing so, we focused on enjoyment and playfulness, as these have been identified as promoting factors [6]. In the following, we discuss how various *Game Elements* [8] have been dealt with in the design of the mobile app:

Immersive environment: We aimed at blending the real world with the digital. As such, the clues are partially in the app, but partially also in the real world. For example, once you follow the clue provided by the app, you might be asked to deal with a real-world challenge (see Figure 4). This proved to have various advantages: the players seemed to have more fun, while they would see how competing teams were fairing.

Feedback: Answering a question immediately provides feedback, notifying the player if they were successful or not. If the question is location-sensitive, then the feedback will include a hint if the player is not at the expected location.

Time pressure: Time is commonly a main aspect of many games. In the treasure hunt, time pressure was used to enhance the gamefulness of the competition, but also to make sure that everything stayed on schedule.

Scoreboards: Besides the typical, in-app scoreboards that are available in many games (including this), a public, big-screen scoreboard was also used (as shown in Figure 2). Besides score and ranking, the location of the teams was also displayed in realtime, visualizing the dynamics of the game, and further enhancing the game experience.

4.2. Experience Report

The evaluation event attracted 65 high school students, with the treasure hunt being one of the most successful features. After the completion of the event, we emailed the students and asked them to complete an online survey for feedback. Out of them, 17 students (i.e. 26%) submitted a feedback report, rating the event positively (65% rating it as good or excellent) and saying that they would recommend it to peers (54% answering that this is likely or very likely).

In addition to this, the students were asked to identify the feature that they liked the best in the event, and the majority of them selected the Treasure Hunt – 11 out of 17 (i.e. 65%).

Based on comments we received, but also on what we observed, we have identified some areas of improvement:

Practice stage: As students were not familiar with the use of the treasure hunt mobile app, they asked for a practice stage where they could familiarize themselves with the app. Having said that, our experience was that the vast majority of them was very quick at picking up how

the competition – and the mobile app – worked.

More mobile platforms: Because of time and resource limitations, we only developed an Android mobile app. However, many students did not own an Android phone or tablet. Even though most of them were able to get one from friends and family, it would be useful to develop at least a web app client so more platforms could be used. Even students with Android devices faced problems, particularly when the device was running an older version of Android (the mobile app requires Android version 4.0 and up).

Location accuracy: As some questions required that the users were at specific locations to submit an answer, having an accurate location service was important. We dependent on the built-in location service of Android, but our experience showed that different devices responded very differently to location sensing, both in terms of accuracy and speed. Also, as most of the treasure hunt took place indoors, getting a precise location reading was even more challenging.

Traceability of answers: The only information available to participants was the scoreboard (see Figure 2). Some students suggested that more information should be made available. For instance, after the termination of the competition, an automatic email could be sent to all the participants with a report on how they did (i.e. when each question was attempted, if the answer was correct, the gained marks – or penalty, etc.)

Treasure hunt length: As mentioned, we used 12 questions in the treasure hunt and allowed the teams one hour. It turns out that today's teenagers are indeed technology natives, and most of them were able to finish the treasure hunt in less than half hour, implying that more and harder questions should be used.

5. Conclusions

This paper describes an approach used for engaging and motivating high school students to take an interest in coding. At the core of this approach is a gamified Treasure Hunt, which is supported by a mobile client and a server platform. Various game elements were used in the design of the mobile app, making the treasure hunt more fun and game-like. The approach was evaluated both qualitatively and quantitatively. For the latter, a Treasure Hunt event was organized and students who participated to that rated the event positively, and said that they would recommend it to others as well.

For future work, we would like to further enhance this platform, possibly allowing teams to interact with each other via the application. Also, we would like to enable more mobile platforms via an HTML5 version of the app, as well as native apps for other popular platforms like iOS and Windows Phone devices. Lastly, we will aim to provide better location support via a custom-made indoors location system.

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References

1. Computer Science: Americas Untapped Opportunity (2014), <http://code.org/stats>
2. Computer Science Education Week (2014), <http://csedweek.org>
3. Europe Code Week (2014), <http://codeweek.eu>
4. The success story of the Cypriot startup Funifi, In: Digital Agenda for Europe - News, June 5, <http://ec.europa.eu/digital-agenda/en/news/success-story-cypriot-startup-funifi> (2014)

5. Tynker: Hour of Code, <http://www.tynker.com/hour-of-code> (2014)
6. Broer, J., Poeppelbuss, J.: Gamification - A New Phenomenon in Information Systems Research?, In: Proceedings of the 24th Australasian Conference on Information Systems Gamification, Melbourne, Australia (2013)
7. Christensen, J. H.: Using RESTful web-services and cloud computing to create next generation mobile applications, In: Proceedings of the 24th ACM SIGPLAN conference companion on Object oriented programming systems languages and applications, ACM, New York, NY, USA, 627-634 (2009)
8. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From Game Design Elements to Gamefulness: Defining "Gamification". In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments. ACM, New York, NY, USA, 9-15 (2011)
9. Gouws, L. A., Bradshaw, K., Wentworth, P.: Computational Thinking in Educational Activities: An Evaluation of the Educational Game Light-bot. In: Proceedings of the 18th ACM conference on Innovation and technology in computer science education. ACM, New York, NY, USA, 10-15 (2013)
10. Guo, P.: Hour of Code: Observations from a Middle School Classroom <http://cacm.acm.org/blogs/blog-cacm/170430-hour-of-code-observations-from-a-middle-school-classroom> (2014)
11. Kapp, K. M.: The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education, Pfeiffer, 1 edition (2012)
12. Lindqvist, J., Cranshaw, J., Wiese, J., Hong, J., Zimmerman, J.: I'm the Mayor of My House: Examining Why People Use Foursquare - a Social-driven Location Sharing Application, In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Vancouver, BC, Canada, 2409-2418 (2011)
13. Mitchell, N., Danino, N., May, L.: Motivation and Manipulation: A Gamification Approach to Influencing Undergraduate Attitudes in Computing, In: Proceedings of the 7th European Conference on Games Based Learning, Porto, Portugal, 394-400 (2013)
14. Mitchell, N., Danino, N., May, L.: The 4 Week Challenge: a Case Study, In: Proceedings of the 5th International Conference of Education, Research and Innovation, Madrid, Spain (2012)
15. Resnick, M., Maloney, J., Monroy-Hernandez, A., Rusk, N., Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J., Silverman, B., Kafai, Y.: Scratch: Programming for All, Communications of the ACM, Vol. 52, No. 11, 60-67 (2009)
16. Richtel, M.: Technology Changing How Students Learn, Teachers Say, In: The New York Times <http://www.nytimes.com/2012/11/01/education/technology-is-changing-how-students-learn-teachers-say.html> (2012)
17. Romero, M., Usart, M., Ott, M., Earp, J., de Freitas, S., Arnab, S.: Learning Through Playing For or Against Each Other? Promoting Collaborative Learning in Digital Game Based Learning, In: Proceedings of the 20th European Conference on Information Systems, Barcelona (2012)
18. Wingfield, N.: Flappy Bird Soars, Then Disappears, Along With a Weekend, In: The New York Times, February 9 <http://bits.blogs.nytimes.com/2014/02/09/flappy-bird-soars-then-disappears-along-with-a-weekend> (2014)
19. Wolber, D.: App inventor and real-world motivation, In: Proceedings of the 42nd ACM technical symposium on Computer science education, ACM, New York, NY, USA, 601-606 (2011)
20. Wortham, J.: Angry Birds, Flocking to Cellphones Everywhere, In: The New York Times, December 11 <http://www.nytimes.com/2010/12/12/technology/12birds.html> (2010)

Towards Sensing Information Systems

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Abstract

Recent advances in the field of pervasive computing, including the approaches and technologies related to Wireless Sensor Networks (WSN), Internet of Things (IoT) and Cyber Physical Systems (CPS) are changing the way we perceive computing capability. Although the scientific communities have already started to discuss about the visionary concepts that will exploit these advances, such as Sensing and Liquid Enterprise, the truly smart and interoperable CPS networks are still confined to the 'valley of death' - between prototyping and mass-production. In this position paper, we propose the concept of Sensing Information System, a novel paradigm that will facilitate the transformation of CPS to Cyber Physical Ecosystems - borderless technical environments in which the devices will become capable to sense, perceive, decide and act, based on the external, common behavioural and context models. A case study is used to demonstrating the use of Sensing Information Systems for extended clinical workflows.

Keywords: Information Systems, Sensing Enterprise, Internet of Things, Future Internet, Cyber Physical Ecosystems.

1. Introduction

In today's dynamic and volatile global environment, businesses need to acquire agility in order to cope with, promptly adapt to, and ideally thrive on changes. The Sensing Enterprise (SE) concept and properties, supported by the paradigms of the Internet of Things (IoT) [2], Cyber-Physical Systems [9] and Future Internet Enterprise Systems [3], have the potential to become essential enablers towards an agile business, displaying awareness, perceptivity, intelligence and extroversion.

This transformation is expected to create new opportunities for the dynamic management of the inherently complex environments in which highly diverse enterprises connect and collaborate in typically short-lived supply chains for very specific purposes - for example, for *promptly* delivering a low number of highly customized products and services.

The SE concept will exhibit universal, on-demand interoperability of enterprises, achieved with a minimum needed commitment to change and adapted to the collaboration conditions. Naturally, the enterprise's (information and other) systems must facilitate, support and importantly, also participate and thus reflect this transformation.

In this paper, we propose the concept of 'Sensing' Information System (SIS) as a main interface of the SE to its environment. The paper presents the conceptual overview of the key requirements for SIS while taking into account new circumstances in which IS operation takes

place and its key capabilities for the awareness property. The SIS should be capable of seamlessly sense and perceive various stimuli, make autonomous and purposeful decisions and finally, act upon these decisions as appropriate. Actually, this anthropomorphic consideration of the future SISs implies that they will become inherently generic; thus, the capability of the envisaged Sensing ISs to process data for a specific purpose will be defined by the internally and / or externally located behavioural and functional models and the models of the internal and / or external contexts in which they process this data.

2. The Sensing Enterprise

As the economy and society are becoming increasingly networked and digital, there seems to be a need to redefine the notion of enterprise, especially as new social and technology tools are provided by recent advances in new research paradigms, such as the above-mentioned IoT, CPS, Future Internet Enterprise Systems and others. Such paradigms facilitate the pervasiveness of the enterprise, blurring its traditional boundaries to the point where internal and external stimuli (coming from within and outside of the enterprise) cannot be readily distinguished. As pervasiveness implies a federation of processing capabilities and knowledge resources, the new paradigms will also make collective intelligence more accessible and coordinated.

In an attempt to reconsider the notion of the enterprise, the FInES cluster [4] has identified several so-called ‘Qualities of Being’ as necessary properties of the future enterprise. They were: humanistic, community-oriented, cognizant, people-centred, inventive, agile, environmentally aware, and ‘glocal’ (with local and global perspective) [ibid.]. An enterprise displaying the above properties would become a so-called Sensing Enterprise (SE).

The SE is also described as “an enterprise anticipating future decisions by using multi-dimensional information captured through physical and virtual objects and providing added value information to enhance its global context awareness” [9]. In fact, it is not characterized only by awareness (as the term implies), but also by decentralized or ultimately, even collective intelligence. This does not only concern collaboration in decision making, but also purposefulness evaluated in its environment. Therefore, an SE is in fact a social enterprise, sometimes also described as ‘liquid’ to suggest its pervasiveness.

The ‘liquid’ character of the SE is supported by the anticipation that sensors will become a commodity in the future [13]; thus, the ownership of an enterprise on the sensors will not necessarily restrict other organizations to provide value-added services, based on observations of these sensors. Santucci et al. point out that “the Sensing Enterprise will be a sort of radar in perfect osmosis with an ecosystem of ‘objects’ supported by several private area networks and delivering in real time a wealth of unstructured data, not only more data but also new data” [ibid.].

2.1. Cyber-Physical Systems

In terms of technical architecture, the SE is considered as a system-of-Cyber Physical Systems (CPS), where these CPSs do not necessarily operate within the boundaries of the enterprise, nor even in its domain of interest or operation. Conversely, an SE may encompass the CPSs owned and governed by the other enterprises.

Cyber Physical Systems are autonomous, functional systems in which the collaborating computational elements are controlling the physical devices, by exploiting data gathered from the different sensors and other devices, which operate in the environment of these elements [9]. CPS research is a highly interdisciplinary area which combines knowledge and expertise in the fields of embedded systems, robotics, Wireless Sensor Networks (WSN), integration and interoperability, Knowledge Management and many others.

CPS are today considered as one of the key technological pillars for addressing many different societal challenges in the fields of urban infrastructure (e.g. smart cities), energy (smart grids), healthcare (smart hospitals), transportation (smart roads), etc.. It brings together automation and intelligent decision making for the benefit of improved safety, quality of life,

security, efficiency and productivity. Since late 2006, US National Science Foundation (NSF) has pushed CPS as a key research topic [15]; in 2014, through the Horizon 2020 program, the European Commission (EC), invests more than 600 MEUR¹ in the research related to Smart CPSs and new Information and Communication Technology (ICT) platforms for their development and implementation. The main goal is to improve Europe's innovation capacity in order to evolve today's embedded systems to more autonomous, more intelligent, pervasive and generic CPSs.

The pervasiveness and technical diversity of a CPS makes its high complexity inherent. For this reason, CPSs are usually specialized by design to individual application fields. Currently however, incoherent design and lack of unifying models typically prevent different, albeit functionally or geographically intersecting CPS to interoperate, and thus, to collaborate.

3. Sensing Information Systems

Sensing Information Systems can be considered the interfaces of the SEs towards their environment. They are deployed in the devices which form the CPSs, implement their processing capabilities and must be intrinsically interoperable, in order to enable the collective intelligence purported by the SE concept (see Fig. 1).

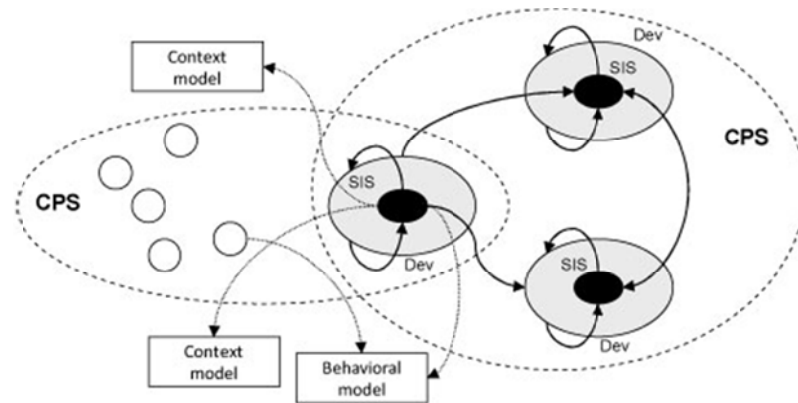


Fig. 1. Illustration of the SIS-driven Cyber Physical Ecosystems

Therefore, the design and architecture of the traditional information systems must be evolved in order to address the new requirements arising from the need to achieve pervasiveness, portability and context-awareness. We identify these new requirements as autonomy, portability and awareness, as argued below.

With the introduction of new computing elements (e.g. devices) that represent the core units of the future SEs, the traditional concept of IS deployment will need to take into consideration new and typically ubiquitous platforms. Hence, one of the most important challenges relating to the pervasiveness of SIS will be their autonomy, especially in terms of reliability and maintenance issues. These new computing elements will be deployed on a variety of hardware platforms, matching a variety of purposes. The key consequence of such new circumstances is the emerging need to achieve a seamless portability of the future SIS. This leads us to anticipate that the functional requirements of one future system will not be intrinsically embedded in its design. Instead, what was earlier considered as business logic tier of the conventional ISs will now be based on the deployment and use of common and shared behavioural models, accessible on IoT. Finally, all these elements operate in varying conditions and environments. Hence, an SIS needs to have capabilities to:

- Sense the physical environment of its device and other devices in its environment;
- Interact with the physical environment of its device and other devices by using its (their) actuation capabilities; and
- Exchange data, information and knowledge with SISs of other devices in its environment.

¹ Call H2020-ICT-2014-1, Topic: Smart Cyber-Physical Systems.

The above capabilities depend on the context models that will facilitate the context-awareness. Formal modelling of the contexts in which one system (or the device) operates will consider its surrounding environment, including technical, social, spatial aspects and interfaces of the systems and people with which it interacts. As these formal models are developed and stored externally, the SIS must also implement the reasoning strategies and techniques (e.g. based on Web Ontology Language (OWL/DL) reasoning), which will enable it to automatically infer the context in which it operates.

3.1. Sensing Information Systems Capabilities

In order to access, combine, use and act upon the extensive, multi-dimensional and multi-modal data (now at the disposal of a liquid enterprise), SISs needs to achieve and maintain capabilities to seamlessly sense this data, perceive its meaning, make decisions and articulate a response - whether this articulation refers to acting (actuating), requesting the additional data, transferring an information to another enterprise, etc.. The stimulus for this cycle may originate from within, or outside the SIS and within, or outside its domain of interest.

The cycle above can be explained in terms of semantic interoperation of two systems. In order to illustrate this cycle, we extend Sowa's [14] formal definition of semantic interoperability of systems; thus, a system S is semantically interoperable with system R , if and only if the following condition holds for any stimulus p that is articulated by S and sensed by R : For every statement q that is implied by p in the system S , there is a perception of p , namely q' , in the enterprise R that: (1) is implied by p in the system R , and (2) is logically equivalent to q (see Fig. 2). This definition is represented in controlled natural language below:

$$\begin{aligned} & \text{system}(S) \wedge \text{system}(R) \wedge \text{semanticallyinteroperable}(S,R) \Rightarrow \\ & \forall p (\\ & \quad \text{stimulus}(p) \wedge \text{articulated-by}(p,S) \wedge \text{sensed-by}(p,R) \wedge \\ & \quad \forall q(\text{statement-of}(q,S) \wedge p \Rightarrow q) \\ & \quad \exists q'(\text{perceived-by}(q',R) \wedge p \Rightarrow q' \wedge q' \Leftrightarrow q) \\ &) \end{aligned}$$

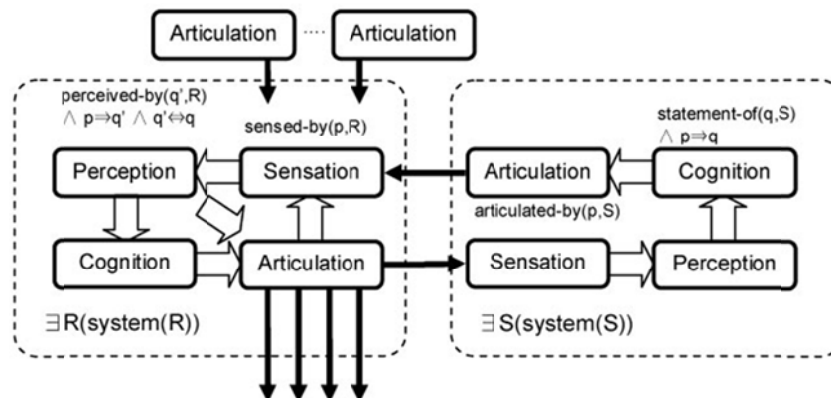


Fig. 2. Semantically interoperable Sensing Information Systems

Based on the assumptions above, we identify awareness, perceptivity, intelligence and extroversion as the key capabilities of the SIS [11, 17].

Although the core concept of SIS does not distinguish between the internal and external stimuli, there is a need to separately consider the self-awareness and environmental awareness of a SE. While the latter is crucial for exploiting the pervasiveness of the SE's SIS, the former is relevant for maintaining SE's multiple identities (e.g. towards suppliers' and customers' systems, but also on web or a social network), as it is suggested by the SE paradigm.

The pervasiveness of an SE extends the conventional domains of interest of an enterprise (e.g. typical channels for detecting new business opportunities). Hence, now one has to consider

not only the functional environmental awareness of an SIS, but also a *universal* awareness concerning observations of any stimuli, even from unknown and unanticipated sources. When arbitrary stimuli are taken into account, it becomes important for the SIS to achieve the capability to perceive any stimulus - be it multi-modal, multi-dimensional, discrete or continuous. Perceptivity is a capability of a SIS to assign a meaning to the observation from its environment or from within itself. Then, based on the perception, the SIS should be able to decide on the consequent action. This decision is a result of a cognitive process, which consists of identification, analysis and synthesis of the possible actions to perform in response to the “understood” observation. The intelligence also encompasses assertion, storing and acquisition of the behaviour patterns, based on the post-agreements on the purposefulness of the performed actions (much like a knowledge-based system).

The last desired attribute of a SIS, extroversion, is related to its willingness and capability to articulate the above action/s and demonstrates the SE’s business motivation and/or a concern about its physical and social environment.

4. Scenario: Pervasive Personalized Healthcare Supply Chains

This section examines the potential benefits related to the application of SIS and related concepts to the field of personalized healthcare supply chains. More specifically, we refer to an ‘extended clinical workflow’ for cases where patient handling assumes the use of a custom medical product that needs to be designed, manufactured and installed (possibly by surgery) in a period of time comparable to the case of a standard medical product. A representative case of this scenario is custom orthopaedic implant design and manufacturing, often needed to address the possible risks of complications arising from geometrical differences between the specific patient bone anatomy and the limited standard implant sizes available.

The proposed patient-centric, extended clinical workflow [16] illustrated in Fig. 3 encompasses all activities of the clinical centre and other actors involved, from patient registration to transfer to other department/s or discharge.

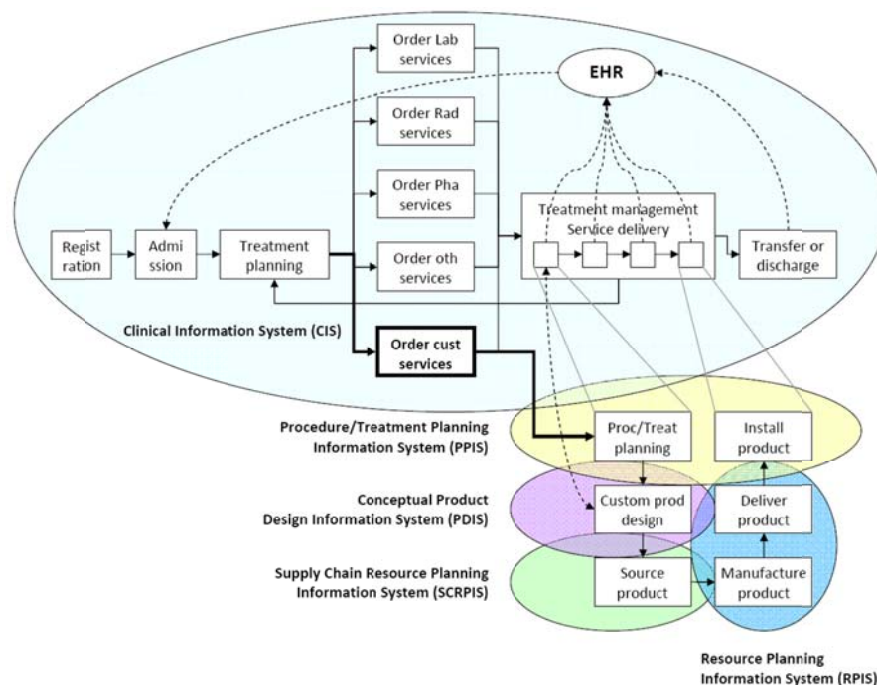


Fig. 3. Simplified representation of the extended clinical workflow

The extended clinical workflow integrates the conventional clinical workflow (represented at the top of Fig. 3 in a large ellipse), with the activities of the different actors, within or outside of Clinical Centre limits, involved in procedure and treatment planning, product design, sourcing, manufacturing and installation.

It is proposed that these activities are to be facilitated by corresponding ISs as illustrated in Fig. 3, with data converging to a patient Electronic Health Record (EHR), defined as the “[...] longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting” [7].

Workflow execution is typically based on the number of interoperations of the ISs, carried out in context of the previous agreements and respective commitments made by the relevant actors; however, the emerging pervasive computing approach is expected to minimize or remove the need to make such agreements. Device-centred collaboration, in contrast to system-centred interoperability, does however require the implementation of the required awareness, intelligence and actuation capabilities into autonomous, context-aware, collaborative and intelligent SIS. Importantly, this implies the reconsideration of the architecture of traditional healthcare IS design and collaboration [10].

4.1. SIS for Ubiquitous Healthcare

The concept of ubiquitous (or pervasive) healthcare [1, 12] supported by infrastructures relying on sensor networks and pervasive internet connectivity has emerged in recent years, creating significant opportunities for implementing the proposed SIS paradigm in practice.

Medical sensors combine transducers for spatial-temporal detection of electrical, thermal, optical, chemical, genetic and other signals with physiological origin with signal processing algorithms to estimate features indicative of a person’s health status [8], e.g. pulse oximetry, respiration rate, temperature, heart rate, blood pressure, etc. The sensors also collect environment and logistics data (e.g. patients’ locations, equipment locations) needed not only for detection, diagnosis and treatment of medical symptoms, but also for the management of the clinical workflow in which these activities occur. Namely, besides the vital signs information, other typical factors in the response to a potential clinical emergency are the patient’s EHR and assignment of the respondent (doctor), based on physical location information [12]. Location and proximity sensing technologies can have significant effect in improving the workflow efficiency in hospitals [5]; for example, sensor networks can be used for automatic triage of patients for providing emergency care in large scale disasters, including tracking the health status of the first respondents [6].

Smart health monitoring devices, powered by the future SISs, should be able to actively participate in the clinical workflows by:

- sensing the changes in physiological parameters of the patients;
- perceiving the meaning of these changes, based on context models fed by data from the EHR of the individual patient and environmental sensors, and
- acting upon these perceptions, e.g. by automatically ordering laboratory, radiology or pharmaceutical services.

This approach would also facilitate reducing the complexity of traditional Clinical IS (CIS), by decomposing it into autonomous units forming the Cyber Physical System of the clinical centre. Such an approach would in addition increase the reliability of CIS by enabling redundancy. Namely, future SIS will be capable to use the behavioural models of other SISs on demand (for example, in case of urgency and failure of the responsible component).

The essential roles of the SIS concept are foreseen in the above-mentioned case of custom orthopaedic implant installation. These roles could be realized in the different phases of the extended workflow, with potential scenarios as indicated below.

The extended clinical workflow paradigm suggests that the successful treatment of some medical disorders could significantly expand the range of actors (and their supporting ISs) displaying the capabilities required to heal the patient. For example, in case of the orthopaedic implants, this may include advanced Computer Aided Design (CAD), Finite Element Analysis (FEA), rapid prototyping and manufacturing. As such capabilities cannot typically be found in a Clinical Centre, there will be a need to research the market, reach the most suitable enterprises and then establish and maintain seamless interoperability between their respective systems. The projected SIS capability to sense digital stimuli (e.g. from social networks or supply network platforms) is envisaged to facilitate this extension. The self-

awareness property will enable SIS to create multiple (agent-alike) identities that will be capable to actively pursue the sensed collaboration opportunities, even by engaging into negotiation processes with other systems, driven by motivations expressed in context models. In the extended clinical workflow (see Fig.3), this role is given to SCRPIIS, which need to be enable to sense the collaboration prospect, including the corresponding RPIS, query the relevant information (e.g. availability, cost, etc.) from RPIS of the new or registered partners and potential actors of the specific workflow's instance.

The CPS and corresponding SIS infrastructure of the Clinical Centre could be also used for the benefit of the partners, involved in the engineering of the implant. For example, the design team could continuously monitor the status of the patient's bone, through the access to a smart immobilization device, and hence become capable to adapt the design decisions to the current circumstances. This approach could be extended to pre-hospital care, where first aid could install a smart traction splint, able to communicate via public wireless connectivity infrastructure. In this case, the smart immobilization device hosts a SIS which interacts with CIS (see Fig.3) which eventually delivers the relevant information to CAD systems of the designers, through the interoperability infrastructure.

The role of SIS in the exploitation phase, namely outside the extended clinical workflow, is also foreseen. The future SIS-embedded smart implants will be capable not only to sense e.g. the stresses occurring at the bone-implant joints and dislocations of the reference points, but also to perceive and interpret critical changes based on the context information, articulate this observation in messages and distribute it to its environment. Then, this information can be used for the improved design, better selection of materials, etc.

It is obvious that the concept of SIS will contribute to increasing collaboration in the extended clinical workflow, through reducing the amount of needed pre-agreements for the relevant systems' interoperations. The Clinical Centre demonstrating the above described capabilities, realized by their SIS, would become a truly sensing and liquid enterprise, with the technical infrastructure deployed through the different CPSs that can easily merge and combine with other CPSs, forming a Cyber Physical Ecosystem for personalized healthcare.

5. Conclusions

The rapid advance of CPS technologies and continuous miniaturization and commoditization of the relevant devices are strengthening the hopes and expectations of a next industrial revolution that will be capable to solve a wide range of societal challenges. In the emerging environment providing new avenues for IS deployment, the IS community needs to consider novel design and lifecycle requirements. In this position paper, we argue that the future SIS will need to display the properties of *awareness* (being able to sense the external or internal, multi-modal, multi-dimensional, continuous or discrete stimuli), *perceptivity* (being able to understand this stimuli, including the context in which this understanding occurs), *intelligence* (being able to decide on the perceptions by using internal or external behavioural models) and *extroversion* (being able to communicate with its environment).

One of the main arguments behind this proposition is related to addressing the various complexity issues arising from the new environment in which the future SISs will operate. It is proposed that SISs' complexity can be reduced by extracting and abstracting their behavioural and context descriptions and enabling their use and reuse as common, shared models. Such an approach will contribute to the need to define unifying standards and as such it will support the de-solidification of the systems themselves. Reducing the complexity of the systems will facilitate emerging efforts to develop more generic and hence, more portable system architectures.

Future research will seek to further develop the proposed concepts so as to enable the transformation of the CPS to 'smart environments', blurring the boundaries of CPSs and thus enabling an evolution towards Cyber Physical *Ecosystems*. This new paradigm will also facilitate the desired transformation of the traditional enterprises into a sensing, 'liquid' form.

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References

1. Arnrich, B., et al.: Pervasive Healthcare – Paving the Way for a Pervasive, User-Centered and Preventive Healthcare Model. *Methods Inf Med.* 49(1): pp. 67-73 (2010)
2. Ashton, K.: That 'Internet of Things' Thing, in the real world things matter more than ideas. *RFID*, <http://www.rfidjournal.com/articles/view?4986>, (2009)
3. FInES:Future INternet Enterprise Systems - Research Roadmap 2025 (2012) http://cordis.europa.eu/fp7/ict/enet/documents/fines-researchroadmap-v30_en.pdf [Accessed July 10 2014].
4. FInES Cluster: Position Paper on Orientations for FP8: A European Innovation Partnership for Catalysing the Competitiveness of European Enterprises (2011) <http://cordis.europa.eu/fp7/ict/enet/documents/fines-position-paper-fp8-orientations-final.pdf> [Accessed July 20 2014].
5. Fry, E.A.Lenert, L.A.: MASCAL: RFID tracking of patients, staff and equipment to enhance hospital response to mass casualty events. *AMIA Annual Symposium Proceedings Archive*. Vol. 2005: pp. 261-265 (2005)
6. Gao, T., et al.: Wireless medical sensor networks in emergency response: Implementation and pilot results. *Proceedings of IEEE Conference on Technologies for Homeland Security*. 187-192 (2008)
7. Health Information Management Systems Society:HIMSS History (2013) http://www.himss.org/content/files/HIMSS_HISTORY.pdf [Accessed 2013].
8. Ko, J., et al.: Wireless sensor networks for healthcare. *Proceedings of the IEEE*. 98(11) (2010)
9. Lee, E.: *Cyber Physical Systems: Design Challenges*. Technical Report No. UCB/EECS-2008-8, University of California, Berkeley (2008).
10. Noran, O.Panetto, H.: *Modelling a Sustainable Cooperative Healthcare: An Interoperability-driven Approach Lecture Notes in Computer Science*. 8186: pp. 238-249 (2013)
11. Noran, O.Zdravković, M.: Interoperability as a Property: Enabling an Agile Disaster Management Approach, In: *4th International Conference on Information Society and Technology (ICIST 2014)*: Kopaonik, Serbia (2014).
12. Rastegari, E., Rahmani, A., Setayeshi, S.: *Pervasive computing in healthcare systems*. World Academy of Science, Engineering and Technology. 2011(59) (2011)
13. Santucci, G., Martinez, C., Vlad-Câlcic, D.:*The Sensing Enterprise* (2012) <http://www.theinternetofthings.eu/sites/default/files/%5Buser-name%5D/Sensing-enterprise.pdf> 2014 [Accessed Jun 30 2014].
14. Sowa, J.: *Knowledge Representation: Logical, Philosophical, and Computational Foundations*. CA: Brooks/Cole Publishing Co. (2000)
15. Wolf, W.: The Good News and the Bad News (Embedded Computing Column). *IEEE Computer*. 40(11): pp. 104-105 (2007)
16. Zdravković, M.Trajanović, M.: On the extended clinical workflows for personalized healthcare. *International IFIP Working Conference On Enterprise Interoperability (IWEI 2013)*, LNBIP 144: pp. 65-76 (2013)
17. Zdravković, M., Trajanović, M., Panetto, H.: Enabling Interoperability as a Property of Ubiquitous Systems: Towards the Theory of Interoperability-of-Everything, In: *4th International Conference on Information Society and Technology (ICIST 2014)*: Kopaonik, Serbia (2014).

Using Knowledge-based Information Systems to Support Management of Wireless Sensor Networking Systems

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Abstract

Currently, researches on Wireless Sensor Networks (WSN) mainly focus on how to efficiently gather sensing data from WSN, but little attention has been paid to how to effectively manage the large amount of collected sensing data. Information Systems (IS) are appropriate tools for data input, storage, processing, and output. Knowledge Management (KM) further transforms useful information into domain knowledge for decision making by domain experts. In this paper, we propose an approach to management of sensing data and transformation of sensing data into valuable knowledge using knowledge-based information systems. Firstly we propose a framework for knowledge-based information systems which deals with internal and external information using intelligent agents to generate domain knowledge with KM methods. Then we definite a model of knowledge-based information system for WSN to implement intensive sensing data storage, knowledge discovery, statistical analysis, sharing, inquiry, decision support. Finally, a prototype system is developed and tested for the aforementioned ideas.

Keywords: WSN, Information System, Knowledge Management, Intelligent Agent

1. Introduction

A wireless sensor network (WSN) is an autonomous network system that is usually laid in an unattended area, and can complete monitoring tasks. It is composed of a large number of tiny sensor nodes to monitor physical and/or environmental conditions, such as temperature, sound, and pressure. Wireless sensor node is low-powered device equipped with a processor, a memory, a power supply, a transceiver, and one or more sensors, in some cases, with an actuator. A WSN, as an IT hotspot technology, has a significant impact on human being lifestyles in the 21st century, following the Internet technology [8]. Wireless sensor networks link the virtual world of information with the objective physical world, and change the interactive way between humans and environment. WSN has very broad application prospects. It can be widely used in military, environmental monitoring, health care, traffic management and commercial applications and other fields [4].

With applications of WSN in various fields, enormous sensing data are generated constantly. Consequently, many issues occur, for example, how to share effectively the huge sensing data, how to maintain so many WSNs working normally, and how to find out useful information for decision making.

The "Global Sensor Networks (GSN)" project [1] comes true to share sensor data in wide range with middleware technologies. And it offers virtual sensors to integrate sensor network

data through plain SQL queries over local and remote sensor data sources. The GSN mainly focus on integration and sharing of heterogeneous and very large scale sensor data, while WSN is only a kind of tools for gathering sensor data in the GSN project. The literature [5] proposed middleware architecture which is Service Oriented (SOA) for normal node and gateway node in WSN. The knowledge management (KM) and ontology are used to monitor and take decisions. It focuses on how to design the middleware architectural and the communication protocol between components at the node level.

Information system (IS) is used to enhance business processes through information technologies. IS usually involves a number of processing steps including analysis, design and implementation of IT systems and applications to support business functions [10]. A knowledge management system (KMS) is an information technology (IT) based system, which is developed to support and enhance the processes of knowledge creation, storage, retrieval, transfer, and application [9]. KMS can help an organization's management strategy to become more competitive in a rapidly changing environment [6].

In order to effectively manage a large amount of sensing data of WSN, we propose a knowledge-based information system for WSN (KIS4WSN) which is composed of three components: Wireless Sensor Networks (WSN), Knowledge Management (KM), and Information System (IS), see Fig. 1. Meanwhile, we can use the intelligent agent technology to gather sensing data, provide services for different users in KIS4WSN.



Fig. 1. The KIS4WSN system uses WSN to collect data, IS to store and manage data, and KM to extract and analyze data, and yield controls on WSN

The remainder of this paper is organized as follows. Section 2 describes how to design architecture of a knowledge-based information system for WSN that could support the management of a WSN, as well as supporting knowledge, experience and decision-making. Section 3 introduces the key information processes and technologies for system implementation. Section 4 shows a prototype system and a brief evaluation. And section 5 concludes overall paper and lists future work.

2. Methods

In order to develop the KIM4WSN, we consider a working framework consisting of topologic structure of a WSN, a set of functions built on the WSN, and a collection of implementation methods applied to the functions (operations). In this section we introduce a conceptual model for the basic concepts of wireless sensor network structure in a formal representation, relations among the WSN states, functions, and implementation methods. We also propose a structural system to indicate various working components used to realize the model.

2.1. Concepts

Definition 1 (WSN) A WSN is a directed graph with a time dimension, denoted as

$$N = \{V, E, t\} \quad (1)$$

where $V = \{v_1, v_2, \dots, v_n\}$ represents the set of nodes, $E = \{(v_i, v_j) \mid v_i, v_j \in V\}$ represents the set of edges, and t is a time at which the network has a state S , which will be defined later. We assume that the WSN N can change its state from time t_1 to time t_2 .

Definition 2 (**Connected Network**) Suppose that N is a WSN. N is **connected** for any two nodes v_1 and v_2 ($v_1, v_2 \in V$) in N , if there is at least one reachable path. If there are k paths, N is called **k-connected**.

Definitions 3 (**Sub-WSN**) Suppose that $N_s = \{V_s, E_s, t\}$ and $N = \{V, E, t\}$ are two WSN's. N_s is defined to be a sub-WSN of N if $V_s \subseteq V$ and $E_s \subseteq E$ at time t . Let $N_i = \{V_i, E_i, t\}$ and $N_j = \{V_j, E_j, t\}$ are two sub-WSN's. N_i and N_j are defined to be **independent** from each other (independent sub-WSN's) if $V_i \cap V_j = \phi$, and for any $v_1 \in V_i$ and $v_2 \in V_j$, there exists no edge (v_1, v_2) .

Definition 4 (**Functions**) $F = \{F_1, F_2, \dots, F_n\}$ is a set of functions defined on the WSN N , where, F_i is a kind of operations applied to various components, including nodes, edges, and sub-network, and the whole network, of N . Usually, there are three categories of operations i.e. the operations for the nodes (e.g. node positioning and storage management), the operations for the edges (e.g. status monitoring and coverage control), and the operations for the parts (sub-network) or the whole network (e.g. network routing, data fusion, time synchronization, network security, and topology control).

To develop a conceptual model for the WSN4KIS, we propose an important concept here, which is the state of a WSN N . A state of a WSN N is associated to the time dimension t , as we define in Definition 1 (WSN). The basic concept for the state of a network is whether a node, an edge, or a part of N is occurring in the network N . The node state includes the node physical state and node network state. The node physical states are composed of the node physical characteristics, e.g., the radius of the communication, the residual energy, storage capacity, processing capacity, position coordinates, and so on. In this paper, the node network state indicates whether a node is capable to communicate with other nodes.

Definition 5 (**Network State**) A set of the nodes state and edges state at a moment for a network,

$$S_t(N) = \{S_t(V), S_t(E)\} \quad (2)$$

where $S_t(V)$ indicates the status of nodes in the network at time t , $S_t(E)$ represents the status of edges in the network at time t .

The node state includes the node physical state and node network state. The node physical states are composed of the node physical characteristics, e.g., the radius of the communication, the residual energy, storage capacity, processing capacity, position coordinates, and so on. In this paper, the node network state indicates whether a node is capable to communicate with other nodes.

The state of node v_i can be expressed as follows (at the time t).

$$S_t(v_i) = \begin{cases} 0 & \text{node disable} \\ 1 & \text{node normal} \end{cases} \quad (3)$$

The state of edge is that there is available communication between two nodes when the nodes are normal. The edge state from node v_i to node v_j at moment t can be expressed as:

$$S_t(e_{ij}) = S_t(v_i \rightarrow v_j) = \begin{cases} 0 & \text{not communicating} \\ 1 & \text{is communicating} \end{cases} \quad (4)$$

Definition 6 (Function Implementation): a set of the different implementation methods for a function F_i .

$$I_i = \{I_{i1}, I_{i2}, \dots, I_{im}\} \quad (5)$$

where I_{ij} ($1 \leq j \leq m$) represents the j th implementation method of m different methods for a function F_i .

In general, a function in WSN can be implemented in many methods. For example, network routing which is an important function in WSN can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure [2]. There are many implementation methods for three above mentioned three kinds respectively. More details please read the conference [2].

2.2. Relations of Networks, Functions and Implementations

For different application scenarios (e.g., wildlife monitoring, military detection, health monitoring, medical monitoring, traffic monitoring, etc.), the WSN needs different network model. The structure, setting, information processing mode, real-time, security requirements of WSN are different, so there are different functions need to deal with the particular application networks. Meanwhile the implementation of a function is different in different kind WSN application.

For the convenience of dealing with complex application requirements, we construct three sets to store all kinds of WSNs, all functions, and all implementations. They are called the set of network of WSN (N), the set of function (F), and the set of implementation (I).

A WSN N_i ($N_i \in N$) maybe include several functions F_1, F_2, \dots, F_m ($F_i \in F$ ($i=1,2,\dots,m$)), while a function F_i must be implemented using several different methods or algorithms $I_{i1}, I_{i2}, \dots, I_{in}$ ($I_{ij} \in I$ ($j=1,2,\dots,n$)). So it exists a map between the WSN set N and the function set F, and another map between the function set F and the implementation set I. The relations of N, F and I is shown in Fig. 2.

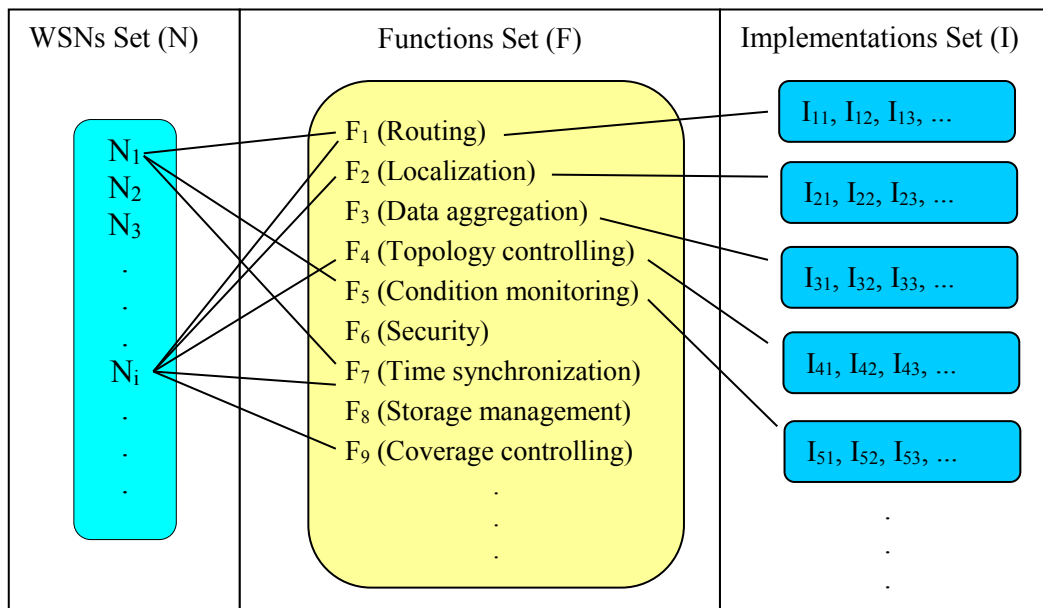


Fig. 2. Relations of WSNs, functions and implementations

2.3. An Example of Function: Routing

The following brief description of an example shows the network routing conception and one of the basic implementation methods.

A routing is the process of forwarding a packet of data from a source node to a destination node. Routing algorithm can be briefly described as follows:

Algorithm Routing

- 1: Input N, v_s, v_d //network, source node, and destination node
- 2: Find the path set $P = \{p_1, p_2, \dots, p_n\}$ from the node v_s to node v_d ;
- 3: Select the optimal path p from set P ;
- 4: Output p ;

There are a lot of implementation algorithms as described above for network routing. The classic algorithm is gradient-based routing, for example, sensing data between the network nodes forwarding process follows the algorithm shown below [7].

Algorithm basic-gradient-routing // Forwarding process

Message forwarding on node n :

- 1: Reception of packet p
- 2: **if** ($p.depth > n.depth$) **&&** ($p.seq \notin n.seqlist$) **then**
- 3: **if** ($n \neq sink$) **then**
- 4: $p.depth = n.depth$;
- 5: $n.seqlist \leftarrow p.seq$;
- 6: broadcast packet p ;
- 7: **else**
- 8: Process packet p ;
- 9: **end if**
- 10: **else**
- 11: Drop p
- 12: **end if**

2.4. System Architecture

We propose the architecture of KIS4WSN which is shown in Fig. 3. It includes five layers, i.e. user request analysis layer, interaction layer, knowledge management layer, information processing layer and data handling layer.

User request analysis describes user requests for a variety of applications of WSN. Such as, real-time monitoring, web browsing sensing data, information query, statistical analysis, data mining, trend analysis, decision support, and so on.

Interaction is the information exchanging or service interface between the KIS4WSN and the users, is carried out by interface service agents. The interface service agents response user's requests, analyze the requests, and patch related function agents to execute the tasks, then collect the results from function agents, and finally return the results to the users.

Knowledge management is a result of processes including synthesis, filtration, comparison and analysis of available information by the domain experts. In KIS4WSN, knowledge management includes acquisition and storage of knowledge, creation and representation of knowledge, discovery and application of knowledge, inference and sharing of knowledge. It is supported by domain knowledge, empirical knowledge and domain experts.

Information processing is the process of raw data into meaningful information. In our information system, information processing includes two parts. The first part is the information processing for current wireless sensor networks, and the other part is information processing for historical sensing data. For current WSNs, there are many corresponding functions of network operation, such as, network routing, node positioning, data fusion, time synchronization, security control, topology control, condition monitoring, information collection, storage management, coverage control, data forwarding, data query, statistics and analysis, and so on. For historical sensing data, there are information index, data sorting, trend analysis, data statistics, abnormality detection, data selection and filtering, etc.

Data handling stores and provides all kinds of raw data, information, algorithms and knowledge. It includes sensing data, network information, operating functions, implementation algorithm, meta-knowledge, conceptual knowledge, content knowledge, reasoning rules, etc.

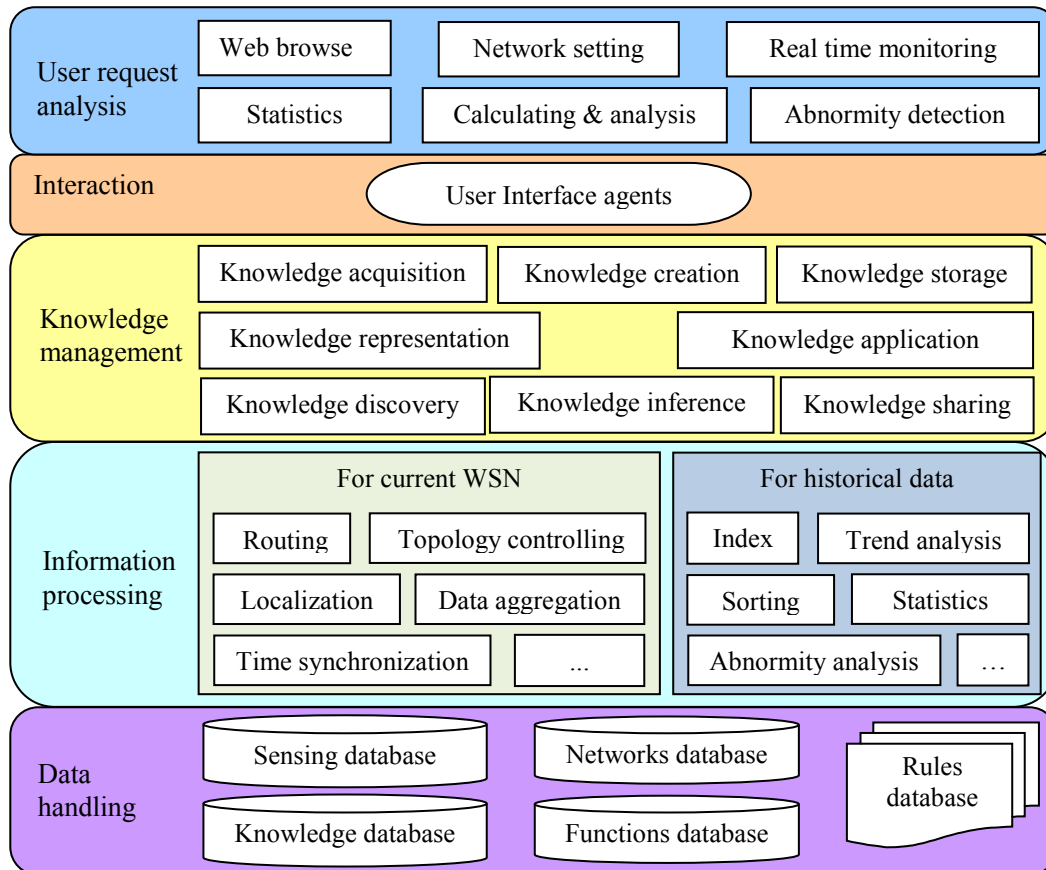


Fig. 3. The architecture of KIS4WSN

3. System Implementation

According to above ideal of the architecture, we describe the implementation in three aspects: the data organization, the main information processing, and knowledge acquisition method.

3.1. Related Databases

All kinds of data, information, knowledge and methods need to be stored in the KIS4WSN, so it includes the following databases:

Wireless sensor networks database contains all kinds of description information for WSN of different application scenarios. Such as military reconnaissance, wildlife monitoring, environment monitoring, health care monitoring, traffic monitoring, forest fire monitoring, and bridge health monitoring.

Functions database stores the various processes and operations functions for all types of wireless sensor networks. For example, network routing, node positioning, data fusion, time synchronization, security control, topology control, condition monitoring, information collection, storage management, coverage control, data forwarding, information query, statistics reports, and trend analysis.

Implementations database manages a set of different implementation methods of the functions for different wireless sensor networks. For example, storage management includes main three kinds of methods as external storage, local storage, and data-centric storage.

Sensing information database stores all kinds of historical data collected from wireless sensor networks, such as temperature, humidity, light, pressure, vibration, speed and acceleration for each node at different time period.

Knowledge (rules) Library manages the various knowledge or rule for agents to judge and reason. Such as domain knowledge, empirical knowledge, rules knowledge, etc. For example, some rules can be

- **if** temperature is higher 60 **then** sound alarm;
- **if** results of user query are in current database **then** return for user **else** gathering the data from WSN and dealing with them according to user requirements, meanwhile storing results into current database.

3.2. Information Processing

User Requests / Service Process

Different users have different needs and send different requests. The interface agents should be able to analyze user requests with the support of the knowledge base and rules library, and select the suitable type of WSN, confirm the requested operation functions according to the analysis results, then dispatch different implementation agents to complete related functions. The implementation agents will return the results to the interface agents after finishing the tasks. The final results will be sent back to the requesting user by the interface agents. Therefore, these processes require collaboration of multiple agents. The process is shown as Fig. 4.

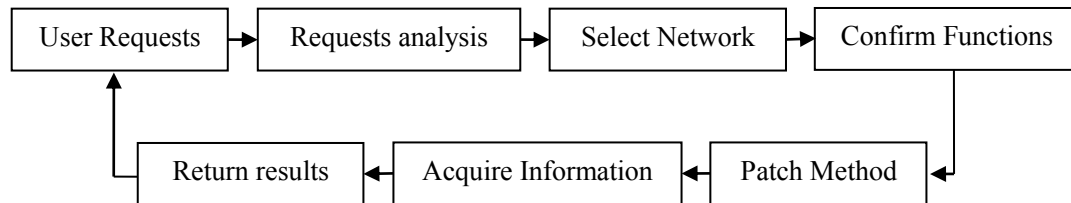


Fig. 4. User requests / service processes

Sensing Data Forwarding Process

The sensing data forwarding process is that the monitoring data of hotspots in the form of packets transmit to the Sink node by a kind of routing algorithm. Satisfying different user's needs, Sink node usually send the collected monitoring data to PC by serial communication connection. In the same time, the monitoring data can be used for real-time monitoring, and stored in the database (or sensing information document) for history query or data analysis in future. The process is shown as Fig. 5.

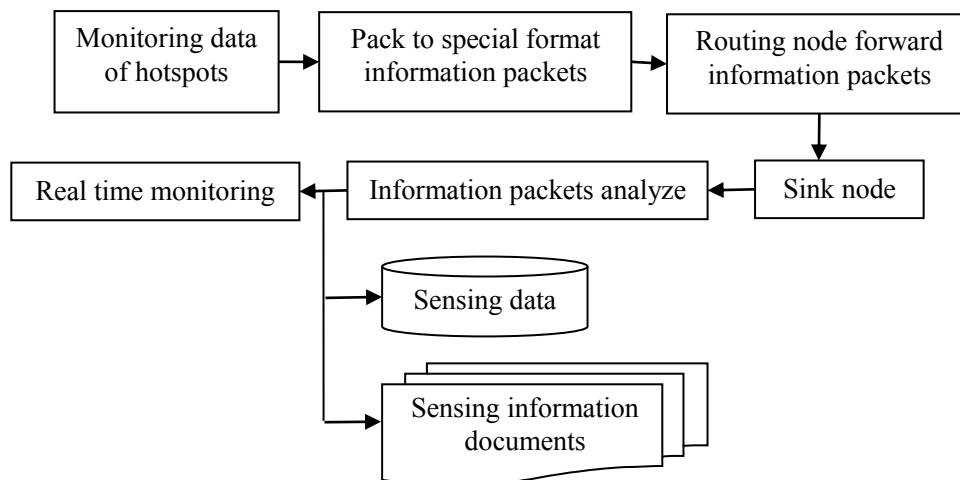


Fig. 5. Forwarding process of sensing data

XML Format Conversion

In order to facilitate information distribution and query on the Web, we need to convert the packets information into XML format. The process which sensing information packets convert into XML format is shown in Fig. 6. The XML analyzer (e.g. SAX) converts sensing data streams into XML data streams with XML Schema. It can offer a variety of services on the Web by related operations (e.g. queries) to XML data streams.

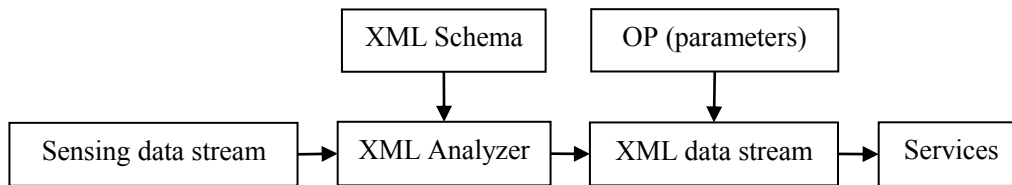


Fig. 6. Process for sensing data converting to XML format

3.3. KIS Model Based on Multi-agents

After putting forward the architecture of KIS4WSN, but there are huge information, and complex operation or functions, now the question is who can act as the important role to deal with the complex business? We select the agent technology.

In computer science, an intelligent agent is an autonomous entity which observes and acts upon an environment and directs its activity towards achieving goals using learning or knowledge [3]. WSN is a distributed system too. The nodes in WSN own the ability of solving problem independently, and have the characteristics of self-organization. These features are very similar as multi-agent system, so the agent technology is applied to WSN is a natural thing to do.

From an intelligent agent’s point of view, the KIS means knowledge acquisition, processing and use for rational decision-making, choosing the best action and generating new knowledge. Therefore, a multi-agent system (MAS), which consists of multiple interacting intelligent agents, will be needed to solve problems that are too difficult or impossible for an individual agent. A proposed KIS model which combines KM and MAS is shown in Fig. 7.

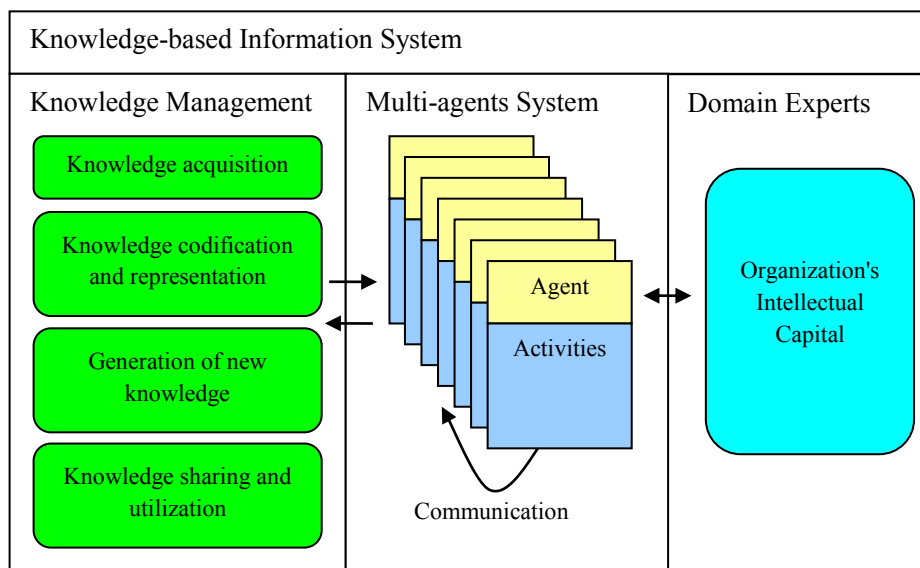


Fig. 7. KIS model based on multi-agents

The conceptual framework of a KIS based on multi-agents consists of three main parts: a KM, a MAS and domain experts for business process support. The KIS is an integrated set of

technologies, hardware and software, to provide knowledge acquisition, storage, processing, retrieval and representation. The KM is usually supported by AI techniques. The purpose of adding KM into the KIS is to identify intellectual capital of the organization and organize that knowledge to make it easily accessible and applicable. The MAS is a physical or virtual environment where intelligent agents may communicate with each other for effective. The domain experts provide intelligent support.

There are main two kinds of agents in KIS4WSN, one is interface agents, and another is function agents. The typical interface agents include: agents between users and IS, agents between PCs and WSNs, and agents between functions and database. The function agents include all kinds of operation functions to database or WSN. Meanwhile the correlative agents can complete the same goal cooperation each other.

4. A Prototype System and Evaluation

According to the above design ideas, we have developed a prototype system called "Wireless sensor network data gathering and analysis system". The prototype system is developed using Visual Studio 2005, and the database management system selected Oracle 9g.

The main functions include system management, network status, data management, real time monitoring, and help information, see Fig. 8.

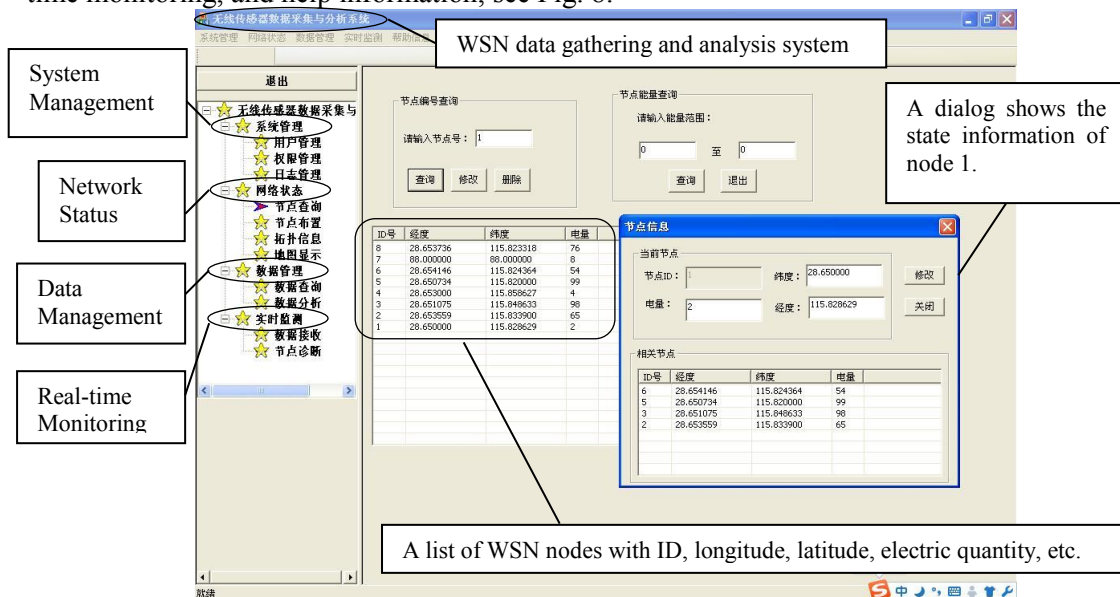


Fig. 8. Nodes status query

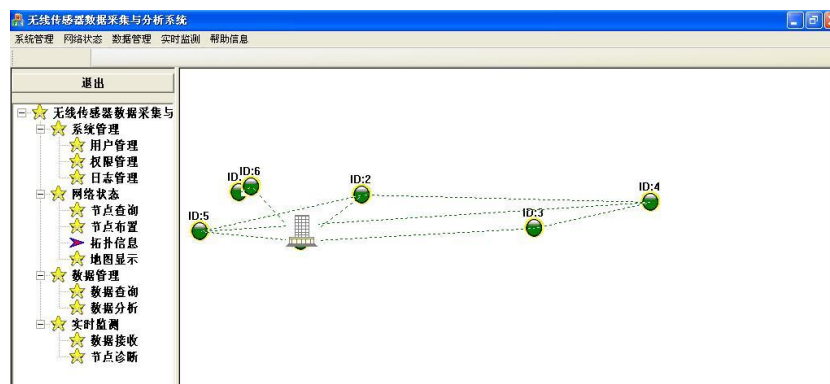


Fig. 9. Nodes topology information

System management main includes user management, privilege management and log management. Network status includes node status query, node layout, topology information

and map displays. Fig. 8 is a snapshot of nodes status query. Fig. 9 is a part of the screenshot of nodes topology information. Data management includes historical data query and data analysis. Real-time monitoring includes data receiving and node diagnostics.

We focus on gathering sensing data and optimizing performance of WSN now, although a prototype system has developed. In the prototype system, it is short of knowledge management and sharing information in Web, and knowledge discovery and trend analyses are insufficient.

5. Conclusions and Future Works

Wireless Sensor Networks (WSN) has become a hot research topic recently and researchers' interests have been focused on how to improve the performance of nodes and networks and efficiently gather sensing data from WSNs. However, little attention has been paid to efficient management of the huge sensing data that are gradually formed, let alone effective use of these data. Meanwhile, different WSN application scenarios may require specific wireless sensor networks, which, apparently increases the complexity of the operation functions placed on the networks and their massive sensible data as well. In this paper, consequently, we put forward a knowledge-based information system solution to these problems in WSNs, which applies the information systems approach (IS) to efficiently manage the huge sensing data and exploit knowledge management (KM) systems and multiple agent systems (MAS) to turn information into knowledge.

In this paper, we introduced briefly related conceptions, including WSN, KM and IS, to address the issues of how to manage gradually increasing WSN sensing data, and consider an ideal knowledge-based information system for WSN data management. We proposed a system architecture for KIS4WSN, and a number of key technologies for implementation guidance. We also discussed how to develop a system prototype of KIS4WSN, and its interfaces to accommodate required functions placed in the networks and data. However, there are still shortages in this prototype system, which we will try to overcome in our future work. In the following, we consider a more concrete idea of how these problems can be solved in the future.

First, the system intelligence needs to be enhanced, by incorporating into the system, not only using multi-agents, but also adding further data analysis methods with artificial intelligence technologies, such as artificial neural networks (ANN), pattern recognition, and generic algorithms. These added functions can be considered services, which are flexibly attached to our system (viewed to be a platform).

Second, the application area of system can be broadened. The prototype system, proposed here, is an experimental system for the WSN research. We try to enable it to adapt to different application scenarios, e.g. wildlife monitoring, environment monitoring, health care monitoring, traffic monitoring, forest fire monitoring, bridge health monitoring, and other fields. Recently we explore to use this idea at a project proposal, in which patients can be fully monitored when they are at home while doctors and nurses are still able to follow the patients' situations before and after taking medication.

Third, the system functions can be further improved. For example, the system can show nodes of WSN on a map with GIS techniques, locate the position of a mobile sensor with GPS, and use many apps from mobile phones, which take immediate measures of the WSN data when timely processing of these data is critical.

Finally, we also intend to explore whether a sound foundation for routing algorithms for wireless sensor networks could be established – a so called optimization algorithm could be further discussed based on 1) the structure (deep structure and whose components at different layers) of WSN nodes and networks (graphical partitioning and clustering), 2) the interdependencies between nodes, nodes' components, and connections, and 3) the probability of energy use of nodes, and transitions, and data accuracy.

Acknowledgements

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References

1. Aberer, K., Hauswirth, M., & Salehi, A.: Global sensor networks. School of Computer and Communication Sciences Ecole Polytechnique Federale de Lausanne (EPFL). Tech. Rep. LSIR-REPORT-2006-001 (2006)
2. Al-Karaki, J. N., & Kamal, A. E.: Routing techniques in wireless sensor networks: a survey. *Wireless communications, IEEE*, 11(6), 6-28 (2004)
3. Chen, B., Song, W. W., Feng, Y., Qiu, Y., & Tavner, P.: Knowledge-Based Information Systems: A Wind Farm Case Study. In *Information Systems Development* (pp. 539-550). Springer New York (2013)
4. Khadar, F., & Razafindralambo, T.: Performance evaluation of gradient routing strategies for wireless sensor networks. In *NETWORKING 2009* (pp. 535-547). Springer Berlin Heidelberg (2009)
5. Martínez, J. F., Castillejo, P., Zuazua, M., García, A. B., López, L., DaSilva, A., & Hernández, V.: Wireless sensor networks in knowledge management. *Procedia Computer Science*, 1(1), 2291-2300 (2010)
6. Osis, K., & Grundspenkis, J.: Agent based personal knowledge management system supported by mobile technology cross-platform solution. *New Research on Knowledge Management Technology*, 139-164 (2012)
7. Priti, S. S., Rajendra, A.: Knowledge-Based Systems for Development. In: Sajja & Akerkar. *Advanced Knowledge Based Systems: Model, Applications & Research*, pp.1-11. TMR e-Book (2010)
8. Raghavendra, C. S., Sivalingam, K. M., & Znati, T.: *Wireless Sensor Networks*. Springer (2006)
9. Tseng, S. M.: The effects of information technology on knowledge management systems. *Expert systems with applications*, 35(1), 150-160 (2008)
10. Xia, W., & Lee, G.: Complexity of information systems development projects: conceptualization and measurement development. *Journal of Management Information Systems*, 22(1), 45-83 (2003)

E-Military Recruitment: A Conceptual Model for Contextualizing the Problem Domain

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Abstract

The rapidly changing labor market led by the hypergrowth of Information and Communications Technologies (ICTs) has forced organizations from different sectors to adopt e-recruitment. Among these sectors is the military. The migration from compulsory recruitment to a self-choice force relying on labor market has made the military sector encountering challenges to harness e-recruitment. This paper examines the various problems embedded with a unique case study of military recruitment and develops a conceptual model based on this. The objective of model is to contextualize the problems perceived and maps them to organizational recruitment objectives thereby enabling informed decisions about how to solve them. The result of analysis has given insight into the viability of model developed.

Keywords: Military Recruitment, E-recruitment, Problem Domain, Problem Domain Analysis.

1. Introduction

The Internet-led labor market has become increasingly competitive and full of diverse skills turning many organizations towards e-recruitment [8]. One of which is the military. In fact, the migration from compulsory military recruitment to an all-volunteer force relying on labor markets, in addition to a higher educational level of the new generations, strong economic situations and a low unemployment rate [11], has pushed the armed forces to get into the continuum. From a military perspective, e-recruiting brings value which includes being agile in filling vacancies, fitting to normal and exceptional circumstances, sourcing diverse and qualified applicants, and being inexpensive. However, new strategic, organizational, functional and social challenges are still expected to emerge [7]. The military is often featured with ambiguity, uncertainty, mobility, and modular organizing [12] that possibly hamper the interest of a talented job seeker in the military. Hence, our research has been driven by the question: “will the military be able to get a competitive advantage from e-recruitment?”

In order to approach the answer of this question, we conducted research that gives insight into the problems that might be faced by the military in the pursuit of e-recruitment. Thus, we base our research on a typical case study of enlistment in Land Forces (LFs). Given enlistment process being a type of external recruitment, we define it as attracting potential job candidates who do not currently work for the military, influencing them to apply, maintaining their interest until being offered, and finally influencing them to accept a job offer. Thus, e-recruitment is the practice of using the Internet to enable such activities. Given the rise of a

global internet culture and different ways in which an employer can bring a job opening to the attention of job seekers (e.g. web-based marketing postings), the focus of e-recruitment in this paper is after the arrival at an employer's website. Moreover, the tight interrelatedness between recruitment and selection procedures [9] is also considered. Preparation training is always incorporated as part of the enlistment process [12].

2. Problem Description

The current maturity of ICTs enables a relatively simple development and delivery of e-recruitment. However, the focus should be shifted into the desired effects (i.e. requirements) that an employer wishes to be brought in the work practice [2]. The literature has emphasized the effects of recruitment activities which may satisfy a potential applicant at the operational level. That is, for example, advertising and offering complete information that generates the number and type of individuals, professional treatment that may affect an applicant's retention, and certain actions that may influence job choice decisions (e.g. the timeliness of a job offer) [1,3]. However, moving to higher levels of analysis is necessary in order to provide comprehensive and relevant answers to many important recruitment questions [9]. To this point, very little research has been focused upon process related domain-dependent requirements that affect recruitment process. Hence, we extend our research into strategic and structural requirements to investigate the type of effects they bring into recruitment process and how the process reacts to these effects.

According to [2], problem domain analysis is the achievement of understanding problem domain and the problems (requiring solution) that exist within that domain. Given the context of enlistment process, a problem domain analysis approach can strongly contribute to a better understanding of the domain-dependent requirements and help military organizations defining the problems to be solved. Thus, the introduction of suitable action plans towards building innovative e-recruitment systems is enabled. The structure of this paper is as follows. The case study background, enlistment process and development stages are presented in Section 3. The research method is provided in Section 4. The conceptual model is developed and described in Section 5. Discussions and contributions of the conceptual model are provided in Section 6. Conclusions and future work are provided in Section 7.

3. Case Study Background

SecureLand is an anonymous country from which the real case study is brought. The mission of Land Forces (LFs) in SecureLand is protecting national lands from all external threats [6]. Enlistment is one of the key processes on which LFs rely to ensure its military readiness and effectiveness in combating operations. An enlistee is a non-commissioned member who is recruited after the basic education, i.e. postsecondary student. The strategy of enlistment process is centrally set by the Chief of Military Personnel (CMP) of LFs, and run by a number of corps in coordination with their own schools. The mission of enlistment formally states [6] "attracting and recruiting a set of applicants; who are relatively matching job vacancies, well-qualified, and regionally diverse in a timely and efficient way". Thus, the objectives of enlistment process are recruiting the appropriate number of applicants, increased level of Knowledge, Skills, Abilities (KSAs), increased level of regional diversity, the timeliness of activities, and cost savings.

The structure of LFs is established based on seven military regions. These regions cover the whole land of SecureLand. In each region, there are a number of military units which, in turn, consist of different types of jobs belongs to different schools. The total number of military jobs allocated for each region, irrespective of their types, is relatively equal. This is to ensure equal job opportunities among SecureLand's population. However, the population consists of ethnically diverse communities which often spread over large areas of the country and sometimes stretch across borders to the neighboring countries. To enhance national security, LFs formally impose a policy that ensures a regionally diverse set of soldiers in each military region. Hence, the responsibility lies on each school to comply with this policy over

its jobs when assigning graduated enlistees. A school (i.e. recruiter) is located in one specific region based on the appropriateness of the geographical properties of that region with the type of training given. As a result, schools are unequally distributed over military regions.

3.1. Description of Enlistment Process and Improvement Stages

Enlistment process has undergone two key improvement stages: prior-2008 process and post-2008 process [6]. Each of which was pursued to achieve the objectives aforementioned. In general, the activities of enlistment process were almost rigid over the two stages and timed simultaneously with the end of basic education cycle. On the other hand, the entry requirements and location of job openings were possible to change. These activities are: announcement, reception and assessment, selection, training, and job offering. The basic military training and specialization are considered as part of enlistment activities being prerequisites of offering jobs.

Once announcement takes place often by newspaper, a potential applicant has to move to the site where the job opening is. When arriving, an application form is filled in, and then documents and educational qualifications are checked. After that, an applicant who passes this check will be booked regular appointments for assessment activities such as paper exams, interview and physical fitness, and asked to wait for results. At the end of assessment, the number of applicants obtained is checked against a target number taking into account possible withdrawals. If it is inadequate, then a call for recovery is carried out and the already checked applicants are kept on hold. When an applicant is selected, a set of official enquires (e.g. crime record and employment) are conducted, and medical fitness is finally checked. If the results are positive, then a candidate will be registered as cadet and notified with the start date of basic military training.

When passing basic training, specialization training takes place. At the end, graduated cadets are assigned to jobs spread over military regions. A cadet's preferences of jobs are matched based on accumulated points collected from registration portfolio, and results of both basic and specialization training. However, the criteria must maintain regional diversity over jobs offered in a certain region with which preferences are difficult to match.

3.2. Comparison between Two Enlistment Processes

The major difference between the two processes was structure-based. In prior-2008, the results analysis showed that the overall level of diversity measured at the end of process was high whereas the level of KSAs measured just before the commencement of basic training was low. The timeframe of activities performed was long, and a high rate of withdrawals existed. In this process, Military Preparation Centers (MPCs) are entitled to run most of enlistment activities, except the uptake of specialization course and job offering carried out by schools. A number of MPCs are deliberately set at places with a relatively equal distance from regions to enhance regional diversity among applicants attracted. Because of equal opportunities, a regionally diverse pool of applicant is easily attracted. At the end of basic training, a subset of cadets formed from every MPC is selected and then assigned to a certain school for diversity purpose. This occurs for every school and the accumulated points at that point of time are used for school assignment. Hence, the first item of information relevant to the job (i.e. corps) is informed at this stage. Other items (e.g. salary, rank granted, location, etc. are hidden until the end of specialization training. Mobility and modularity of military units account for hiding such valuable job characteristics.

The shift to the post-2008 process was led by the LFs' tendency to satisfy both members (i.e. applicants and schools). For this, MPCs were cancelled and their roles were totally assigned to schools. This would encourage more applicants to apply being free to select among schools whatever they wish. It would also reduce the number of an applicant's previous movements between regions in prior-2008 process (i.e. from the MPC dedicated to the school assigned, and from the school to the job offered). From a school's perspective, this would help tailoring entry requirements based on their needs for improved training and

enforce accountability. The analysis of post-2008 results demonstrated opposite outcomes. The level of KSAs slightly increased whereas the level of regional diversity considerably dropped. However, the overall rate of withdrawals remained high and the process cycle time became longer because of certain schools being perceived having hazardous training. This, in turn, caused many calls of recovery. Unequal opportunities between those applicants live in the same region where a certain school is and those do not, resulted in a high rate of difference between the two categories in both the number and KSAs. Although schools were enabled to apply positive actions when selecting candidates to remedy inequality, they seemed unable to reach a desired level of regional diversity. The high level of KSAs scored among the category of local applicants was sacrificed by applying positive actions. The rate of withdrawals was high among remote applicants whereas the overall rate was negatively impacted by duplicate selection of an applicant with many schools in absence of control. Thus, cost went higher than prior-2008 process.

4. Research Method

The research draws upon a case study based approach. The case study of enlistment process in LFs has been selected. According to [14], a case study approach is considered when: the focus of the study is to answer “how” and “why” questions; and various contextual conditions are relevant to the phenomenon under study. A hallmark of case study approach is the use of multiple research methods [14]. We conducted a number of regular semi-structured interviews with the central planning body of enlistment process to capture various goals related to enlistment, the patterns of enlistment activities, and to collect data related to the performance. Using BPMN, the process was modeled and validated through a number of enlistment site visits. The results of initial research indicated that there were a list of enlistment objectives articulated and two development stages conducted to pursue them. In cooperation with a focus group [5] composed by R&D members of LFs, Focal points, HR representative of each corps, and representative of recently enlistees, we posed many questions about whether or not the outcomes of enlistment process match objectives and the intervening problems that impact performance. Facilitated by the process model, the discussion within the members of group was encouraging.

Inspired by SSM [4], in particular human activity model, the conceptual model presented in Section 5 was derived based on a detailed analysis of: (a) the results of interviews and documents inspected related to LFs’ enlistment goals and objectives, (b) problem areas and their associations suggested by focus group, and (c) the results of discussion within expert workshops on the artifacts of conceptual model and their relevance. Later, the model was subject to a number of tests at the level of LFs’ corps. Finally, the results of tests gave insight towards the applicability of model.

5. Results: The Conceptual Model

The authors develop a conceptual model that helps identifying the key problems embedded in recruitment practices and mapping their impact to organizational recruitment objectives. The conceptual model is depicted in Fig. 1. We emphasize the notion of applicant centricity and build the model based on it. We argue that the ultimate objective of a competitive e-recruitment practice should always be linked to applicant satisfaction since the Internet-led labor market enables job seekers to be more selective in their choices. In the context of military enlistment, there has been concern that the military is still unable to be the first choice of many job seekers so that it attracts different breed of person compared to other sectors (e.g. less advantaged [12]). Moreover, the rate of enlistment entry is positively correlated with unemployment rate and negatively with the level of social perception of military service being dangerous [11]. An applicant-centric strategy to be achieved requires an organizational capability to reconfigure processes, structures, reward systems, and people practices. According to [10], organizational structure and business processes are the main elements that need to be strongly connected to achieve the business strategy. Hence, the

conceptual model is based on such connectedness. As depicted in Fig. 1, we adopt some notations: ovals, circles, and arrows. The large oval represents the problem of organizational structure which influences other process problems (small ovals) to exist. The impact of each process problem is linked to the strategic objectives by a number that indicates the direct impact of it on a certain objective. The interrelationships between problems are represented by arrows which indicate the reasons of such relationships.

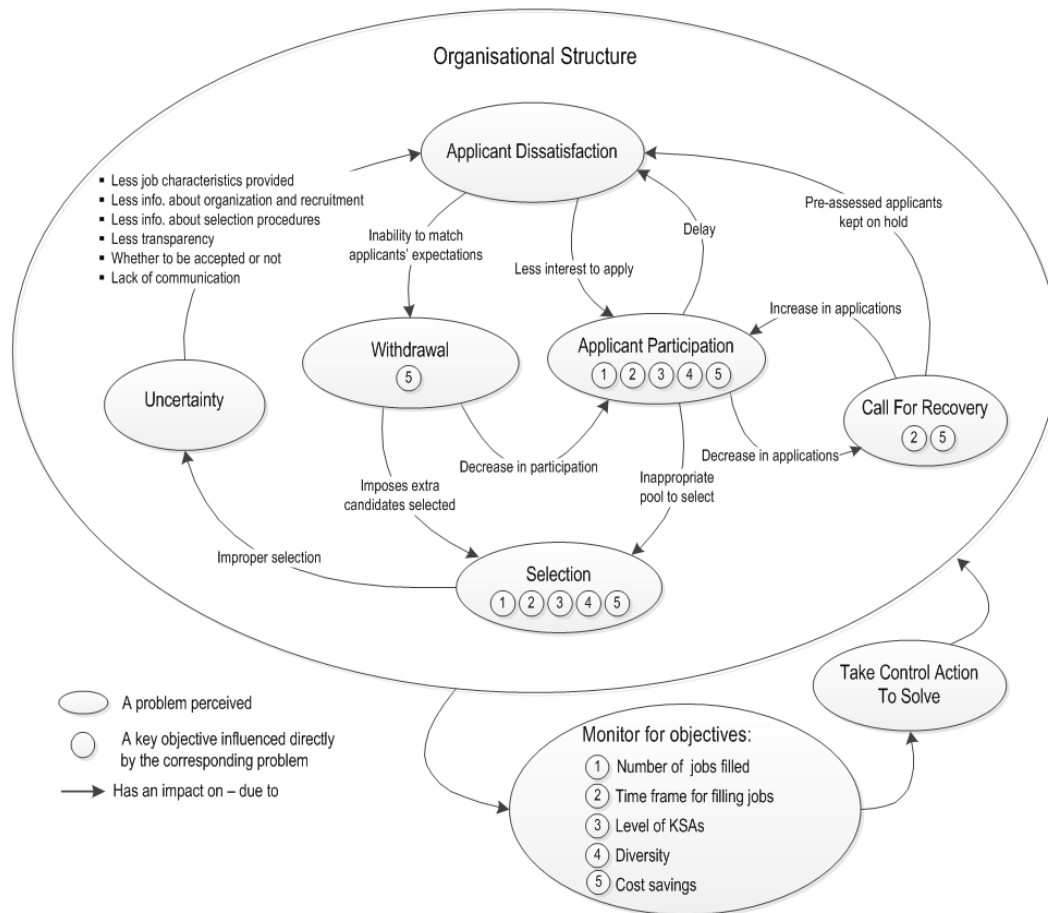


Fig. 1. Conceptual model for contextualizing the problems embedded with enlistment process

There are a number of organizational structure problems that affect process performance and describe the extent to which the structure is aligned with the process (i.e. applicant-centric). Some are size and complexity, (de)centralization, formalization, specialization and so on. In the context of recruitment process, we focus on two structural problems. One is the level of misfit between location of applicant, job, and recruiter. Most studies have addressed the importance of location in recruitment practice as a characteristic of the employer [9], but little has addressed it as a job characteristic. That is, the analysis being conducted confined to a single organization located at one place. The second is inability of integration between organizational units in the case of that many job alternatives of a single applicant exist. The literature has emphasized the positive correlation between job alternatives and applicant interest [3].

The problem of applicant dissatisfaction is at the core of this model. It serves as an interface between organizational structure and process, which links the effects of structural problems with their implications at the process level. For instance, any failure in the structure being not applicant-centric (e.g. remote distance between applicants and recruiters) would lead to applicant dissatisfaction. At the process level, applicant dissatisfaction may result from a number of causes. Uncertainty and a long time process are the main causes.

The problem of participation concerns the quantity and quality of applicants attracted and retained. The policy of attracting as many applicants as possible influences the key objectives by increased time and cost, and less speed in filling vacancies. However, less number of applicants received may entail a call for recovery which, in turn, may cause ready applicants kept on hold. This also results in new rounds scheduled and further operating costs. Duplicate applications in absence of control will affect time and cost. In terms of quality, it is determined by the type of participants based on KSAs and diversity. It is more likely that highly qualified applicants who have multiple job alternatives are most strongly affected by unpleasant subsequent action such as delay [13].

The problem of selection refers to an improper selection device or inappropriate pool to select from [9]. Improper device may lead to less qualified candidates being selected, which influences the level of KSAs and diversity. Improper device may also lead to an applicant being offered with undesired position so that it influences his/her decision about whether or not to accept a job offer. Moreover, it may cause a candidate being selected many times which, in turn, affects the number of candidates needed and someone's right to be selected, and return on investment. For inappropriate pool of applicants, it is unlikely that a selection device produces high quality selectees, if participation does not provide it.

The problem of withdrawal relates to that an applicant self-selects out of the process whether at early stages or later after being selected. The main driver of this problem is applicant dissatisfaction. Unmet expectations of an applicant result from lack of information about jobs, improper selection device, delay and uncertainty. Withdrawal affects applicant participation where it may lead to a call for recovery. It may also influence selection by adding extra selectees in avoidance of potential withdrawals. With regard to the effects of withdrawal on key objectives pursued, it appears to directly influence cost. However, it has many indirect influences on the number and type of participation and time.

6. Discussion

Given the criticality of applicant dissatisfaction, uncertainty seems the major problem that leads to dissatisfaction. The effects of this will be addressed in different parts of the discussion. At the beginning, it is very important that an employer's general marketing actions attract the attention of potential job applicants to a job opening. The model suggests that such actions should not leave any room of uncertainty since they are meant not only to attract, but also to generate initial interest [9]. The Internet, as recruitment method, easily brings a job opening to the attention and allows an access to several resources at every time and from any place. It has been suggested that organizations that provide more complete and accurate information will attract and influence more applicants to apply [8]. Despite this may help generating the number of applicants needed, it may not guarantee the level of KSAs required. What makes difference is the type of information provided. The conventional wisdom [9] is that job attributes (e.g. salary, job tasks, job location, work hours, etc.) are more important to applicants than anything else such as the content of a job advertisement, the design of an employer's website, or even a recruiter's behavior. Back to LFs enlistment process, although LFs enjoy an increased rate of applicant every year, the quality (e.g. KSAs) has been still an issue. The problem was inability of LFs to provide valuable information about job attributes. In prior-2008, such attributes were completely absent and the level of KSAs, therefore, was very low. In contrast, we observed a slight increase in the level of KSAs after the mission had been shifted from MPCs to schools. That referred to the fact that a valuable item of information related to the type of job was conveyed, i.e. specialization.

The dynamicity of a military's operational environment often limits disclosure of job attributes, particularly location [6]. In such a case, LFs' decision makers might think about having a strategy that allows temporarily static jobs for new enlistees (e.g. as a reserve force) so that they get encouraged to apply. The potential effectiveness of such a solution builds on that military training is later meant to prepare them mentally, emotionally, and physically for reassignment [12]. Another solution might be to enable them adjusting their choices to remote

assignment after training and link that with incentives. This might need a more flexible pay system. However, all of which should be clearly and fully informed at the time of application.

More certainty (i.e. more job attributes and requirements) adds another value where an applicant can decide whether or not he/she fits the job available. Thus, if he/she perceived fit, then an application might be set and then an obligation to remain would be more likely to occur. Otherwise, an applicant would self-select out of the process at the beginning. Due to uncertainty, withdrawal of applicants was manifest in both LFs' enlistment processes. The rate of withdrawals was high after school assignment in prior-2008 because of unmet expectations related to the type of job needed. It was also high after job assignment in post-2008 because of unmet expectations related to job location.

However, an applicant's expectations should be realistically managed and directed into more alternative opportunities that clearly match his/her qualifications [3]. This can occur not just at the time of placing an application but also when rejection takes place, if jobs are still unoccupied. We address inability of an employer to provide job alternatives as a structural problem (i.e. integration) which can occur either at the micro or macro level. However, at the process level, it can be easily managed using web tools. Certainty should be also taken into account when managing preferences (i.e. selection). For example, the MPC-centric prior-2008 was signaling that many job alternatives by the type are available. However, when it comes to assignment applicants realized unmet expectations. On the other hand, the school-centric post-2008 signaled job alternatives by location while unmet expectations existed. That was, due to improper selection device. Based on above, certainty must be guaranteed at the time of application.

By adopting e-recruitment, diverse participation (e.g. by race, sex, location, ethnic, etc.) can be obtained at the time of application. Given the wide spread of Internet and reduced digital divide, equal opportunity is almost present. Because of lack in equal opportunity, we realized the problem of diverse participation in post-2008 where location inequality affected remote potential applicants being less encouraged to apply. Having generated good participation of applicants, the focus should be on maintaining their interest until they get a job offer. Interest is more likely to continue as long as an applicant perceives that he/she is at the core of an employer's attention. Hence, if uncertainty still exists, then withdrawal can occur at any time. Delay due to either a long time process or call for recovery might get participants dissatisfied and then they might withdraw out. Lack of communication is also very critical since delays are seen by applicants as reflecting something going wrong with their applications. In both LFs' enlistment processes, communication was almost absent and withdrawal, therefore, was high.

A full e-recruitment process seems almost far to harness, at least in enlistment due to, for example, physical assessment needed [6]. Thus, the location where to host recruitment activities (e.g. interviews, tests, etc.) is very critical. That is location of recruiter. However, more important to an applicant is the location of job as it is a job characteristic. Managing the level of fit between those two locations compared to the location of applicant is very necessary. Any misfit might lead an applicant not to apply, or not to stay after applying. We refer to this in Section 5 as a structural problem that needs to be managed in order to generate an applicant's interest and maintain it. Back to enlistment process, in prior-2008 the locations of applicant and recruiter were fitted by MPCs whereas it was not the case at schools after assignment. Job location nearly did not fit because of diversity mandated. In that process, the level of fit increased diversity among applicants at MPCs. However, withdrawals increased later at schools. In post-2008 the level of fit between locations of applicant and recruiter was left to an applicant's choice but job location was not guaranteed. Because of inequality in schools distributed over regions, diversity was low at the beginning and increasingly became worse by withdrawal. To increase an applicant's interest and maintain it, job location must be uncovered, and then any misfit is solved either by incentives or structure redesign, or by both.

Lack of transparency in selection procedures, particularly when direct invention (e.g. positive actions) exists, adds more uncertainty to applicants. Hence, the likelihood of a high quality applicant being receiving a job offer becomes less which, in turn, leads to less participation or less interest to remain. In enlistment processes, both of them were having

complex selection procedures that caused a high rate of withdrawal especially among high quality applicants. In this case, a recruiter might have to increase the number of selectees to compensate potential withdrawals. That occurred at both enlistment processes. The quality of selection in both number and type depends on the quality of participation (e.g. pool of applicants). The problem of participation (i.e. less number attracted, less retention, low level of KSAs or diversity) affects the quality of the pool prepared for selection. Compared to prior-2008 process, highly diverse candidates were selected because of high level of diversity provided by participation, and vice versa at post-2008 process despite positive actions applied.

7. Conclusion and Future Work

Military organizations are concerned about whether or not they can compete in today's tight labor market led by technological advances, i.e. e-recruitment. The model developed helps identifying the potential problems of recruitment practices and links the impact of those problems to recruitment objectives. Having understood those problems within the domain where they exist, the process of deciding how to solve them towards a more competitive e-recruitment would be enabled. Some solutions were provided. Although the model is developed based on a single case study of military sector, we generalized it in a way that provides further exploitation by other industries. It can be also used as a criteria for selecting best practices to investigate the way those problems were solved. The scope of research was limited to mapping the problems perceived at the process level with some consideration of the most relevant strategic and structural aspect. Further research is needed to map the impact of organizational problems to the corresponding process problems. The model developed needs to be validated by a set of cases studies from different domains.

References

1. Barber, A.: *Recruiting Employees*. Thousand Oaks, CA: Sage Publications (1998)
2. Bray, I.: *An Introduction to Requirements Engineering*. Addison Wesley, England (2002)
3. Breaugh, J., Starke, M.: *Research on Employee Recruitment: So Many Studies, So Many Remaining Questions*. *Journal of Management*. 26, 3, 405--434 (2000)
4. Checkland, P., Scholes, J.: *Soft Systems Methodology in Action*. John Wiley & Sons Ltd. (1990)
5. Fern, F.E.: *Advanced Focus Group Research*. Sage Publishing, London (2001)
6. Land Forces: *E-Recruitment Strategy*. Official Document, Land Forces, SecureLand (2013)
7. Ministry of Defense: *Recruitment and Retention in the Armed Forces*. National Audit Office NAO, London: (2006)
8. Pfielfelmann, B., Wagner, S., Libkuman, T.: *Recruiting on Corporate Web Sites: Perceptions of Fit and Attraction*. *Int. J. of Selection and Assessment*. 18, 40--47.
9. Rynes, S.: *Recruitment, Job Choice, and Post-Hire Consequences*. In: Dunnette, M., (ed.) *Handbook of Industrial and Organizational Psychology (2nd ed.)*, pp. 399--444. CA: Consulting Psychologists Press, Palo Alto (1991)
10. Shani, A., Docherty, P.: *Learning by Design: Building Sustainable Organizations*. Malden, MA: Blackwell Publishing (2003)
11. Tresch, T.: *Challenges in the Recruitment of Professional Soldiers in Europe*. In: Vasile, P., Corina, V., George, R. (eds). *Strategic Impact 2008*, vol. 3, 28. National Defense University, Romania (2008)
12. United States Army Recruiting Command: *Recruiting Operations*. USAREC Manual, No. 3-0 (2009)
13. Wanous, J.: *Organizational Entry*. MA: Addison-Wesley, Reading (1992)
14. Yin, R.: *Case Study Research: Design and methods*. Sage Publishing, USA (2008)

A Rule-Based Method for Comparison of SLAs in Service-Oriented Computing

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Abstract

Service selection based on non-functional properties (NFP) of services is one of the most important and challenging task in service-oriented computing. NFP are usually described in service-level agreements (SLA). Therefore, the problem of comparison of SLAs arises naturally if there is more than one service with the same desired functionality. SLAs are usually written in a special XML-based format (WS-Agreement, WSLA, RBSLA, etc.). They describe some rules of using the service at the proper level, set the metrics by which that service is measured, and the remedies or penalties in case the agreed-upon levels are not achieved. The paper proposes a method to find differences between SLAs using rule-based knowledge representation and first-order logic-based derivation.

Keywords: Service-oriented Computing, Service-level Agreement, Quality of Service, Rule-based Knowledge Representation, Model Generating.

1. Introduction

Service-oriented computing is increasingly gaining ground in the developing of enterprise applications and sets a particular type of relationships between and inside business entities. This inherently raises an issue of contracting relationships, as services in real life are subjects for negotiation and contracting.

The term “contract” has originated from law and means an agreement with legal obligation. However, in the service-oriented architecture (SOA), the definition of the service contract achieves mostly technical rather than legal spirit. In case of Web Services, that are the most common implementation of SOA services, the contract usually means service description documents – WSDL definition, XSD schema, and policy [4]. It should be noted that mostly technical understanding follows the traditions of Bertrand’s Meyers’s “design by contract” that was first introduced in 1986, in connection with the creating of the object-oriented programming language Eiffel. Beside such contracts, there are other types of agreements in SOA. The most popular is a Service Level Agreement (SLA). SLAs describe rules of using the service at the level expected by a customer from a provider, define their obligations and rights, set metrics to measure quality of service (QoS) (for example, mean time between failures, mean time to repair, various data rates, throughput, etc.), and the remedies or penalties in case the agreed-upon levels are not achieved. SLAs are usually written in a special XML-based format (WS-Agreement, WSLA, RBSLA, etc.).

The problem of SLAs analysis arises naturally if there is more than one service with the same desired functionality and it is necessary to select one of them. To this aim, one needs to compare non-functional properties of the services. The comparison of SLAs is also useful in negotiations, as it can help to put a negotiation offer to change some item of a SLA proposed by a provider, on the grounds of SLAs from other providers. Moreover, the detection of differences is useful in the managing changes in SLAs.

The paper proposes a method to find differences between SLAs using rule-based knowledge representation and first-order logic-based derivation.

The remainder of this work is organized as follows: in Section 2, related work is discussed; Section 3 presents the proposed method for SLAs comparison, including

definitions of difference between SLAs, model generating, algorithms, and proofs of related theorems; Section 4 contains conclusions of the work.

2. Related Work

WSLA [8] and WS-Agreement [2] are the most widely accepted approaches to describe SLAs. However, they have limited expressiveness to represent rule sets and complex conditionals. In [11, 12], a declarative rule-based knowledge representation framework for SLA and policy representation and management is proposed by introducing ContractLog and RBSLA languages. The ContractLog framework provides a declarative rule language based on logic programming and explicitly expressing contractual logic. The ContractLog knowledge representation uses an extended ISO Prolog related scripting syntax. RBSLA (Rule-Based Service Level Agreement) presents XML syntax for ContractLog knowledge representation. It adapts and extends the XML-based rule standard RuleML to the needs of the SLA domain. According to [6], SLAs that are written in WS-Agreement or similar language can also be transformed into corresponding sets of logical rules.

There are two main trends in service selection approaches: optimization-based approaches and negotiation-based approaches [10]. In the first approach, services are ranked by a value of utility on the ground of some criteria. The value of utility is calculated encompassing all QoS attributes. The ranking of services allows to compare them by their suitability for a customer. No rule-based derivation is made in this case, only numerical values of attributes are considered. In optimization-based approach, these values are assumed to be undiscussable. In contrast, negotiation-based approaches assume the possibility to change SLAs through information exchange and compromises between a customer and provider. A good review of existing service selection approaches is presented in [10].

Most papers on SLA comparison are focused on the computable parts of SLAs (e.g., [1], [3], [5]). As mentioned previously, they propose methods of ranking services on the basis of quantitative attributes (e.g., response time, availability, accuracy, and cost) and weights of the attributes, indicating their relative importance for a service customer. Our work differs from others in that we consider rule-based representation of SLAs and investigate how to compare logical consequences (not necessary numeric values) that can be derived from the SLAs. Our method can help to analyze and compare rules that cannot be expressed in WS-Agreement or similar language, but can be expressed in rule-based language. At the same time, mainly all SLAs can be transformed into rule-based form, and therefore they become objects for the proposed rule-based method.

In order to make possible the comparison of SLAs, it is important to have some common standards or ontology for SLAs. According to the European Commission report [7], there is a serious lack of standards for different elements and parts of the SLA lifecycle. In particular, for the quantitative and qualitative comparison of SLAs, it is expedient to develop an SLA Reference model. At present, SLA attributes are not universally standardized. SLA templates are often used to define the structure of an SLA, the names of the service attributes, and the attribute values [9]. As there can be a variety of different public and private SLA templates, a problem of the template matching arises. Service Measurement Index (SMI) was proposed by the Cloud Service Measurement Index Consortium (CSMIC) [3], [5] for measuring and comparing services. It ranges QoS attributes in the hierarchical structure. Appropriate attribute names of different services are not required to be unified, and their matching is a separate task. SLA meta-models that are proposed in [1] also seek to generalize and standardize SLA attributes. So, though it is so far unrealistic to require the same ontology from different service providers, SLAs can be transformed to some common standards in order to be comparable. The selection of a particular method of such standardization (SLA Reference model, template matching, meta-models, or other) is beyond the scope of this paper.

3. Method of SLAs Comparison

3.1. Basic Principles

When we have the task of the SLAs comparison, we assume that the SLAs are standardized and share the same ontology, as stated in Section 2.

In the proposed method, we also assume that SLAs are formalized as logic programs, with facts and rules, and are stored in knowledge bases. Thus, the task of comparison of SLAs is partly transformed into the task of comparison of appropriate knowledge bases.

Rules in the knowledge bases have the form $head \leftarrow body$. Facts are rules without a body, with a head only. The head (also called the *consequent*) is an atom (a positive literal), and the body (also called the *antecedent*) is a conjunction of literals, that can be positive and/or negative. This is Prolog-like representation.

ContractLog has the similar knowledge representation. For example, the requirement “between 0 and 4 a.m., the service availability will be measured every 10 minutes, if maintenance is being performed” can be formalized as follows (untyped formalization is shown for simplicity; the symbol “: -” is used instead of the arrow “ \leftarrow ”) [11]:

```
schedule(maintenance, Service) :-
  sysTime(datetime(Y,M,D,H,Min,S)),
  lessequ(datetime(Y,M,D,H,Min,S), datetime(Y,M,D,4,0,0)),
  interval(timespan(0,0,10,0), datetime(Y,M,D,H,Min,S)),
  service(Service), maintenance(Service).
```

As it was stated above, SLAs that are written in other languages (including the most popular WS-Agreement) can be transformed into corresponding sets of logical rules. Therefore, our comparison method is suitable not only for initially rule-based RBSLA/ContractLog.

We specify the task of the comparison of SLAs as the detection of differences between them. We define the difference between SLAs as the difference between conclusions derived from possible situations. The set of conclusions is actually a model of the logic program. The comparison of SLAs is considered as the comparison of models generated from the SLAs. The proposed model generating algorithms is presented in the next section.

3.2. Model Generating Algorithm

The comparison of SLAs is considered as the comparison of models generated from the SLAs. We use the model generating algorithm that implements negation as failure. We will denote $KB \vdash_M N$ to state that the model N can be generated from the knowledge base KB using this algorithm. According to our algorithm, we firstly add facts to the model, and after that we add conclusions derived from the facts by using rule chains. Let’s describe it formally.

Model generating algorithm. The initial model is an empty set. The model is generated as follows:

1. *Horn clauses.* Let the knowledge base has a rule $C \leftarrow A$, where A is a set (possibly the empty set) of positive literals, and C is a positive literal (that is, the rule is a Horn clause). Let there exists a ground substitution σ such that $A\sigma$ is true in the so far generated model N , and $C\sigma$ does not belong to N . Then the model N is to be supplemented with $C\sigma$. As it is known, a ground substitution in first-order logic is a total mapping $\sigma: V \rightarrow T$ from variables to variable-free terms.

Example 1. Let us look at the model generating in the simplest case, when there are no variables. Let the knowledge base consists of the following rules and facts:

- 1) $e \leftarrow a, d.$
- 2) $f \leftarrow b, e.$
- 3) $c \leftarrow a.$
- 4) $d \leftarrow b.$
- 5) $h \leftarrow g.$
- 6) $a.$
- 7) $b.$

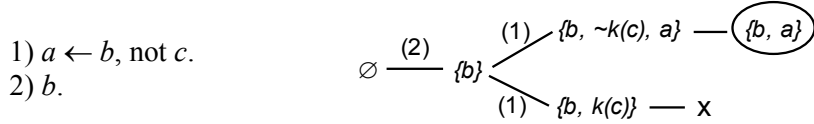
The model of the knowledge base will be generated as follows:

$$\emptyset \xrightarrow{(6)} \{a\} \xrightarrow{(7)} \{a, b\} \xrightarrow{(3)} \{a, b, c\} \xrightarrow{(4)} \{a, b, c, d\} \xrightarrow{(1)} \{a, b, c, d, e\} \xrightarrow{(2)} \{a, b, c, d, e, f\}$$

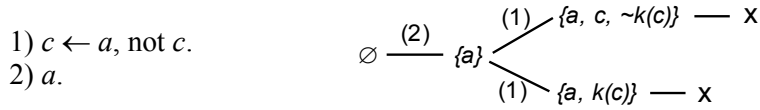
2. *Non-Horn clauses.* Let the knowledge base has a rule $C \leftarrow A, \text{not } P_1, \dots, \text{not } P_n$ ($n > 0$), where A is a set (possibly the empty set) of positive literals and P_1, \dots, P_n are positive literals (that is, the rule is non-Horn clause). Let there exists substitution σ such that $A\sigma$ is true in so far created model N , and $C\sigma$ does not belong to this model. Then N is to be supplemented in such a way that two models are given with special modal operator k : model $N \cup \{C\sigma, \sim k(P_1\sigma), \dots, \sim k(P_n\sigma)\}$ and model $N \cup \{k(P_1\sigma, \dots; P_n\sigma)\}$. Here $\sim k(P)$ means that it is expected that the model will not have the fact P , whereas $k(P_1; \dots; P_n)$ means that it is expected that the model will have at least one of facts P_1, \dots, P_n . Later we will eliminate models that contain both $\sim k(P)$ and P . If a model has $k(P_1; \dots; P_i; \dots; P_n)$ and some P_i ($i=1, \dots, n$), then $k(P_1; \dots; P_i; \dots; P_n)$ will be removed from the model. After finishing the generating of models, we will remove $\sim k(P)$ from models that does not have P ; and we will eliminate models that have $k(P_1; \dots; P_n)$, but do not have any P_i ($i=1, \dots, n, n > 0$). Therefore, final models will not have any facts with operator k .

Unlike the Horn clause case, in the case of non-Horn clauses we will receive not necessary only one model. It is possible to get several models or no model at all. Let us look again at the model generating in the simplest case, when there are no variables.

Example 2. The knowledge base below has only one model $\{b, a\}$ that is generated in the following way (x means the elimination of a model):



Example 3. The knowledge base that is presented below has no models. The model generating is pictured on the right.



Example 4. Let the knowledge base contain two rules: 1) $a \leftarrow \text{not } c.$ 2) $c \leftarrow \text{not } a.$ This knowledge base will have two models – $\{a\}$ and $\{c\}$.

We will consider only knowledge bases that satisfy the following restrictions:

1. *Bound variables.* All variables in rule consequents and negative literals of antecedents are also used in positive literals of the antecedent.
2. *Exactly one model.* The generated model is only one. This restriction is appropriate in the domain of SLA regulations, because every situation should imply concrete conclusions.
3. *Finite model.* The generated model is finite.

ContractLog/RBSLA has the possibility to use typed logic constructs, the scoped negation as failure, and some other additional features [12]. In the paper, we do not consider these cases.

3.3. Definition of Difference

Let us define formally what we call the difference between knowledge bases.

Definition 1. We say that there is the *internal difference* between knowledge bases KB_1 and KB_2 , if $KB_1 \vdash_M R_1, KB_2 \vdash_M R_2$, and sets R_1 and R_2 are not equal. We define an *internal difference set* as $DiffInt(KB_1, KB_2) = (R_1 \cup R_2) \setminus (R_1 \cap R_2)$.

Definition 2. Let S be a set of facts describing a situation. We say that knowledge bases KB_1 and KB_2 are *different in situation S* , if $KB_1 \cup S \vdash_M R_1, KB_2 \cup S \vdash_M R_2$, and sets R_1 and R_2 are not equal. We define a *difference set in a situation S* as $Diff(S, KB_1, KB_2) = (R_1 \cup R_2) \setminus ((R_1 \cap R_2) \cup DiffInt(KB_1, KB_2))$. According to this definition, elements of the internal difference set are not included in the difference set.

Definition 3. Knowledge bases are *different* if there is internal difference between them or they are different in some situation.

3.4. Elementary Test Situations

In order to find all differences between knowledge bases, we need to find their internal difference, all situations that the knowledge bases are different in, and their difference sets in these situations. There can be a lot of possible situations. If function symbols are used in terms, then there can be the infinite number of situations. It is not possible to check all off them. We will show that instead of the checking of all possible situations it is sufficient to check test situations that we will define below. We need some additional definitions to this aim.

Definition 4. A substitution instance of a formula without negative literals is called an *elementary substitution instance*, if the substitution replaces all variables by variable-free terms (constants), and:

- 1) these constants have no functional symbols,
- 2) these constants do not belong to the Herbrand universe of the knowledge base (i.e. they are not used in the knowledge base),
- 3) different variables are replaced by different constants.

Definition 5. Let KB_1 and KB_2 be two knowledge bases to be compared. Let KB_1 contains a rule $C \leftarrow A, \text{not } P_1, \dots, \text{not } P_n$ ($n \geq 0$, A consists of atoms or is the empty set, P_1, \dots, P_n are atoms). A set of facts E is called an *elementary test situation*, if one of the following conditions is true:

- 1) $E = A\theta$, where $A\theta$ is an elementary substitution instance of A (if $A = \emptyset$, then this condition is not considered),
- 2) $A\theta \subset E$, where $A\theta$ is an elementary substitution instance of A , and the knowledge base KB_2 contains at least one rule $D \leftarrow B, \text{not } R_1, \dots, \text{not } R_m$ ($m > 0$, B consists of atoms or is the empty set, R_1, \dots, R_m are atoms) such that $B\theta \setminus V_2 \subseteq A\theta$, where V_2 is the set of internal facts of KB_2 , and there exists R_i ($1 \leq i \leq m$) such that $R_i\theta \in E$.

This definition means that if the positive part of the antecedent of a rule is a subset of a positive part of the antecedent of a rule from another knowledge base, then facts from the negative part of the antecedent must be also considered in constructing elementary test situations.

We propose the following algorithm for the construction of an elementary test situation from a knowledge base rule:

1. Construct the elementary substitution instance of the positive antecedent part of a rule in the following way:

- 1.1. replace every variable with a constant, using the variable name. If variables start from a capital letter like in Prolog, then the constant can be obtained just by replacing capital letters with the same small (lower-case) letters (for example, a variable X can be replaced with a constant x).

- 1.2. if the obtained constant belongs to the Herbrand universe of KB_1 or KB_2 , we need to change its name in order to obtain a distinct constant. To this aim, its name can be appended by a symbol, for example, "1" (in this case, the constant abc will be changed to $abc1$). If the obtained constant still belongs to the Herbrand universe, the same symbol is added again. This process proceeds as long as we receive a distinct constant.

2. Apply the elementary substitution instance to the positive part of the rule antecedent. The obtained set of facts is an elementary test situation. If we take an example from an SLA, the elementary test situation generated from $\text{maintenance}(\text{Service})$ will be $\text{maintenance}(\text{service})$. It is obtained by replacing the variable Service with the constant service . Such constant can be understood as a representative of possible values of the variable.

3. If KB_2 contains rules with negative literals that satisfy the condition of the part 2 of the Definition 5, construct additional elementary test situations, using various combinations of facts from negative parts of the rules, according to the part 2 of the Definition 5.

In order to compare knowledge bases (that represent SLAs in our case), we need to construct elementary test situations from all rules, and then generate models from them in different knowledge bases. The result of the comparison is a set of those test situations that lead to different conclusions, and the corresponding difference sets, as defined in Section 3.3.

Example 5. The example below shows two knowledge bases and models, generated from different elementary test situations. The situations were constructed according to the algorithm above, and models are generated using model generating algorithm described in Section 3.2. There are four elementary test situations: $\{S(x)\}$, $\{S(x), P(a)\}$, $\{S(x), R(x)\}$, and $\{S(x), P(a), R(x)\}$. As we can see, the knowledge bases are different (have different conclusions) in the situation $\{S(x), P(a)\}$ only. For this test situation, the conclusion $Q(x)$ is obtained only in KB_1 , and the conclusion $R(x)$ is obtained only in KB_2 .

KB_1	KB_2
$R(X) \leftarrow S(X), \text{ not } P(a)$	$R(X) \leftarrow S(X)$
$Q(X) \leftarrow S(X), \text{ not } R(X)$	
$\{S(x)\} \cup KB_1 \vdash_M \{S(x), R(x)\}$	$\{S(x)\} \cup KB_2 \vdash_M \{S(x), R(x)\}$
$\{S(x), P(a)\} \cup KB_1 \vdash_M \{S(x), P(a), Q(x)\}$	$\{S(x), P(a)\} \cup KB_2 \vdash_M \{S(x), P(a), R(x)\}$
$\{S(x), R(x)\} \cup KB_1 \vdash_M \{S(x), R(x)\}$	$\{S(x), R(x)\} \cup KB_2 \vdash_M \{S(x), R(x)\}$
$\{S(x), P(a), R(x)\} \cup KB_1 \vdash_M \{S(x), P(a), R(x)\}$	$\{S(x), P(a), R(x)\} \cup KB_2 \vdash_M \{S(x), P(a), R(x)\}$

3.5. Theorems about Elementary Test Situations

In this section, we present theorems about the sufficiency of using elementary test situations in order to find differences between knowledge bases. The first theorem is formulated for Horn logic programs, and the second one is for non-Horn logic programs.

Theorem 1. *Let KB_1 and KB_2 be knowledge bases defined as Horn logic programs. Then KB_1 and KB_2 are different if and only if there is an internal difference between them or they are different in an elementary test situation.*

Proof. Sufficiency of the condition is obtained directly from Definition 3.

Let's prove necessity of the condition. According to Definition 3, knowledge bases are different in two cases: (a) if there is an internal difference between them, or (b) if they are different in some situation S . The first case is repeated in the formulation of the theorem, so this case is proved. Let's prove the theorem in the second case, using proof by contradiction.

Let $d \in \text{Diff}(S, KB_1, KB_2)$, and d is generatable from $S \cup KB_1$ and not generatable from $S \cup KB_2$. Let's construct a sequence $T = [t_0, \dots, t_n]$ of ground substitution instances of KB_1 clauses such that: (a) for each i ($0 \leq i \leq n$) and for each antecedent element A_{ij} of the clause t_i , either $A_{ij} \in S$ or A_{ij} is an internal fact of KB_1 or there exists $k < j$ such that A_{ij} is a consequent of t_k (that is the rules are linked in a chain), (b) d is a consequent of t_n .

Let's prove that at least one of the following statements is true: (1) in sequence T , there exists $C_S \leftarrow A_S$ such that A_S is an internal fact of KB_1 and does not belong to the model of KB_2 , (2) in sequence T , there exists $C_S \leftarrow A_S$ such that if $A_S \cup KB_2 \vdash_M M$ then $C_S \notin M$. This is true, because otherwise d would be generatable from $S \cup KB_2$, contrary to our assumption that $d \in \text{Diff}(S, KB_1, KB_2)$.

The truth of the first statement means that the knowledge bases have internal difference, and the theorem is proven in this case.

Let's consider the second statement. Let $C_S \leftarrow A_S$ be obtained from $C \leftarrow A$ using a substitution σ . Let's prove, that if we replace this substitution by a substitution θ such that $A\theta$ is an elementary substitution instance of formula A , then $C\theta$ is not generatable from $A\theta \cup KB_2$ just as $C\sigma$ is not generatable from $A\sigma \cup KB_2$. Then the theorem will be proven, and $E = A\theta$.

Let's consider different cases of an element X/t (X – variable, t – term) of the substitution. We use notation $P(\dots X \dots)$, where P is a predicate name, and X is occurrence of the variable, for example, $P(X)$, $P(X, Y)$, $P(b, f(a, X), c)$, etc. Let's consider what is the substitution instance of $P(\dots X \dots)$ for different types of t in the substitution X/t , and what formulas can be unified with it:

t	$P(\dots X \dots)\{X/t\}$	Can be unified with
$x, x \notin U_H$	$P(\dots x \dots)$	$P(\dots Z \dots)$
$a, a \in U_H$	$P(\dots a \dots)$	$P(\dots Z \dots), P(\dots a \dots)$
$f(x)$	$P(\dots f(x) \dots)$	$P(\dots Z \dots), P(\dots f(Z) \dots)$
$f(a)$	$P(\dots f(a) \dots)$	$P(\dots Z \dots), P(\dots f(Z) \dots), P(\dots f(a) \dots)$
$g(f(x))$	$P(\dots g(f(x)) \dots)$	$P(\dots Z \dots), P(\dots g(Z) \dots), P(\dots g(f(Z)) \dots)$
$g(f(a))$	$P(\dots g(f(a)) \dots)$	$P(\dots Z \dots), P(\dots g(Z) \dots), P(\dots g(f(Z)) \dots), P(\dots g(f(a)) \dots)$
...

Here U_H is the Herbrand universe of the union of knowledge bases $KB_1 \cup KB_2$. We see that if an element X/t of the substitution (t is an arbitrary term) is changed to X/x (x is a constant that does not belong to Herbrand universe), we will have less formulae that can be unified with the obtained substitution instance. Consequently, number of applicable rules can decrease, but not increase. Additionally, the set of applicable rules can be narrowed if the initial substitution replaces different variable by the same term, whereas we replace them with distinct terms. As an example let's consider $P(X,Y)\{X/t,Y/t\}=P(t,t)$. This substitution instance can be unified with $P(Z,V)$ and $P(Z,Z)$, whereas $P(X,Y)\{X/x,Y/y\}=P(x,y)$ and this substitution instance can be unified only with $P(Z,V)$. So, the set of rules that can be applied to the situation $A\theta$ at the first step of the model generating is a subset of rules which are applicable for the situation $A\sigma$ at the first step. After we apply these rules we receive the same conclusions as in the case of the initial substitution, but we will have X/x instead of X/t . Therefore, the set of later applicable rules can also shrink, but not expand. If we continue, we will see that the generated model is a subset of the initial model, only with another substitution for X . Analogical consideration of other elements of the substitution θ will lead to the conclusion that if $C\sigma$ is not generatable from $A\sigma \cup KB_2$, then $C\theta$ is not generatable from $A\theta \cup KB_2$. The theorem is proven. ■

We may conclude that an elementary substitution instance of every rule antecedent is a representative of situations for which model generating is passing through these rules. In this sense, the whole set of such instances covers the set of all possible situations. To the aim of the difference finding, the check of the elementary instances can be used instead of the check of all possible situations.

Theorem 2. *Let KB_1 and KB_2 be knowledge bases defined as non-Horn logic programs and satisfying the restrictions of bound variables, exactly one model and finite model. Then KB_1 and KB_2 are different if and only if there is an internal difference between them or they are different in an elementary test situation.*

Outline of proof. Sufficiency of the condition is obtained directly from Definition 3. If there is an internal difference between the knowledge bases, necessity of the condition is also obtained directly from Definition 3. If there is no internal difference, the necessity can be proved by contradiction. Let's assume that the knowledge bases are not different in any elementary test situation, but different in some other situation. This difference can be caused by the case when negative parts of one or more rules have facts that prevent the consequent from being included in the model. However, these negative parts are included in corresponding elementary test situations; therefore, there would also be a difference in these situations, contrary to our assumption. Sufficiency of using elementary substitution instances in test situations can be proven analogically as in Theorem 1, i.e. by analyzing conclusions from different types of substitutions. ■

4. Conclusions

The proposed method of the comparison of SLAs makes use of elementary test situations for detecting differences between SLAs. In order to get all conclusions derivable from a particular situation and to compare them, we use formal proof that is based on model generating. We concluded that an elementary substitution instance of every rule antecedent is a representative of situations for which the model generating is passing over these rules, and the whole set of such instances covers the set of all possible situations. To the aim of the

difference finding, the check of the elementary instances can be used instead of the check of all possible situations.

The detection of differences is useful not only for the choosing of a SLA, but also for the negotiating of SLAs and managing changes in SLAs. Indeed, one change can cause outcomes that are not observable at once, because they are derivable by rule chains.

Such comparison is not expedient as a frequently executed operation. Model generating can cause problems in real-time use because lots of rules fire in any cycle and many conclusions are drawn, leading to a lot of redundancy in the memory-based fact base. However, the method can be used before establishing long-term SLAs. Results of the comparison are presented for the analysis that can be performed by a human or by an intelligent agent according some stated criteria.

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References

1. Alkandari, F., Paige, R.F.: Modelling and Comparing Cloud Computing Service Level Agreements. In: Proceedings of the 1st International Workshop on Model-Driven Engineering for High Performance and Cloud Computing (MDHPCL'12). pp. 3:1–3:6. ACM New York (2012)
2. Andrieux, A., Czajkowski, K., Dan, A., Keahey, K., Ludwig, H., Nakata, T., Pruyne, J., Rofrano, J., Tuecke, S., Xu, M.: Web Service Agreement Specification (WS-Agreement). Open Grid Forum (2007)
3. CSMIC (2014), <http://csmic.org>. Accessed July 08, 2014
4. Erl, T.: Service-Oriented Architecture (SOA): Concepts, Technology, and Design. Prentice Hall (2005)
5. Garg, S.K., Verseteg, S., Buyya, R.: SMICloud: A Framework for Comparing and Ranking Cloud Services. In: Proceedings of the 4th IEEE International Conference on Utility and Cloud Computing (UCC 2011). pp. 210–218. IEEE Computer Society (2011)
6. Haq, I.U., Paschke, A., Schikuta, E., Boley, H.: Rule-Based Workflow Validation of Hierarchical Service Level Agreements. In: 2009 Workshops at the Grid and Pervasive Computing Conference. pp. 96–103. IEEE (2009)
7. Kyriazis, D. (editor): Cloud Computing Service Level Agreements - Exploitation of Research Results. European Commission, Directorate General for Communications Networks, Content and Technology (2013)
8. Ludwig, H., Keller, A., Dan, A., King, R.P., Franck, R.: Web Service Level Agreement (WSLA) Language Specification. IBM Corporation (2003)
9. Maurer, M., Emeakaroha, V.C., Brandic, I., Altmann, J.: Cost–benefit analysis of an SLA mapping approach for defining standardized Cloud computing goods. *Futur. Gener. Comput. Syst.* 28 (1), 39–47 (2012)
10. Moghaddam, M., Davis, J.G.: Service Selection in Web Service Composition: A Comparative Review of Existing Approaches. In: *Web Services Foundations*. pp. 321–346. Springer-Verlag (2014)
11. Paschke, A.: RBSLA: Rule-Based Service Level Agreements – knowledge representation for automated E-contract, SLA and policy management. Institut für Informatik der Technischen Universität München (2007)
12. Paschke, A., Bichler, M.: Knowledge representation concepts for automated SLA management. *Decis. Support Syst.* 46 (1), 187–205 (2008)

Confirming a Taxonomy of Decision Constructs in Business-to-Consumer Commercial Transactions

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Abstract

One might assume information systems (IS) are developed so systems enhance the user experience and facilitate a satisfying, productive interaction. From prior research, the authors established this assumption was not safe and certain design features amongst some online retailers were atypical of 'good' design elsewhere. It was apparent the transactional process was being used to present consumers with optional extras (and other decisions) that not only slowed the process down, but also stressed and agitated users. The research identified some new and unusual decision constructs such as the 'must-opt'. The objective of the research presented herein is two-fold: to make an incremental contribution in first theorizing and then identifying and categorizing into a taxonomy some new decision constructs alongside established ones encountered throughout on-line Business-to-Consumer (B2C) transactional processes followed by a preliminary study confirming their existence.

Keywords: IS development, User experience, Website design, Must-opt, Decision constructs.

1. Introduction

Many consumers are now experienced in purchasing goods and services online. It may be reasonable to assume they are quite familiar with the transactional process and able to navigate comfortably toward the final payments page. From prior research [2], [17], the authors established this assumption was unsafe and consumers exhibited significant levels of frustration and confusion. The transactional process was being used to present consumers with optional extras (and other decisions) that not only slowed the process down, but also stressed and agitated users through the use of atypical design features.

This paper is concerned with Business-to-Consumer (B2C) purchasing transactions. The non-transactional aspect is the browsing interaction that consumers engage in as they peruse and explore websites. Consumers may add items to a basket or shopping trolley but nothing is really psychologically committed until they complete their product selection and head for the checkout. Thereafter, they have passed the 'committal point' and begin the transactional process, the part of the interaction that interests the authors. This process between a business and a consumer is comprised of a number of decisions, typically across a number of pages, until payment is made and the process concluded. The critical importance of the user and their interaction with information systems is generally recognised and there is a universal supposition that a central objective of systems development is to maximise usability and deliver a satisfying user experience [14, 15, 16]. It is expected IS/IT practitioners employ good web design practices and consider the user in the development of interactions that are usable, useful and, often, enjoyable. In practice, most businesses seek to offer a satisfying

user experience, are honest brokers of their product and treat consumers fairly. Not all firms, however, are so benign – whether through neglect or clear intent. The transactional processes of some are peppered with elements that seem designed to force consumers to slow down, sometimes stop and perhaps accidentally select options they did not intend. To understand why consumers are experiencing these intermittent junctures, it was first necessary to categorize the types and the nature of decisions encountered in the transactional process.

The study is not concerned with decisions core to the actual product or service, such as quantity, shoe size or colour. It is the decisions that involve some element of optionality that are of more interest in this paper. Each decision point presents some form of a decision ‘construct’. A construct is a graphical user interface (GUI) control or mechanism that allows a user, in this case, to make a selection. Early controls were radio buttons, checkboxes, drop-down lists, spinners and sliders. New technologies have meant, for example, icons as buttons or images, or interactive elements may be presented on-screen or in pop-ups or as widgets. The authors, by means of theorizing and analysing websites have proposed an exhaustive taxonomy of decision constructs, which is laid out in Section 4 and followed by a study presented in Section 5 confirming their existence.

Another dimension of decision constructs is question framing. Questions may be framed in terms of acceptance (e.g., I would like to receive e-mail) or rejection (e.g., I would not like to receive e-mail). Alternatively, Lai and Hui [10] described these as ‘choice’ and ‘rejection’ frames, where positive phrasing corresponds with choice and negative phrasing corresponds with rejection of an option. This framing is discussed in detail in Section 2.2.

2. Regulations and Studies on Optional Charges and Pricing

2.1. Regulatory Attention

The Office of Fair Trading in the UK [1] carried out a study on the impact of pricing practices on consumer behaviour. In this study, they described a process referred to as ‘drip pricing’. The tactic is to present the user with an element of the price up front and then present additional components as ‘drips’ throughout the buying process. The drips can be either compulsory, where they are inherent to the price of the product (e.g., shipping cost) or optional, where they are generally add-ons (e.g., an optional warranty). These ‘drips’ can be presented in a variety of ways including opt-ins and opt-outs.

The European Union (EU) has addressed the notion of optionality in a number of regulations. Direct marketing email messages may be sent only to subscribers who have given their prior consent (‘opt-in’) [5]. The notion of ‘opt-in’ was further considered for optional price supplements for the airline industry [6]. Article 23(1) of this regulation states “optional price supplements shall be communicated in a clear, transparent and unambiguous way at the start of any booking process and their acceptance by the customer shall be on an ‘opt-in’ basis”. The concept of optional price supplements was further clarified by European Court of Justice [4] who, in a judgement, stated optional price supplements are not unavoidable and are neither compulsory nor necessary for the carriage of passengers or cargo. This distinction informs our presentation of essential and optional constructs in Section 4. While the regulation only applies to airlines, its reference to optional price supplements is clear and could be used to define optional price supplements on other e-commerce sites.

The EU has introduced a new directive on consumer rights [7] whose intent is to protect the consumer in distance contracts, including e-commerce transactions. This directive states additional payments above and beyond the minimum cost of the transaction require the explicit consent of the consumer. They also recognise consumers need to be protected against unscrupulous practices that may result in an inadvertent purchase that is not a necessary part of the transaction. However, neither piece of legislation described above defines what is meant by an ‘opt-in’ or what type of constructs are allowed where the consumer must make a decision on an optional extra. It is therefore at the discretion of the vendor to determine the most suitable method of obtaining the consent.

2.2. Research on Option Framing

Much research, albeit not in the area of e-commerce, has been carried out to determine whether users are more likely to participate when an option is framed as an opt-out rather than an opt-in [8, 9], [11, 12]. They generally conclude an individual is more likely to retain the default option than to change it even if the decision is detrimental to them. That is, they are more likely to participate if an option is presented as an opt-out, rather than an opt-in. Johnson and Goldstein [8] also found there was little difference in acceptance rates between an opt-out and a must-opt (see Section 4.4 for a full explanation and Table 1 for an illustration). The reasons identified for this negligible difference are participant inertia and a perception that the presentation of a default is a recommendation.

Previous studies [3], [10] have examined the impact of question framing on user decisions. They found users were more likely to accept an option when the language was expressed in an acceptance format rather than a rejection format for both opt-in (e.g., ‘Please send me newsletters’ with the checkbox un-ticked versus ‘Please do not send me newsletters’ with the checkbox ticked) and opt-out (e.g., ‘Notify me about more health surveys’ with the Yes button pre-selected).

3. Research Approach

It is necessary, in as far as possible, to identify an exhaustive list of the various decision constructs users encounter when purchasing a product or service whilst on-line and to consider some of the more salient factors that surround the process. As outlined earlier, the authors had noted a number of decision constructs that did not conform to typical design patterns in user interactions in the airline industry [2]. Thus, a study was conducted to examine e-commerce transactions to identify and categorize various forms of decision constructs. It was comprised of two parts as outlined below.

Initially the authors, by means of theorizing and analysing websites, proposed an exhaustive taxonomy of decision constructs. The methodology involved identifying the highest-level meta-categories and sub-dividing each logically until a series of mutually exclusive constructs were identified. A large number of retailers’ websites were explored and on some, several products or services were studied. This discussion is laid out in Section 4. Secondly, 195 decision constructs during typical B2C encounters across 25 representative B2C websites were examined in detail. The study is presented in Section 5.

4. Identifying Decision Constructs

4.1. Essential versus Optional Decisions

The transactional process on each website is normally made up of a number of sequential webpages that end in a payments page. During the process, and after the core product or service has been selected, the user is presented with various decisions points. Most of these decision points relate to real ‘options’ that may or may not be chosen. The customer will be able to complete the purchase without choosing the option, such as an extended warranty. It is an ancillary aspect of the product or service usually at an extra cost. However, there are also common decisions that must be made involving some element of choice. Such decisions are ‘essential’ to obtaining the product or service. Examples of these would be choosing a delivery method or choosing between different payment methods. Thus, the first meta-category of decisions is whether they are essential or truly optional.

4.2. Opt-in versus Opt-out

Optionality proffers the proposition that an option presented to a user is a straightforward choice - you either wish to secure the option or not. In reality, optionality is far more complex. When the European Union recognized particular problems within the airline

industry in how they dealt with the presentation of an optional extra or charge, they produced a directive [6], stating “all optional price supplements should only be accepted by the consumer on an ‘opt-in’ basis”. However, it did not define what is meant by an opt-in. Some firms appear to have taken great care to reflect considerably on this concept. In seeking to clarify this, various dictionaries were consulted. While they were broadly similar, the most relevant, pertinent definitions were found in Wiktionary.org [18]:

- To opt-in - of a selection, the property of having to choose explicitly to join or permit something; a decision having the default option being exclusion or avoidance.
- To opt-out - of a selection, the property of having to choose explicitly to avoid or forbid something; a decision having the default option being inclusion or permission.

4.3. Un-selected versus Pre-selected

In exploring various decision constructs it soon became clear that some opt-in, opt-out and essential decisions were sometimes un-selected and sometimes pre-selected. Some ways in which the decision is presented are quite peculiar. Opt-in decisions normally involve explicitly choosing one of a number of options, thus, an *un-selected opt-in*. However, a *pre-selected opt-in* is more ambiguous. A ticked check box, for example, is suggestive of something having been pre-selected for the user. However, using rejection framing such as ‘I do *not* want an extended warranty’, the action of un-ticking the box means the user opts-in. The juxtaposition of pre-selection (something appears chosen) against negative framing (something not being received) is counter-intuitive and is likely to be deliberate design.

Table 1: Taxonomy of transactional decision constructs

Decision Construct	Description	Illustration
Un-selected opt-in	<ul style="list-style-type: none"> • Default: don't receive the option • Normal presentation: un-ticked • Framing: acceptance 	<input type="checkbox"/> I want an extended warranty
Pre-selected opt-in	<ul style="list-style-type: none"> • Default: don't receive the option • Normal presentation: ticked • Framing: rejection 	<input checked="" type="checkbox"/> I do not want an extended warranty
Un-selected opt-out	<ul style="list-style-type: none"> • Default: receive the option • Normal presentation: un-ticked • Framing: rejection 	<input type="checkbox"/> Quote valid for 30 days. We would like to email you reminders over this period. If you don't wish to receive these emails please tick here.
Pre-selected opt-out	<ul style="list-style-type: none"> • Default: receive the option • Normal presentation: ticked • Framing: acceptance 	<input checked="" type="checkbox"/> Transit Insurance (optional) €0.75
Must-opt	<ul style="list-style-type: none"> • Default: cannot proceed • Normal presentation: multiple option variants, one of which allows the option to be declined, all un-ticked • Framing: normally acceptance 	Additional drivers: <input type="radio"/> Yes <input type="radio"/> No
Un-selected essential decision	<ul style="list-style-type: none"> • Default: cannot proceed • Normal presentation: multiple decision variants, all un-ticked • Framing: normally acceptance 	<input type="radio"/> Express delivery in 2 days (€5.00) <input checked="" type="radio"/> Fast delivery in 3-4 days (€2.00) <input type="radio"/> Free delivery in 5-7 days (free)
Pre-selected essential decision	<ul style="list-style-type: none"> • Default: variant selected • Normal presentation: multiple decision variants, one ticked • Framing: normally acceptance 	<input type="radio"/> FREE Super Saver Delivery (4-5 business days) <input checked="" type="radio"/> Standard (3-4 business days) <input type="radio"/> Two-Day Delivery : get it on Monday, December 9

Opt-out decisions normally appear as a pre-selected tick in a checkbox with associated acceptance framing, e.g., ‘I want an extended warranty’. However, an opt-out construct can

be designed so that it is un-selected, appearing like a ‘normal’ opt-in decision. This construct requires the decision be framed to imply rejection or a negation of the decision (e.g., an un-ticked checkbox accompanied by the text ‘I do *not* want Collision Damage Waiver’). which is unconventional and extraordinarily confusing. Conventionally, a user might safely overlook an un-selected option, assuming it to be opt-in. However, the un-selected opt-out construct is designed so a user must tick a box to reverse out of the decision which may result in the user giving the option more consideration than otherwise. The same juxtaposition can be applied to essential decisions that may be pre-selected (e.g., a fast delivery method) or, more usually, un-selected (e.g., choice of a payment method), see Table 1.

4.4. Must-opt - Neither Opt-in or Opt-out

Previously, the authors identified and described a new decision construct (a ‘*must-opt*’ decision) in online transactions [2]. It appears its use in the airline sector was an attempt to side step the 2008 EU Directive [6]. A must-opt decision occurs when an optional extra is presented with no option selected, ostensibly an opt-in decision. However, it is not truly an opt-in since it is impossible to progress to the next webpage until the user explicitly accepts or rejects the option – thus, they must-opt. The normal presentation of a must-opt is multiple option variants, one of which allows the option to be declined (see Table 1).

4.5. A Taxonomy of Decision Constructs

From the discussion above, a taxonomy made up of seven decision constructs is proposed (see Table 1). While the authors believe they have identified all decision construct types in use across a range of sectors and commercial transactions, in time the number may increase as firms choose increasingly inventive ways of presenting users with optional extras.

5. Descriptive Analysis

A descriptive analysis of a number of websites accessible to Irish consumers was conducted in order to: (a) determine whether the decision constructs identified are, in fact, used in practice; and (b) determine whether any additional decision constructs need to be added to the list. A total of 25 websites were examined. The websites represented a number of different industry categories: Travel, Consumer Products, Financial Services, Accommodation, and Entertainment and Recreation with between 2 and 9 websites selected from each category.

Table 2. Illustrations of transactional decision constructs

Type of Decision Structure	Encounters by Sector				
	Financial Service (3 websites)	Travel (6 websites)	Consumer Products (9 websites)	Accommodation (2 websites)	Entertainment and Recreation (5 websites)
Pre-selected opt-in (n=6)	4	2	0	0	0
Un-selected opt-in (n=112)	20	57	7	18	10
Pre-selected opt-out (n=9)	1	1	4	2	1
Un-selected opt-out (n=5)	3	2	0	0	0
Pre-selected essential decision (n=15)	2	3	6	3	1
Un-selected essential decision (n=30)	3	5	9	2	13
Must-opt (n=18)	2	14	0	0	0
Total (n=195)	35	84	26	25	25
Mean number of decisions per transaction	11.67	14	2.89	12.5	5

A single representative task was chosen for each website (e.g., rent a car) and each decision point encountered during that transaction was recorded and examined in order to determine whether they could be categorised according to the construct types identified above. Some websites had multiple decision points, while others had very few (e.g., the Travel websites had a total of 84 decisions based on 6 websites whereas consumer products had 26 decisions based on 9 websites).

For the Travel, Accommodation and Financial Services websites, the mean number of decisions encountered per transaction was considerably higher than for Consumer Products and Entertainment & Recreation (see Table 2). The high number of decision points on both the Travel and the Financial Services websites is due to product deconstruction, now common in both sectors. This approach was also apparent in the Accommodation websites, with hotels offering multiple options, often at additional charge (e.g., flowers or wine in the room). However, Accommodation websites tended to offer the options in a simple un-selected opt-in format, whereas Financial Services and Travel websites used more complex structures such as pre-selected opt-ins, un-selected opt-outs and must-opt. The difference in approach meant while there were many options presented on the accommodation websites, a user could easily traverse the website without paying too much attention to the options. Ignoring the options meant the user simply purchased the base product without additional options.

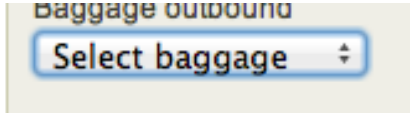

Presentation	Illustration
Pre-selected opt-in	<input checked="" type="checkbox"/> I do not want an extended warranty
Un-selected opt-out	<input type="checkbox"/> We would like to send you information about other products and services from FBD group companies (further info). If you do not wish to receive this information please tick here.
Must-opt using radio buttons	Additional drivers: <input type="radio"/> Yes <input type="radio"/> No
Must-opt using a dropdown menu	
Must-opt dropdown menu once clicked on	

Fig 1. Presentation of non-standard transactional decision constructs

In contrast, the more complicated decision constructs used by Financial Services and Travel websites made traversal of those websites more complicated, requiring careful scrutiny of the options offered in order to avoid inadvertent purchase. These included:

- Pre-selected opt-ins, where the user needs to do nothing in order to avoid purchase (see Figure 1). This construct requires more attention by the user as they may assume that a ticked box is an opt-out. If the user proceeds under this assumption and quickly de-selects without reading the text closely, they would inadvertently choose the option. This construct is made even more complex by the necessary use of negative framing that requires careful attention in order to fully grasp the meaning of the text.
- Un-selected opt-outs, where the user needs to ‘tick the box’ in order to avoid the purchase (see Figure 1). This construct is complex for similar reasons to the pre-

selected opt-in as it is a non-standard format. The normal format for an opt-out is a pre-selected opt-out where the user deselects in order to indicate they do not wish to select an option. A hurried user could easily presume that an un-selected checkbox is, in fact, an un-selected opt-in, resulting in inadvertent selection of the option. The negative framing also requires considered attention to fully understand the option.

- Must-opts, where the user must, for example, tick a box, indicating whether they wish to choose an option or not in order to continue with the transaction. While this format is less likely to result in inadvertent selection of an option, it does require that the user consider the option and then indicate whether they wish to select it or not.

A user could be easily forgiven for mistaking the must-opts in Figure 1 for un-selected opt-ins as there is no indication that the user must take action in order to make a decision. In the case of the radio buttons it would be reasonable for the user to presume that they were not required to consider the options unless they wished to add a driver. In the case of the dropdown menu, the user could also reasonably presume that no action is required unless they intend bringing carry-on luggage. Once the user clicks on the menu, it is more apparent that action is required. However, if the user has continued with the interaction without engaging with either of these must-opts, they will have no indication that action is required until they attempt to proceed to the next page. At this point they will be informed that they must specify whether they wish to add additional drivers or whether they wish to bring check-in baggage.

In addition to the use of non-standard formats, some of the websites use a variety of constructs for options. For example, an un-selected opt-in might be presented just before an un-selected opt-out, with the user having to pay close attention to ensure they fully understand the options. The travel websites also managed to introduce additional potential confusion by presenting the must-opts in multiple ways during a single transaction. For example, one must-opt could be presented as a drop-down menu, with the next must-opt presented using radio buttons arranged horizontally, and a third must-opt presented using radio buttons arranged vertically. This design requires the user to pay attention to all options, as they can never be sure what type of construct they have encountered until it has been examined carefully and the consequences of action or inaction considered.

6. Conclusions

This study set out to identify all possible ways in which essential and optional decision constructs can be presented to a user in on-line transactional processes and then proceeded to examine whether the constructs are used in practice and to identify any additional constructs that had been missed in the initial process. The genesis for the research question was to explore whether firms were acting in good faith in relation to consumer protection regulations. As noted earlier, the EU has recognised that programming constructs are being used to nudge consumers to behave in a way that airlines wish and have recently enacted additional legislation that applies to all distance contracts. It would appear these constructs are being used in many sectors. Furthermore, with the must-opt and other ambiguously presented decisions, it is clear EU regulations deal with the notion of optionality inadequately.

Based on this study, the authors believe they have captured all decision constructs presently in use. It is evident from the results of this study that firms, in most cases, are using obvious decision constructs that allow the user to make quick decisions that require little deliberation or thought. However, there are a small number of firms using more complex constructs such as the must-opt, the un-selected opt-out or the pre-selected opt-in for certain options, presumably in order to increase the likelihood of the user selecting the option. It would appear, in certain instances, the consumer needs to pay close attention to all decisions encountered if they are to successfully negotiate the obstacle course placed in their path throughout the course of a transaction.

It is likely firms will continue to behave inventively as they seek ways of attracting users attention to various ancillary products and services. The theory of cultural lag identified by Ogburn [13] is a resilient one in this case; firms are using new technologies to shape user behaviour in their favour - researchers and regulators take note.

7. Further Research

A number of issues emerged that will contribute to further research. Some of the constructs were encountered infrequently, while others were more prevalent. The number of websites examined will need to be expanded considerably in order to carry out statistical analysis on the results. Furthermore, subjective responses from consumers will form part of the proposed research framework. Factor analysis will be carried out in order to determine the nature of the relationships between independent variables such as industry category and decision constructs; and factors such as ease of use, level of persuasion, clarity and trust. Additionally, a more intense analysis of the presentation of the decision constructs will be conducted.

References

1. Ahmetoglu, G., Fried, S., Dawes, J. and Furnham, A.: Pricing Practices: Their Effects on Consumer Behaviour and Welfare. Prepared for the Office of Fair Trading by Mountain Learning (2010)
http://www.offt.gov.uk/shared_offt/business_leaflets/659703/Advertising-of-prices/Pricing-Practices.pdf. Accessed: 11/10/2013
2. Barry, C., Hogan, M. and Torres, A.: Perceptions of Low Cost Carriers' Compliance with EU Legislation on Optional Extras. In: 20th International Conference on Information Systems Development. Edinburgh, Scotland, August 24 - 26, (2011)
3. Belman, S., Johnson, E., and Lohse, G.: To Opt-In or Opt-Out? It Depends on the Question. *Communications of the ACM*. 44(2), 25-27 (2001)
4. eBookers.com Germany v BVV 2012. Case C-112/11, European Court of Justice Judgment. (2012)
5. European Union. 2002/58/EC. Directive on Privacy and Electronic Communications. (2002)
6. European Union. 1008/2008, Regulation of the European Parliament and of the Council on Common rules for the Operation of Air Services in the Community (recast). (2008)
7. European Union. 2011/83/EU, Directive on Consumer Rights. (2011)
8. Johnson, E. and Goldstein, D.: Do Defaults Save Lives? *Science*. (302), 1338-1339 (2003)
9. Junghans, C., Feder, G., Hemingway, H., Timmis, A., and Jones, M.: Recruiting Patients to Medical Research: Double Blind Randomised Trial of "Opt-in" Versus "Opt-out" Strategies. *British Medical Journal*. doi: 10.1136/bmj.38583.625613.AE (2005)
10. Lai, Y. and Hui, K.: Internet Opt-in and Opt-out: Investigating the Roles of Frames, Defaults and Privacy concerns. In *Proceedings of SIGMIS-CPR'06*, April 13-15, Claremont, California, USA (2006)
11. Madrian, B., and Shea, D.: The Power of Suggestion: Inertia in 401(k) Participation and Savings Behavior. *The Quarterly Journal of Economics*. 116(4), 1149-1187 (2001)
12. McKenzie, C., Liersch, M., and Finkelstein, S.: Recommendations Implicit in Policy Defaults. *Psychological Science*. 17(5), 414-420 (2006)
13. Ogburn, W.: Cultural Lag as Theory. *Sociology & Social Research*. 41(3), 167-174 (1957)
14. Rogers, Y. Sharp, H. and Preece, J.: *Interaction Design: Beyond Human-computer Interaction*. 3rd Edition. John Wiley (2011)
15. Shneiderman, B. & Plaisant, C.: *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. 5th Edition. Addison-Wesley Publishing (2010)
16. Sklar, J.: *Principles of Web Design*. Thomson Learning (2006)
17. Torres, A., Barry, C. and Hogan, M.: Opaque Web practices among low-cost carriers. *Journal of Air Transport Management*. 15, 299-307 (2009)
18. Wiktionary (2013), <http://en.wiktionary.org/wiki/opt-in>. Accessed: 12/7/2013

A Toolkit for ADM-based Migration: Moving from PHP Code to KDM Model in the Context of CMS-based Web Applications ¹

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Abstract

In the last few years, many organizations have based their Web applications on Content Management Systems (CMS) because of the advantages they provide to manage their huge amount of digital content. The objectives of these organizations change, for this reason they may see the necessity of migrating their CMS-based Web applications to other CMS platforms meeting better their needs. Thus, we propose a method based on Architecture-Driven Modernization (ADM) to automate this migration process. In this paper we present the toolkit supporting this ADM-based migration method. For space restrictions, we focus on the implementation of two modules of this ADM-based toolkit: i) the ASTM_PHP DSL, a modeling language which allows to model the code of a system implemented in PHP (ASTM_PHP models) and ii) the model-to-model transformation rules which allow to generate KDM models from the information captured in the ASTM_PHP models. To show its usability, we present a case study where a widget listing online users of a CMS-based Web application is migrated from Drupal to Wordpress.

Keywords: Content Management System; Web Application; Architecture-Driven Modernization; Reverse Engineering and Model-driven Engineering.

1. Introduction

In the last decade, the volume of digital content managed by Web applications has grown dramatically as well as the processes supported have become more complex. Thus, organizations have experienced the necessity of using powerful management platforms to maintain their large-scale Web applications and manage all their content in a robust and reliable manner [12]. One of the most adopted solutions has been to base Web applications on Content Management Systems (CMS) [1]. These CMS-based Web Applications provide with some features such as, dynamic creation of content or flexible functionality extension [24].

Currently, a considerable number of different CMS platforms is found in the market. This fact, along with the changes in the objectives of organizations, can cause organizations to see

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the necessity of migrating their CMS-based Web applications to other CMS platforms meeting better their needs.

This migration process entails a complex, time-consuming and error-prone reengineering process [5]. Currently, the Architecture-Driven Modernization (ADM) [15] is considered one of the most effective approaches to systemize this process and to mitigate their drawbacks. ADM advocates for the application of MDA (Model-Driven Architecture) [13] techniques and tools in the migration process. Furthermore, it develops a set of standard metamodels to represent the information involved in this process. Two of these metamodels are: the Abstract Syntax Tree Metamodel (ASTM) [14], which allows to represent at platform-specific level the syntax of the code implementing a legacy system, and the Knowledge Discovery Metamodel (KDM) [10] allowing to represent at platform-independent level the syntax and semantics of this code.

To the best of our knowledge, there is not any model-driven reengineering method in the literature [20] systemizing the migration process from a CMS-based Web applications to other CMS platforms. To solve this gap, we define an ADM-based migration method to support this process [21]. It is composed of three reengineering stages defining a “horseshoe” process [5]: *reverse engineering stage*, *restructuring stage* and *forward engineering stage*. Up to now, this method is focused on the migration of Web applications based on open-source CMS platforms such as Drupal [6], Joomla! [11] or Wordpress [25] because of the their spread use and relevant acceptance in the market [18]. Most of these open-source CMS platforms are implemented in PHP, so that we pay special attention on this code.

This paper presents the implementation of the toolkit supporting this ADM-based migration method. For space restrictions, we focus on the implementation of two modules: i) the ASTM_PHP Domain Specific Language (ASTM_PHP DSL), a modeling language based on the standard metamodel ASTM_PHP which allows to define platform-specific models which represent the code of a system implemented in PHP (ASTM_PHP models) and ii) the model-to-model (M2M) transformation rules which allow to generate KDM models, from the information captured in the ASTM_PHP models, which represent the syntax and semantics of the PHP code at a platform-independent level.

To show the usability of this ADM-based toolkit we present a case study where a widget listing online users of a CMS-based Web application is migrated from Drupal to Wordpress.

The rest of this paper is organized as follows: Section 2 provides an explanation of the ADM-based migration method which is supported by the toolkit presented. Section 3 presents the implementation of the two modules of the ADM-based toolkit. Section 4 presents the related works and finally, Section 5 presents the conclusions and future works.

2. An ADM-based Method for Migrating CMS-based Web Applications

The toolkit presented in this paper supports the ADM-based migration method presented in [21]. It is composed of three stages (Fig. 1 shows this process).

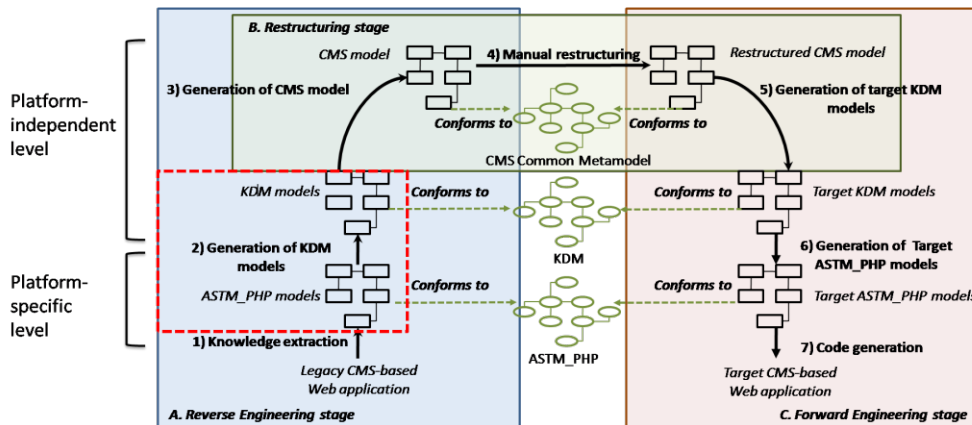


Fig. 1. ADM-based method for migrating CMS-based Web Applications.

A. Reverse engineering stage, this stage is composed of three tasks: 1) *the knowledge extraction*, focused on the extraction of ASTM_PHP models from PHP code by defining text-to-model (T2M) transformations; 2) *the generation of the KDM model*, focused on the M2M transformations generating the KDM models from the ASTM_PHP models.; 3) *the generation of the CMS model*, focused on the M2M transformations generating the CMS model from the KDM models. The CMS model contains the information involved in this migration process but represented into the CMS domain. It conforms to the CMS Common Metamodel [22].

B. Restructuring stage, in this stage the CMS model is manually restructured by the developer taking into account the specific features of the target CMS platform to which is intended to migrate.

C. Forward engineering stage, this stage represents a top-down development process. It is composed of three tasks: 5) *the generation of the target KDM model*, is focused on the M2M transformations generating the target KDM models from the restructured CMS model; 6) *the generation of the target ASTM model*, is focused on the M2M transformations generating the target ASTM_PHP models from the target KDM models and finally, 7) *the code generation*, generates the code implementing the target CMS-based Web application by defining automatic model-to-text (M2T) transformations.

The two modules presented in this paper are framed in the reverse engineering stage. Concretely, in *the generation of KDM models* task (see in Fig. 1 the part marked in a red dotted line).

3. The ADM-based Toolkit

In this section we present the implementation of the two modules of our ADM-based toolkit. Fig. 2.a shows the tasks composing the *reverse engineering stage* of our ADM-based migration method and Fig. 2.b presents the two modules of the ADM-based toolkit framed in *the generation of KDM models* task (see Fig. 1). On the one hand, we have the ASTM_PHP DSL, a modeling language which allows to define ASTM_PHP models representing the syntax of PHP code in a proper and non-ambiguous way (Section 3.2 presents its implementation); on the other hand, we present the implementation in ATL of the M2M transformation rules which automate the generation of KDM models from ASTM_PHP models (Section 3.3 presents its implementation).

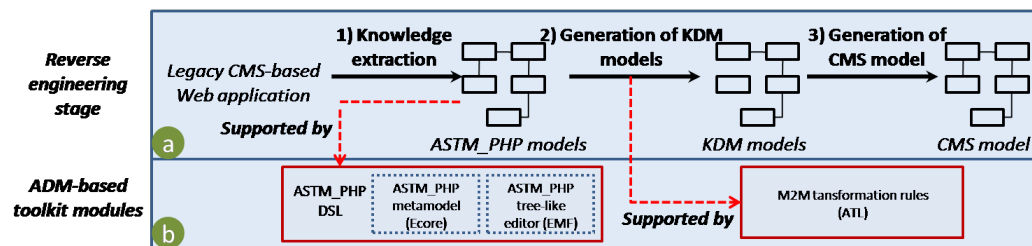


Fig. 2. a) Reverse engineering stage, b) ADM-based toolkit modules.

3.1. Case Study

To show the usability of our ADM-based toolkit, we present a case study where we migrate a widget listing online users from a CMS-based Web application implemented on Drupal to Wordpress. It is a Web application of a wellness and nutrition centre called Websana which provides users with information about diets, exercises and recommendations about healthy habits. Fig. 3.a shows this widget implemented in Drupal and Fig. 3.b in Wordpress.

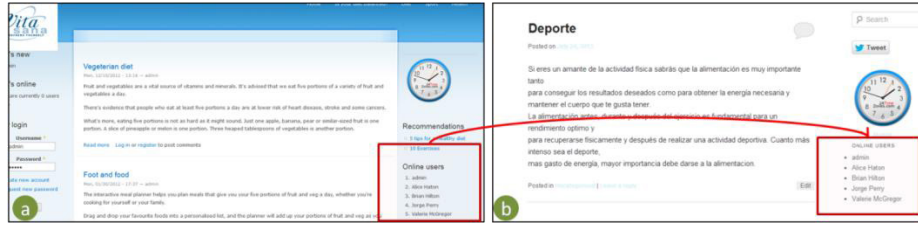


Fig. 3. a) Plugin Online users on Drupal, b) Plugin Online users on Wordpress.

3.2. Implementation of the ASTM_PHP DSL

As we can see in Fig. 2.b, the implementation of the ASTM_PHP DSL requires two tasks: the definition of the ASTM_PHP metamodel (abstract syntax) and the implementation of a tree-like editor (concrete syntax) [8] which allows to define graphically models conforming to the ASTM_PHP metamodel.

The ASTM_PHP metamodel captures all the required elements and their relationships in a model to represent the syntax of the PHP code which implements a system. It is defined as an extension of the standard metamodel ASTM and implemented as an Ecore model [4]. The ASTM metamodel has two parts: the Generic Abstract Syntax Tree Metamodel (GASTM) and the Specific Abstract Syntax Tree Metamodel (SASTM) [14]. For the definition of the ASTM_PHP metamodel, we have extended the SASTM with specific PHP elements. These elements can be classified in those which were not considered in GASTM and those even existing in GASTM did not fit well with the specification of the PHP element and need to be redefined. GASTM provides a set of abstract classes to be extended for defining the specific PHP elements within SASTM.

Table 1 presents all the classes included within SASTM. The first column refers to the abstract GASTM class which has been extended; the second column denotes the name of the SASTM class; the third column indicates whether the SASTM class is a new or redefined element and finally, the fourth column is a description of the SASTM class. Most of these SASTM classes represent new operators and expressions. Otherwise, three of them represent redefined elements (two statements and one expression).

Table 1. Classes composing SASTM.

GASTM class	SASTM class	New/Redefined	Description
BinaryOperator	Xor	New	Boolean operator
	NotIdentical	New	Boolean operator
	Identical	New	Boolean operator
	InstanceOf	New	Boolean operator
UnaryOperator	New	New	Creates an object
	Clone	New	Creates a copy of an object
Statement	ForStatementPHP	Redefined	For loop
	SwitchStatementPHP	Redefined	Switch condition
	ForEachStatement	New	For each loop
Expression	ObjectAccess	New	Access to a item of an object
	ClassAccess	New	Access to a item of a class
	DuplaArray	New	An entry of an array
	ArrayAccessPHP	Redefined	Array access in PHP

The implementation of the tree-like editor is based on the Eclipse Modeling Framework (EMF) [4]. This framework allows implementing automatically the tree-like editor from a generator model (GenModel). From this GenModel, EMF generates the Java code organized in three different packages: the model code, editing model, the editor code and code for the testing. To illustrate the ASTM_PHP DSL, we define in Fig. 4 a model by using the tree-like editor which represents the PHP code of the widget of our case study.

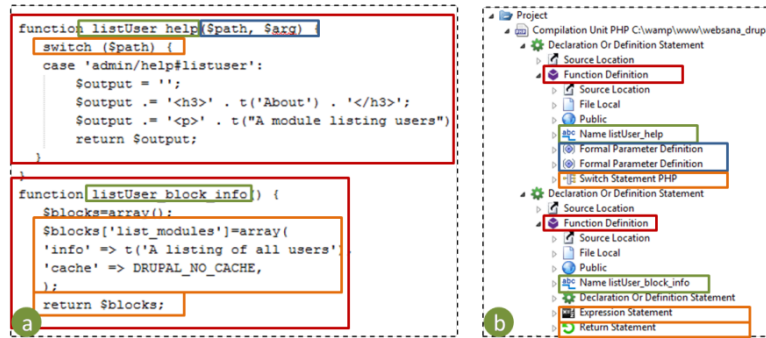


Fig. 4. a) PHP code, b) ASTM_PHP model.

Fig. 4.a shows the PHP code and Fig. 4.b represents the corresponding ASTM_PHP model. As we can see, we have marked in red the function definitions and in green the name of these functions. Furthermore, we have marked in blue the parameters passed to the functions. Finally, we have denoted in orange some of the sentences composing the body of the functions (switch sentence, an array definition and a return sentence).

3.3. Implementation of the M2M Transformation Rules

As we can see in Fig. 2.b, the other module is the M2M transformation rules which support the generation of KDM models from ASTM_PHP models. Their main aim is to raise the abstraction level generating platform-independent models (KDM models) from platform-specific models (ASTM_PHP models). These M2M transformation rules are firstly defined in nature language (see Table 2) and then implemented in Atlas Transformation Language (ATL) [7].

The transformation rules presented in Table 2 correspond to the elements found in the ASTM_PHP model in Fig. 4.b. On the one hand, the first and second column refers to the ASTM_PHP classes and their attributes. On the other hand, the third and fourth column refers to the KDM classes and their attributes.

Table 2. Definition of M2M transformation rules: ASTM_PHP \rightarrow KDM.

ASTM_PHP class	Attributes	KDM class	Attributes
Function Definition	accessKind, identifierName formalParameters body	MethodUnit	export = accessKind name = identifierName codeElement = formalParameters, body
FormalParameter Definition	locationInfo identifierName definitionType	Parameter Unit	source = locationInfo name = identifierName type = definitionType
SwitchStatement PHP	switchExpression cases	Action Element	kind = switch codeElement = switchExpression, cases
Expression Statement	expression	Action Element	kind = expression
ReturnStatement	returnValue	Action Element	kind = return codeElement = returnValue,

For space limitations, we just explain the transformation rule from the *FunctionDefinition* class to *MethodUnit* class. The main attributes of the *MethodUnit* class are: *export*, *name* and *codeElement*. The *export* attribute represents the visibility of the method and takes its value from the attribute *accesskind*. The *codeElement* attribute allows storing the sentences defined within the body of the function as well as the parameters passed. The values of this attribute are taken from the *body* and *formalParameters* attributes. Finally, the attribute *name* takes the value from the attribute *identifierName*.

A transformation rule implemented in ATL can be of three types: *mapped rules*, *called rules* and *lazy rules* [7]. Table 3 shows the implementation in ATL of the transformation rules defined in Table 2. The first column shows the ASTM_PHP classes (source class) and the

second column the KDM classes (target class). The third column presents the name of the transformation rule implemented in ATL and finally, the fourth column shows the type of the transformation rule (*matched*, *called* or *lazy rule*.)

Table 3. Implementation of transformation rules: ASTM_PHP → KDM.

ASTM_PHP class	KDM class	Name	Type
FunctionDefinition	MethodUnit	functionDef2MethodUnit	matched
FormalParameterDefinition	ParameterUnit	CreateParameterUnit	called
SwitchStatementPHP	ActionElement	Switch2Action	matched
ExpressionStatement	ActionElement	ExpressionStatement2Action	matched
ReturnStatement	ActionElement	Return2Action	matched

Fig. 5 shows the implementation in ATL of the transformation rule *functionDef2MethodUnit*. It is implemented as a *matched rule*. The source pattern (*from*) defines a variable called *funcdef* representing the *FunctionDefinition* class (line 3). Otherwise, the target pattern (*to*) creates a variable called *meth* representing the *MethodUnit* class (line 5). In the target pattern the attributes *name*, *export* and *codeElement* are mapped from the attributes of the *FunctionDefinition* class (lines 6-11). To map the parameters from the attribute *formalParameters* it is required to create a *Signature* element created with the called rule *CreateSignature* (line 9). The execution of this matched rule has allowed us to represent correctly in the KDM model all the function definitions in PHP required to implement the widget listing online users of our case study.

```

1 rule functionDef2MethodUnit {
2   from
3     funcdef: astm!FunctionDefinition
4   to
5     meth: kdm!MethodUnit (
6       name <- funcdef.declOrDefn.identifierName.getName.debug('path'),
7       export <- funcdef.declOrDefn.accessKind.getExportKind,
8       codeElement<-funcdef.declOrDefn.body
9       codeElement <- thisModule.createSignature
10      (funcdef.declOrDefn.identifierName.getName,
11       funcdef.declOrDefn.formalParameters),
12    )

```

Fig. 5. FunctionDef2ActionElement ATL rule.

4. Related Works

In this section, we present some of the existing ADM-based approaches found in the literature and compare them with our ADM-based migration method [21] (see Table 4). Due to space limitations only we present the most representative ones.

Van Hoorn et al presents in [9] DynaMod, a method which addresses the model-driven modernization of software systems. It considers static and dynamic analysis for extracting models conform to KDM from Java code. Sadovykh et al presents in [19] a method to extract an UML (Unified Modeling Language) [2] models containing the most persistent part of a system from C++ code. Perez-Castillo et al presents in [16] a reengineering process called PRECISO to recover and implement Web Services in automatic manner from relational databases. They extract a model conform to a SQL-92 metamodel from SQL-92 code. Bruneliere et al presents in [3] MoDisco an extensible approach for model-driven reverse engineering which allows extracting platform-specific models from Java, XML and JSP code. They define three metamodels one for each type of code. Reus et al presents in [17] a reverse engineering process for recovering UML models from PL/SQL code. Vasilecas et al presents in [23] a process which derives business rules from a legacy system. They extract ASTM models from Visual Basic code.

The second column in Table 4 refers to the source code from which the ADM-based approach extracts the models. We can find approaches extracting from Java, C++, SQL-92, XML, JSP and VisualBasic, but none of them addresses the extraction of models from PHP code. Thus, our ADM-based migration method would be the unique existing approach implementing text-to-model (T2M) transformations to extract a code from PHP code.

Table 4. Comparison ADM-based approaches.

Approach	Source code	Metamodel	Context	Toolkit
Van Hoorn et al (DynaMod)	Java	KDM	Generic context	Yes
Sadovykh et al	C++	UML	Generic context	Yes
Perez-Castillo et al (Preciso)	SQL-92	SQL-92	Data base / Web services	Yes
Bruneliere et al (Modisco)	Java, XML, JSP	Java, XML, JSP	Generic context	Yes
Reus et al	PL/SQL	UML	Data base	Yes
Vasilecas et al	Visual Basic	ASTM, KDM, SBVR	Generic context	Yes
Our ADM-based migration method	PHP	ASTM_PHP, KDM	CMS-based Web applications	Yes

The third column refers to the metamodels to which the models conform to. Two of them (Perez-Castillo et al and Bruneliere et al) bet for defining their own metamodels. The former propose a SQL-92 metamodel and the latter three metamodels the Java, XML and JSP. On the other hand, two approaches use the UML metamodel. Finally, two of the approaches (Van Hoorn et al and Vasilecas et al) use the ADM standard metamodels. The former defines models conforming to KDM and Vasilecas et al defines models according to ASTM and KDM. For our ADM-based migration method, we bet for the use of both metamodels.

The fourth column specifies the context of the approach. If the approach is framed in a generic reengineering context we have categorized it as a generic context. Thereby, three of the approaches have been categorized as such. On the other hand, two of them are focused on data base context. It is worth noting that none of them is focused on the context of CMS-based Web applications apart from our ADM-based migration method.

Finally, the fifth column denotes if the approach is supported by a toolkit. As we can see, all of the approaches found are supported by a toolkit to a greater or lesser extent.

5. Conclusions and Future Works

In the last years, organizations have experienced the necessity of using powerful management platforms to maintain their large-scale Web applications and manage all their content in a robust and reliable manner. One of the most adopted solutions has been to base Web applications on Content Management Systems. These CMS-based Web Applications provide organizations with many advantages.

The evolving objectives of organizations may cause them to experience the necessity of migrating their CMS-based Web applications to other CMS platforms meeting better their needs. This migration process entails a complex, time-consuming and error-prone reengineering process. We propose an ADM-based migration method to automate this process and to mitigate these drawbacks. Up to now, this method is focused on open-source CMS platforms which most of them are implemented in PHP. Furthermore, this method is supported by an ADM-based toolkit. In this paper we present the implementation of two of its modules: i) the ASTM_PHP DSL and ii) M2M transformations rules which allow to generate KDM models from ASTM_PHP models.

To define the ASTM_PHP DSL, we have defined an ASTM_PHP metamodel (abstract syntax). This metamodel extends the standard metamodel ASTM (concretely its SASTM part) with specific PHP elements. Moreover, a tree-like editor (concrete syntax) which allows defining graphically models conforming to the ASTM_PHP metamodel has been implemented using EMF. On the other hand, the M2M transformation rules have been defined firstly in natural language and then implemented in ATL.

To the best of our knowledge, the migration process of CMS-based Web applications is not supported by any model-driven reengineering method. Thus, we propose an ADM-based migration method supported by a toolkit to support this process. As for the application of

ADM, we can state that it is pretty applied by the reverse engineering approaches as well as its standard metamodels, mainly ASTM and KDM. Concretely, the use of KDM is more widespread than ASTM. Finally, we think that in the market there is a lack of comprehensive toolkits allowing the extraction of models from PHP code. So far, our migration method is focused on CMS-based Web applications implemented in PHP, so that as a future work, we plan to address the migration of these Web applications implemented in any code.

References

1. Boiko, B.: Understanding Content Management. *Bull. Am. Soc. Inf. Sci. Technol.* 28, 1, 8–13 (2001).
2. Booch, G. et al.: *The Unified Modeling Language User Guide*. Longman (1999).
3. Bruneliere, H. et al.: MoDisco : A Generic And Extensible Framework For Model Driven Reverse Engineering. *ASE '10*. pp. 173–174 (2010).
4. Budinsky, F.: *Eclipse Modeling Framework*, (2008).
5. Chikofsky, E.J., Cross, J.H.: Reverse Engineering and Design Recovery: A Taxonomy. *IEEE Softw.* 7, 1, 13–17 (1990).
6. Drupal: Drupal CMS, <http://drupal.org/>.
7. Eclipse Foundation: Atlas Transformation Language, <http://www.eclipse.org/at/>.
8. Fowler, M.: *Domain Specific Languages*. Addison Wesley Professional (2010).
9. Hoorn van, A. et al.: DynaMod Project : Dynamic Analysis for Model-Driven Software Modernization. 1st International Workshop on Model-Driven Software Migration. pp. 12–13 , Oldenburg, Germany (2011).
10. ISO/IEC: Information technology - Architecture-Driven Modernization (ADM): Knowledge Discovery Metamodel (KDM). (2012).
11. Joomla!: Joomla! CMS, <http://www.joomla.org/>.
12. McKeever, S.: Understanding Web content management systems: evolution, lifecycle and market. *Ind. Manag. Data Syst.* 103, 9, 686–692 (2003).
13. Mellor, S.J. et al.: Model-Driven Architecture. In: (Eds.), J.-M.B. and Z.B. (ed.) *Advances in Object-Oriented Information Systems*. pp. 233–239 Springer-Verlag (2002).
14. OMG: Abstract Syntax Tree Metamodel specification of the OMG, <http://www.omg.org/spec/ASTM/1.0>.
15. OMG: ADM task force.
16. Perez-Castillo, R. et al.: PRECISO: A Reverse Engineering Tool to Discover Web Services from Relational Databases. 16th Working Conference on Reverse Engineering. pp. 309–310 IEEE (2009).
17. Reus, T. et al.: Harvesting Software Systems for MDA-Based Reengineering. Second European Conference, ECMDA-FA. pp. 213–225 (2006).
18. Ric Shreves: Open Source CMS Market Share. (2008).
19. Sadovykh, A. et al.: Architecture Driven Modernization in Practice: Study Results. 2009 14th IEEE International Conference on Engineering of Complex Computer Systems. pp. 50–57 IEEE (2009).
20. Trias, F. et al.: A Systematic Literature Review on CMS-based Web Applications. *ICSOF*. (2013).
21. Trias, F. et al.: An ADM-based Method for migrating CMS-based Web applications. 25th SEKE. , Boston, EUA (2013).
22. Trias, F.: Building CMS-based Web Applications Using a Model-driven Approach. Sixth RCIS. pp. 1 – 6 (2012).
23. Vasilecas, O., Normantas, K.: Deriving Business Rules from the Models of Existing Information Systems. 95–100 (2011).
24. Vidgen, R. et al.: Web Content Management. 14th Bled Electronic Commerce Conference. , Slovenia (2001).
25. Wordpress: Wordpress CMS, <http://wordpress.org/>.

A RIA based VRP Information System: Application to Real-World Petroleum Products Distribution

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Abstract

Over the years, a large body of research and development covers the Vehicle Routing Problem (VRP) and its multiple characteristics, but few investigations examine it as an Information System, and far fewer as how it should be addressed from a development and implementation point of view. This paper tries to address this situation by describing the implementation decisions made by the authors toward the development of an Information System for a VRP solution. In order to achieve a viable VRP Information System in real world activities, authors have developed a Web-based solution with multiple web frameworks for each architecture layer, focusing on functionality and usability. To achieve these goals, authors have used SmartGWT as a powerful Web based RIA SPA framework with Java integration, and multiple server frameworks and OSS based solutions, applied to development of a very complex VRP system for a logistics operator of petroleum products.

Keywords: Web Framework, Web Architecture, VRP, Information System, Routes, Maps.

1. Introduction

Web technology evolution has been a constant from the beginning of the field: changing from CGI (Common Gateway Interface) applications to SOA (Service Oriented Architecture), from simple HTML to RIA (Rich Internet Application) [11] SPA (Single Page Application) [22] and from full page responses to REST services. This evolution has been going along with a strong and growing OSS (Open Source Software) community, which has driven great projects, from infrastructure project as Apache, Tomcat, Jersey, Spring, etc., to high level projects as OSM (Open Street Maps, [27]), that competes with the biggest corporations and offers a great service.

From development point of view, the creation of frameworks like GWT (Google Web Toolkit), SmartGWT [31], GXT, ExtJS, MooTools, EmberJS, AngularJS, etc., are a huge advance in user interface programming tools and capabilities. These frameworks drive the innovation at UI level from simple HTML pages to responsive and dynamic RIA SPA (like the ones used at Twitter, Google plus, Gmail). This kind of RIA SPA leads the user to behave as with native applications, blurring the lines between web and local applications on

perception level [28]. From these frameworks, SmartGWT and ExtJS are the best suited for RIA SPA enterprise class web applications, as they have extremely powerful widgets that drives user interaction in a native application way. SmartGWT is especially useful as it can be integrated into a Java web project, and compiled as a whole, making easy to develop and debug its applications. Other projects like Apache Struts 2, Jersey or Spring in Java language, or Epiphany and Symfony2 in PHP, are examples of enterprise accepted frameworks developed under OSS environment. These frameworks are designed to make easy web development of big scale architecture solutions, using technologies as JSON for data interchange or paradigms like REST for service layer design. The use of JSON is getting higher these days because of its simplicity and low memory footprint, which makes it ideal to be used on mobile devices with constrained resources.

At storage level there have been huge pushes on lasts years, mainly because of new NoSQL databases, and referred to web development it makes sense to look at document oriented storage solutions like MongoDB [23] or CouchDB [8]. Trying to replicate the way those works, there are traditional relational database solutions like PostgreSQL [30] adopting JSON as a native data type in their schemas, even allowing querying JSON data from SQL queries. As persistence solution, document oriented NoSQL databases has been integrated into solutions like Spring Data, and using Spring Data with Hibernate, while others solutions like MyBatis [24] provides a lower level of abstraction and do not try to integrate NoSQL Solutions.

Moreover, OSS project at higher level, as OSM, with a huge growing community providing data and support, has been able to build services with great added value, driving innovation with newer and focused projects like Leaflet JS [20], Nominatim [25] or OSRM [21]. These projects are based on Open Street Maps file format definition [29].

Currently, the use of these technologies enables us to implement highly complex applications with low development time, such as advanced route optimization, delivery scheduling and logistics planning software. During the last decade, there has been acknowledged a tremendous change in enterprise-oriented business software where traditional products have gradually left their place to integrated, friendly, usable and efficient solutions that would rigorously deal with every single business aspect of each individual enterprise. The VRP system presented in this article belongs to this category, as it is developed on SmartGWT, MyBatis and Spring Web-Development platform and possesses modular and flexible structure. Web-based techniques are less expensive, more efficient and lately have been the target of most development efforts. On the other hand, web-based solutions are able to easily interoperate with the whole supply chain entity.

VRP systems allow improving the process of designing the routes to follow by a heterogeneous fleet of trucks that transport a diverse number of products with different features (volume, cost, etc.), petrol and oil in this case, from n-depots to m-possible destinations (customers). There are several variants of the VRP [1, 2], [4], [5], [7], [12], [15, 16], [19]. In order to solve the problem, an extensive group of techniques have been addressed, and they can be classified into three categories: exact, heuristic and metaheuristic methods. All these techniques increase computer-time in order to obtain required optimization results and it is necessary to develop sophisticated programs in order to reduce the computation time. Here, a web-based system is constructed by using several metaheuristics algorithms. The system allows planning engineers to generate a near optimal vehicle assignment and routing plan based on daily shipping demands. The improvements compared to the current situation, embrace the maximum occupancy of trucks, total travelled distance, reduction of delivery times, minimization of distance travelled with minimal or no occupation of the truck, etc. The development of this system has been possible thanks to the use of SmartGWT, Spring, MyBatis, OSRM, Leaflet and OpenStreetMap technologies.

Over the years, a large body of research and development covers the VRP problem and its multiple characteristics, but few investigations examine it as an Information System, and far fewer as how it should be addressed from a development and implementation point of view.

This paper tries to address this situation by describing the implementation decisions made by the authors toward the development of an Information System for a VRP solution. At the

conceptualization phase of the system, authors have been aware of some needs that must be fulfilled to get the system on duty: every order must be served, not matter how hard, long or difficult it is; security on handling and transportation is key; traceability of operations is a must; environmental concern is inside all business process; multiple areas of distribution, with little to none common frontier; constant changes of customer orders.

These needs lead to the creation of key areas like multiple planning locations usually based on truck depots, simple routing from point A to B, manual operation, integrated information of all resources and non-blocking operation, is given, all of them described in Section 2. In Section 3, the VRP algorithm characteristics are described. Section 4 describes the use case where the VRP Information System is applied. Section 5 summarizes the findings and characteristics of the developed VRP Information System.

2. VRP Information System

2.1. Multiple planning locations

Given the area of a country like Spain, it's not logical to set a unique operation centre for fuel distribution. There are some factories/refineries settled along the country in key places where fuel products are ready to serve to the final distributor (gas stations, large buildings, etc.)

Replicating this logic, the fuel distributor uses to set a base for their trucks near the factories/refineries, so it is faster and cheaper to make fuel distribution in this way. With this configuration in mind, the business is ruled by resources localities, and the planning of an area is held by plan engineers sited in that area. This gives better understanding of area based constraints and risks, and makes easier to plan accordingly to the most up to date fleet and customer information. On the other way, the Information System must take this locality feature into account and be able to operate in multiple locations, while sharing all data about fleet and customers so managing staff can get over any problem that could arise in day by day operation. These constraints lead to development of a Web-Based Information System, so it can serve to multiple clients on multiple locations. By contrast, the approach used to the date on Spanish fuel distributors is the use of single seat software, with local databases, unshared or hard to share information, and local optimisation software.

2.2. Simple Routing

The objective of simple routing is to provide a route from point A to point B with 3 information components: distance, time and intermediate GPS coordinates at a fixed zoom level. While it seems a simple problem, there are some initial constraints which must be addressed because simple routing is used for two different objectives: GUI guidance to planning engineers in order to visualize the real route their trucks will cover on a map; and create a distance/time matrix, so it can be used on VRP optimization. Simple routing calculation is handled by OSRM component. This component is built by a dedicated web server on a dedicated machine of the Information System. It loads all map data into RAM memory, so it won't use the disk when OSRM is on duty. It can handle multiples route queries, but it's limited on the amount of CPU cores and how the requests are made.

We have measured 900 request per second with an Intel Core i7 3770 CPU, and while it's a good result, it's not good enough to keep the pace with a VRP problem, NP-hard by nature. The distance matrix creation problem gets harder as new destinations are added to the problem, so a VRP problem with 1 depot and 39 destinations gets n^2-n viable routes: 1.560. But if the number of destinations grows to 199, the number of viable routes goes up to 39.800 routes. We have found that the range of the number of destinations varies from 200 to 500 in real world problem, and it must fulfil orders for about 5 million litres per planning job and zone. These lead us to a worst case scenario of 249.500 viable routes, and that could suppose more than 4 minutes only to get ready to launch VRP algorithm process.

To address this situation a route cache was built. All route queries made by *Chronos System* goes through a database backed cache system to reduce the number of queries made to OSRM component. This approximation gets three key benefits: firstly, the distance matrix creation process is much faster as only new destinations must be processed. Secondly, the routes could be tweaked offline to adapt them to business needs (tolls, dangerous routes, legal limitations, etc.). Thirdly, OSRM component gets more available time to be used by other users on their planning jobs. At the time of writing this paper, the cache system is running with more than 17 million routes, which are refreshed periodically to reflect map's changes and optimizations.

2.3. Manual Operation

As long as *Chronos System* is designed to fulfil the needs of fuel distribution logistic, it must check some compatibility issues when serving the orders to the clients. These issues go from checking capacity of the truck, to marketing compatibility or even contamination episodes with environmental consequences. Nevertheless, all those checking must be pledge to plan engineers will, because there are cases that get out of control easily and must be addressed. These cases go from a human error while handling the fuel, to an emergency call for fuel to firefighter's helicopters or planes, or to terrorist attack to factories and/or depot facilities. Given that these situations are completely out of usual behaviour, cannot be forecasted, and the way to resolve them depends on the situation itself, the *Chronos System* must be able to ignore all its systems checks and usual capabilities so plan engineers can do their distribution plans as they need with the maximum help and minimum limitations from the *System*.

2.4. Integrated Information

While almost all Information Systems tends to integrate all business information, this goal is key in a VRP environment. Within a VRP problem there are multiple constraints which must be testes, checked and evaluated to be able to know if a result is a valid/viable result or if it should be discarded. The present case is extremely difficult in these areas, as it requires multi-element cross compatibility checking, as it may need to check if the products can be downloaded by a pump pulse, or how many litres are wasted on the discharge hose if has a longitude or another and if that quantity will lead to chemical incompatibility with the next download. At the same time, all business distribution resources must be compatible checked with customers (e.g. it's impossible to serve an order with a 3 axis truck in a historical city center, it's too big. There're other constraints with hose length, or with some military facilities). The system must observe and preserve the legal constraints on drivers rest, and it have to find who is the best driver for each order, given his work calendar and other constraints (holidays, inactivity for medical reasons ...)

As shown before, all information is needed to be available to VRP so it can pick a good solution to optimization problem, but taking care of all information implies that the storage of the Information System must fulfil some needs: it must be ACID compliant. Multiple changes must be taken into account as one atomic change, even if they affect multiples objects/entities: it influences the choices available, as Document Oriented NoSQL Databases do not support ACID at database level at this time (only at document level, which it is not enough). The system should be able to be used easily in web based solutions: from persistence view, it should integrate with a persistence solution, and from data logic view inside web service layer, there will be data which should not be processed, but passed, so there is a clear advantage to store it in its original format.

2.5. Non-blocking Operation

While Web UI has gone a long way to lead to non-blocking interaction, using Ajax to be able to send and receive multiples request to a web server, and it is now on common use, non-blocking operation *inside* the service layer of a web server is not so common, and leads to

unusual situations. At a VRP Information System there are some processes that require some time to complete. Given the need of information to create the data needed to a VRP optimization, it is easy to understand that it may take time to complete. In order to address these situations, the *Chronos System* works with asynchronous actions and a pool of semaphores to route the internal logic at service level. By taking this approach, when the *Chronos System* receives a request on one of their asynchronous actions, it split to logical routes inside server code, one to respond with the state of the async job requested, and other to complete the async job if it was not already at work. Hence, the system has a pool of async jobs executing that can be managed by users. Those jobs go from creating a distance/time matrix to control VRP algorithm as an external process, or to update at night the whole route cache system if it is needed.

3. Vehicle Routing Problem (VRP)

The distribution problem in general started with two classical problems in combinatorial optimization: the Traveling Salesman Problem (TSP) and the Vehicle Routing Problem (VRP). The TSP consists, from a departure point, to visit a set of customers with one single truck and to come back planning its tour by finding the sequence of customers with the lowest possible total cost. Historically, [10] is the first work that introduces TSP problem by proposing resolution's methods. The vehicle routing problem addresses the case where each customer has a given request. It consists in determining several tours that all start and end at the depot and where each customer is visited once by a single truck. The first work that addresses the VRP is [9]. The VRP generalizes the traveling salesman problem (TSP) and is much more difficult to solve than the TSP [17]. As we have seen, the physical distribution problem in general, is not a recent problem. As a component of the supply chain, includes a set of activities executed to obtain the delivery of a product from the production location to the end customer. Problems related to physical distribution are: selection of distribution channels, determination of customer service level, distribution centers, location planning, inventory management, transportation means selection, fleet composition, delivery scheduling and vehicle routing, etc., and the objective is double: to minimize the total transportation cost while rationalizing the vehicles utilization. In this sense, vehicle routing refers to a broad group of problems that could be expressed as following: a finite set of customers at fixed locations with defined demand, must be supplied with goods by a number of vehicles having a finite capacity and predefined starting points and terminals.

The vehicle routing problem literature is abundant. At the origin of routing problems, [18] provided a bibliography of 500 studies. [13] presents a VRP literature classification, based on a review of about 1,500 documents. Extending the basic VRP approach, numerous variants have emerged over the years, among which, the most discussed are: CVRP ("Capacitated VRP"): *each vehicle has a limited capacity*. MDVRP ("Multi-Depot VRP"): *the seller uses several depots to supply customers*. PVRP ("Periodic VRP"): *orders can be taken only on certain days*. SDVRP ("Split Delivery VRP"): *customers can be served by different vehicles*. SVRP ("Stochastic VRP"): *some values such as the number of customers, their demands, length of service or travel time are random*. VRPB ("VRP with Backhauls"): *customers can return the goods*. VRPPD ("VRP with Pick-Up and Delivering"): *customers have the option to return some goods to depot*. VRPSF ("VRP with Satellite Facilities"): *vehicles can be supplied without returning to the central depot for other auxiliary route*. VRPTW ("VRP with Time Windows"): *each customer has to be served within a certain time window*.

We can state that the VRP and all extensions listed above are a generalization of the TSP ("Travel Salesman Problem") and, therefore, are within the combinatorial optimization problems, which means that, from the standpoint of computational complexity, is one of the most complex because it is NP-Complete kind of problem: It cannot be solved in polynomial time [3], [14]. In order to solve the VPR problem, a group of techniques have been addressed. They can be classified into three categories: exact, heuristic and metaheuristic methods. We can say that the exact methods are efficient in problems up to 50 depots [2] due to the computational time constraints. Furthermore, heuristic methods provide us with acceptable

solutions obtained by a limited exploration of the search space. A review of these can be found in [26]. Finally, the metaheuristic techniques, developed in the late 90s, are characterized by performing a search procedure to find acceptable solutions by applying domain independent operators that modify intermediate solutions guided by the suitability of its objective function. Within these Neural Networks, Tabu Search, Genetic Algorithms or Ant Algorithms can be found, among others. A review of these methods can be seen in [6].

4. Case Studies

4.1. Background

The case study concerns one of the biggest Spanish companies for oil distribution products by road. The enterprise is located in different areas of Spanish territory and operates on great public and at the same time has several individual customers. Every day, several times a day, a customer network needs to be serviced by a fleet of heterogeneous capacitated vehicles located on a several depots or distribution centers. A Complex-VRP system was designed in order to automatically generate vehicle routes, which vehicles should deliver to which customers and in which order, minimizing simultaneously the vehicle cost and the total distance travelled by the vehicles, subject to the high number of constraints, such as: the vehicles are multi-depot or single-depot; the capacity of a vehicle cannot be exceeded; a single vehicle supplies each customers demand; the number of vehicles used is pre-determined; schedule of the drivers must be respected; the number of drivers is pre-determined; the time to serve the customers should be respected; the shipping demand of a depot cannot be divided. It should be delivered by the same vehicle, unless the shipping demand of the depot exceeds the loading capacity of a vehicle; the time-window constraint is known, the driver will be given the time limitation so that over-time driving can be eliminated; the cargo loading cannot exceed the vehicle loading capacity at each delivery; there are over ten different types of products; etc.

4.2. System Implementation

The Chronos System is composed of multiple modules working as a whole to achieve the distribution's plan. Taking into account all modules, the Chronos System (Figure 1) has a management module, an ERP module, an Orders module and an Optimization Module. These modules are integrated into the System as first class citizens, as its functionality is needed to make the system work as it should. There are other modules like HCAE or RTCM (Real time Control Module), that are not indispensable to the planning work, but are needed for subsequence business process. Other external modules are the Web Map System, generated with Leaflet framework and integrated into SmartGWT and Spring, and the OSRM module as high performance routing system installed on a different machine. All modules are connected to the central database, where all information is kept always in a coherent way, warranting all data is up to date and ready to use in VRP optimization process. To develop all these modules, a combination of SmartGWT, Spring, MyBatis, LeafletJS, OSRM, OSM and PostgreSQL is used.

4.3. Implementation Benefits

Through the use of the developed VRP system, the enterprise obtained as results: significant cost-reductions; improvement of the maximum occupancy of trucks; reduction of the total travelled distance; reduction of delivery times; minimization of distance travelled with minimal or no occupation of the truck; improving business processes of major importance; reducing personnel's occupation times; more flexible and efficient planning; improved communication and data, transfer of critical information for the whole enterprise; instant access to real-time data; etc.

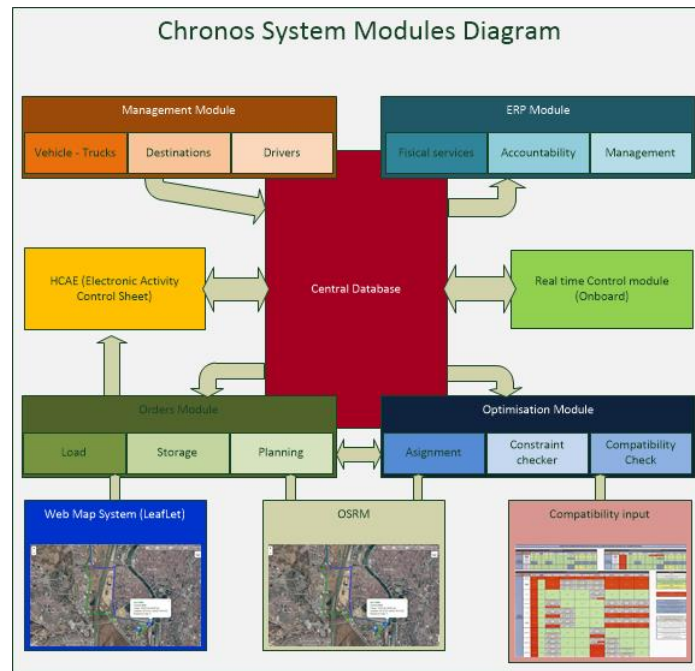


Fig. 1. Chronos system: Modules diagram.

5. Conclusions

In this paper we have used SmartGWT framework for RIA SPA UI, Spring for service level architecture at web server, MyBatis as persistence solution, PostgreSQL as database backend, OpenStreetMaps as map data source, OSRM as high performance routing engine and LeafletJS as map visualization framework, building a technological stack ideal for VRP systems. The use of these technologies has allowed the development of a web-based complex vehicle routing planning system that helps the company to solve the daily vehicle routing problems. The system routing problem developer for the case company was formulated based on the company's current delivery network, and it is able to reduce the operating costs and increase the competitiveness of the company. With the aid of this system, the time needed to generate a routing plan is significantly reduced if compared with the time needed in the older planning system, and helps to shorten the learning curve for new staff in dealing with the routing process. As a result, the overhead cost is reduced and the possible loss due to poor routing plans is avoided.

References

1. Archetti, C.; Mansini, R. and Speranza M. G.: The split delivery vehicle routing problem with small capacity: In Technical Report n. 201, Department of Quantitative Methods, University of Brescia, (2001).
2. Azi, N., Gendreau, M. y Potvin, J.: An exact algorithm for a vehicle routing problem with time windows and multiple use of vehicles. In European Journal of Operational Research, Vol. 202, No. 3, pp 756-763, (2010).
3. Balinzki, M. L. y Quandt, R. E.: On an Integer Program for a Delivery Problem.: In Operational Research, Vol. 12, No. 2, 1964, pp 300-304, (1964)
4. Baptista, S.; Oliveira, R. C. and Zúquete, E.: A period vehicle routing case study. In European Journal of Operational Research, 139:220-229, Elsevier, (2002).
5. Bard, J. F.; Huang, L.; Dror, M. and Jaillet, P.: A branch and cut algorithm for the VRP with satellite facilities. In IIE Transactions 30, pp. 821-834, (1997).
6. Contardo, C.A.: Formulación y solución de un problema de ruteo de vehículos con demanda variable en tiempo real, trasbordos y ventanas de tiempo. In Memoria para

- optar al título de ingeniero civil matemático, Departamento de Ingeniería Matemática, Universidad de Chile, Santiago de Chile, Chile, (2005).
7. Cordeau, J.-F.; Desaulniers, G.; Desrosiers, J.; Solomon, M. M. and Soumis, F.: VRP with time windows. In P. Toth and D. Vigo (eds.): *The vehicle routing problem*, SIAM Monographs on Discrete Mathematics and Applications, vol. 9, Philadelphia, PA, 157-193, (2002).
 8. CouchDB, Apache CouchDB project, <http://couchdb.apache.org/>, April 14, 2014.
 9. Dantzig G. B., Ramser J. H.: The truck dispatching problem. In *Management Science*, Vol. 6; pp 80–91, (1959).
 10. Dantzig G.B., Fulkerson R., Johnson S.: Solution of a large-scale travelling salesman problem. In *Operations Research*, Vol. 2, pp. 393–410, (1954).
 11. Driver M, Valdes R, and Phifer G.: Rich Internet Applications are the next evolution of the Web. In *Technical Report*, Gartner, (2005).
 12. Dror, M.; Laporte G. and Trudeau P.: Vehicle routing with split deliveries. In *Discrete Applied Mathematics* 50, 239-254, (1994).
 13. Eksioglu B., Vural A. V., Reisman A.: The vehicle routing problem: A taxonomic review. In *Computers & Industrial Engineering*, Vol. 57 (4), pp. 1472-1483, (2009).
 14. Garvin, W. W.; Crandall, H. W.; John J.B. y Spellman, R. A.: Applications of Linear Programming in the Oil Industry. In *Management Science*, Vol. 3, 1957, pp 407, 1957.
 15. Hjorring, C.: The vehicle routing problem and local search metaheuristics. In PhD thesis, Chapter 2, Department of Engineering Science, The University of Auckland, (1995).
 16. Jacobs-Blecha, C. and Goetschalckx, M.: The vehicle routing problem with backhauls: properties and solution algorithms: In *Technical Report*, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia. Presented at the National Transportation Research Board, January 13-15, Washington DC, 1992.
 17. Laporte G.: Fifty years of vehicle routing. In *Transportation Science*, Vol. 43 (4), pp. 408–416, (2009).
 18. Laporte G., Osman I.H.: Routing problems: A bibliography. In *Annals of Operations Research*, Vol. 61, pp. 227–262, (1995).
 19. Laporte, G. and Louveaux, F. V.: Solving stochastic routing problems with the integer L-shaped method. In: *Fleet Management and Logistics*, T.G. Crainic and G. Laporte (eds.), 159-167, Kluwer Academic Publishers, Boston, (1998).
 20. LeafletJS, project website, <http://leafletjs.com/>, April 9, 2014.
 21. Luxen, D., & Sanders, P.: Hierarchy decomposition for faster user equilibria on road networks. In *Experimental Algorithms* (pp. 242-253). Springer Berlin Heidelberg, (2011).
 22. Meliá S., Gomez J.: The WebSA Approach: Applying Model Driven Engineering to Web Applications, *Journal of Web Engineering*, Vol. 5, No. 2, pp. 121-149, (2006).
 23. MongoDB, project website, <https://www.mongodb.org/>, April 10, 2014.
 24. MyBatis, Project webpage, <http://blog.mybatis.org/>, April 14, 2014.
 25. Nominatim, Project webpage, <http://www.nominatim.org/>, April 7, 2014.
 26. Olivera, A.: Heurísticas para problemas de ruteo de vehículos. In *Reporte de investigación*, Instituto de Computación – Facultad de Ingeniería, Universidad de la República, Montevideo, Uruguay, (2004).
 27. Open Street Maps, project web site, <http://www.openstreetmap.org/>, April 7, 2014.
 28. O'reilly, T.: What is Web 2.0: Design patterns and business models for the next generation of software. In *Communications & strategies*, 65, (2007).
 29. OSM Data format, http://wiki.openstreetmap.org/wiki/OSM_XML, April 7, 2014.
 30. PostgreSQL, <http://www.postgresql.org/docs/9.3/static/datatype-json.html>, April 9, 2014.
 31. SmartGWT, Isomorphic software, <http://www.smartclient.com/smartgwt/showcase/>, April 21, 2014.

IFML-Based Model-Driven Front-End Modernization

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Abstract

Since late 90's the use of web application frameworks has been the default choice to develop software applications inside the web domain. In parallel, Model Driven Web Engineering approaches have been defined and successfully applied to reduce the effort of web application development and reuse, fostering the independence of the implementation technology. A direct result of the success of these approaches is the elaboration of the Interaction Flow Modeling Language (IFML) as an Object Management Group (OMG) standard. However, the real fact is that there is a huge amount of legacy web systems that were developed before MDWE approaches were mainstream. The work presented herein tries to leverage IFML to modernize the front-ends of framework-based legacy web applications. In concrete, a systematic model-driven reverse engineering process to generate an IFML representation from such applications is presented.

Keywords: Web Models Transformations, Reverse Engineering, Model-Driven Web Engineering

1. Introduction

Since late 90's, widespread language-specific Web development frameworks (e.g. Struts¹) have supported most of the actual development of Web Applications (WAs). These frameworks are

¹<http://struts.apache.org/>

often strongly tied to the programming-language level, increasing the complexity of application maintenance and evolution. At the same time, within an academic context, Model Driven Web Engineering (MDWE) approaches [7] have been defined to leverage model driven engineering methods and techniques in the development of WAs increasing the independence of the implementation technology. MDWE approaches allow defining WAs in a declarative way by means of conceptual representations and provide code generation engines to tackle the constant change of implementation technologies. The recent publication of the IFML² standard has confirmed the convenience of MDWE approaches.

This work proposes a model-driven reverse engineering process to approximate these two different worlds of Web application development. Such process defines the necessary activities, artifacts and tools to generate a conceptual representation from a legacy web application developed by means of a Model View Controller Pattern (MVC)-based framework. In order to provide a detailed description, a concrete application scenario implemented by a concrete set of frameworks (Struts v1.3 and Hibernate v3.6), conventions (naming, configuration, etc.) and design patterns (e.g. Data Access Object pattern) has been specified. On the other hand, IFML has been selected as target conceptual representation. A case study has been performed to validate the approach, the Conference Review System (CRS)³. Obviously, the proposed process is described at a conceptual level and different realizations are possible.

The reverse engineering process defined is organized as a sequence of three steps: (1) technology-dependent model extraction; (2) conceptual MVC model generation; and (3) MVC to MDWE transformation. Since some preliminary works have been already published [5, 6], the work presented herein mainly focuses on steps 2) and 3) and supposes a major extension providing a comprehensive reverse engineering process not limited to the navigational concern and extending the work to generate a IFML-based specification.

The rest of the paper is structured as follows. A presentation of related work is done in Section 2. A detailed presentation of the generation of the MIGRARIA MVC model is performed in Section 3. The final transformation to IFML is introduced in Section 4. Results are commented in Section 5. And, finally, main conclusions and future work are outlined in Section 6.

2. Related Work

Web Application information extraction has been traditionally performed by reverse engineering techniques [3]. Most approaches presented in that survey propose strategies of static analysis taking just web pages as input of the extraction process. They treat the legacy system as a black box and focus on analyzing its output (HTML pages). Meanwhile, the approach presented herein proposes to extract the information concealed in the source code of the legacy system by means of static analysis. Moreover, most of these approaches are not conceived as model-driven approaches and pursue other aims than the generation of a conceptual representation.

The work presented in [2] and [1] proposes a model-driven process to generate a conceptual representation of a web application by using the Ubiquitous Web Application (UWA) approach. However, they also apply static analysis to the web application output without considering the system source code. That approach generates directly the final model without intermediate representations. Similarly, [4] proposes a reverse engineering process to obtain a WebML representation from a legacy PHP web shop application based on static code analysis. First, the source application is refactored to obtain a MVC version of it. Next, a code to model transformation into an intermediate model of the MVC web application is carried out. The last step is a model to model transformation from the MVC model into a WebML model. However, the MVC metamodel proposed by the authors is tied to the WebML schema while the MIGRARIA-

²<http://www.ifml.org/>

³Additional material <http://uex.be/migrariaifml>

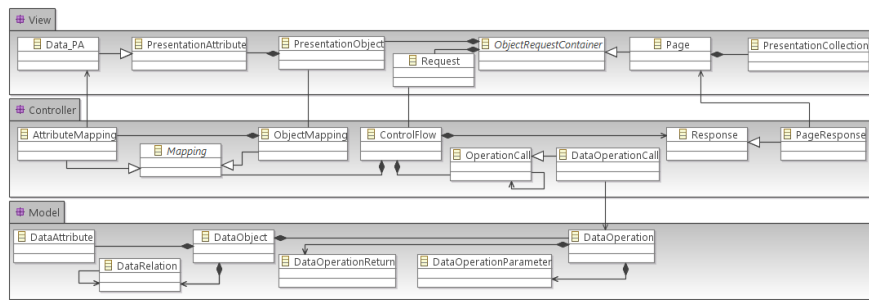


Fig. 1. MIGRARIA MVC metamodel overview

MVC one represents the general concepts defined by mainstream MVC-based web application frameworks, providing a higher degree of reutilization.

[8] presents a revision of existing approaches for reverse engineering of web applications. Most of the work related to reverse engineering of web applications has been presented before 2009. Since then the main approaches have moved to analyze Rich Internet Applications and its related technology. The authors conclude that the current trend in web application reverse engineering is the used of general reverse techniques. They also state that the use of web application frameworks make the reverse engineering process harder. In contrast we think we may take advantage of the knowledge of the framework to guide conveniently the analysis of the software artifacts.

3. MVC Model Generation

In order to generate a conceptual MVC-based representation of the legacy system is necessary to define (1) a MVC metamodel for web applications and (2) the generation process by means of model2model transformation rules.

3.1. MIGRARIA MVC Metamodel

According to the goal of the MIGRARIA project, defining a modernization process framework for legacy web applications, a specific language has been defined to generate a conceptual representation of a legacy MVC-based web application, the MIGRARIA MVC metamodel (see an excerpt in Figure 1). This metamodel specifies the main concepts of the development of a web application arranged in the three main components of the MVC pattern: Model, View and Controller. The Model package provides elements to represent data objects, their attributes, their relationships and the operations defined over them. The View package provide elements to represent pages, as main containers, and presentation objects and requests, as main containments. Presentation objects, basically, have a set of attributes, can indicate data input or data output and can be presented individually or inside a collection. Meanwhile, requests are characterized by their parameters and path and define connection points with controller elements by means of the request-handler association. The Controller package provides elements to represent request handlers (ControlFlow), their mappings defined between presentation and data objects, their response defining a relationship with the target page element, and the sequence of operation calls performed to execute the requested action or to fetch the requested data.

3.2. MIGRARIA MVC Model Generation

The generation process is accomplished in three sequential steps, one for each package defined by the MVC metamodel. First, all the interesting information related with data schema and data operations is collected in the model representing the Model component of the legacy system.

Second, all the information concerning web pages composition and interaction is gathered in the model representing its View component. Those two models are generated independently of each other. And finally, all the information related to request handling and operation execution is collected by the model representing its Controller component. This last model plays a fundamental role and connects the former ones by defining mappings and relationships between them.

The generation of the Model component is performed by analyzing Java data objects and data access object classes and the Hibernate mapping configuration files. Due to space reasons, it is not deeply explained.

Bearing in mind our approach is focused on data-driven web applications, next we detail how some CRUD operations are represented by our MVC model.

Figure 2 presents an example of a create operation. In this case, at the left, an excerpt of the author submission page from the CRS case study is shown that is basically composed by a HTML form allowing to specify the title, abstract, subjects and track of the paper to submit. The form contains a pair of input text controls and a pair of select controls. The JSP producing the submission page is analyzed to get its presentation objects and requests. The product of that analysis is the page *PaperCreate* of the View model. This model element is composed of an input presentation object (HTML form) that contains a pair of data presentation attributes (input text) and a pair of dataset presentation attributes (select) representing corresponding form controls. Dataset attributes have associated two presentation collections that allow to specify the set of elements populating each dataset presentation attribute. And the view also contains the specification of the request *new* that represents the submission of the form and references to the input presentation object *paperForm* by means of its *submit* attribute.

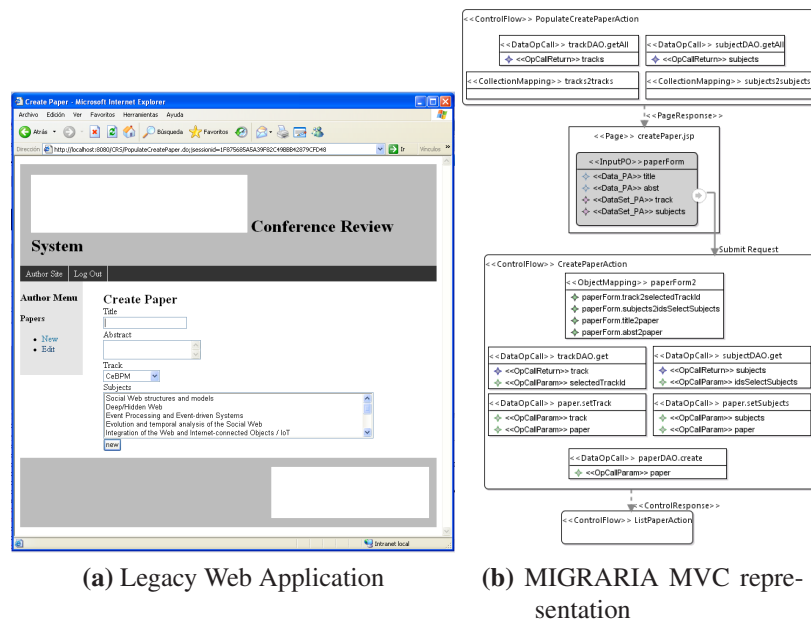


Fig. 2. Create paper operation

As a basic common pattern, at least, two different controllers are related to a concrete view, one populating its objects and collections and the other one handling the request generated from the view. In this case, the controller *PaperPopulateCreateAction* specifies the data operations called (*trackDAO.getAll* and *subjectDAO.getAll*) and the mappings defined to fetch the data for every dataset presentation attribute of the presentation object *paperForm*. The mappings define the relation between the controller instances storing the return of the operation calls (tracks, subjects) and the corresponding presentation collections defined in the view (*tracks* and *subjects*).

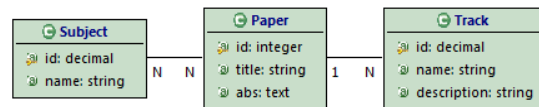


Fig. 3. WebML data model

Meanwhile, the second controller, *PaperCreateAction*, is responsible of handling the request *new*. A controller that receives a presentation object as input defines a controller instance to define the mapping. In the example, the controller instance *paper* is defined as an instance of the data object *Paper* and a mapping is established between that instance and the input presentation object *paperForm*. The mapping attributes allow defining fine grain mappings. In this case, on the one hand, the data presentation attributes of the input presentation object are mapped to the corresponding attributes of the data object *paper*. And on the other hand, the dataset presentation attributes are both mapped to two different controller instances: one to store the selected track id and the other one to store the ids of the selected subjects. Those instances are used as parameters of data operation calls to fetch the data objects for those ids (*trackDAO.get* and *subjectDAO.get*). The returned data objects are stored on controller instances (*tracks* and *subjects*) and passed again as parameters of data operation calls to associate them with the instance *paper* representing the object in creation. Finally, the last data operation call of the sequence represents the creation of a new *Paper* object from the controller instance *paper* (*paperDAO.create*).

Additionally, controllers specify its response by means of a response element. This response element may have two different types, page or control, indicating whether the controller returns directly a view or delegates the control to another handler to generate the response view. Figure 2 presents both types of response. These two different control response types allow capturing the common response patterns of a web application, such as returning a view in a HTTP GET request or redirecting to a different path (action) in a HTTP POST request. That way the association of a request contained in a page with its handler and the handler response with its corresponding page specifies the navigation map of the legacy web application.

For the sake of brevity the recovery and representation of the rest of the CRUD operations has been omitted.

4. IFML Model Transformation

In order to get a fully functional IFML specification of the legacy web application, WebRatio has been used as supporting tool in this work. This is the most featured IFML supporting tool so far. We can additionally use the professional-level model edition and code generation tools of WebRatio while keeping the specification conformed to the IFML standard. In this sense, for the sake of simplicity, regarding the data model specification, WebML Data model schema has been used. Although IFML standard does not state a concrete data representation, WebRatio requires to use WebML data representation.

4.1. Data Model

WebML Data model schema is subsumed by MIGRARIA MVC metamodel, so a simple straightforward transformation process may be defined. MIGRARIA MVC model provides an extension of WebML data schema by introducing concepts to specify the operation set related with a concrete data object. Basically, transformation rules are defined to scan all the data objects, its data attributes and relationships to generate their WebML counterparts (entities, fields and relations). Figure 3 shows an excerpt of the WebML data model generated for the CRS system concerning the entities involved in the reverse engineering example illustrating the approach.

4.2. IFML Model

In order to illustrate the details of the transformation process in a manageable way, the resulting models for the CRUD operations aforementioned are presented and the generation of every one of their elements is traced back to the MVC model.

Figure 4 presents the elements generated to model the creation of a paper (a new submission) from the MVC model of Figure 2. The main structure of this model is conformed by the following elements:

- IFML model elements:
 - A *page*, named *paperCreate.jsp*, as main container, representing the author submission page.
 - A *View Component Form*, named *paperForm*, representing the HTML form to input the submission data.
 - Two *Actions*, named *PopulateCreatePaperAction.execute* and *CreatePaperAction.execute*. The first one represents the population form operation and the second one the registration of a new paper in the system.
- *PopulateCreatePaperAction.execute* action elements
 - Two *Selector Units*, named *getAll - IN!subjectDAO.getAll* and *getAll - IN!trackDAO.getAll*, (HTML select inputs).
 - Given that action has not got input parameters, its *Input Collector Unit* is empty.
 - Its *Ok Collector Unit* contains the following four output parameters: *subjects.id[output]*, *subjects.name[label]*, *tracks.id[output]* and *tracks.name[label]*. They are related to the 2 select controls (*track* and *subjects*) of the *paperForm* form.
- *CreatePaperAction.execute* action elements:
 - A *Create Unit*, named *CreateUnitPaper*, representing the creation of a new data object paper.
 - Its *Input Collector Unit* binds five parameters: *abst*, *fileLocalPath*, *subjects*, *title* y *track*.
 - A *Get Unit* to set the active user as the main author of the submitted paper.
 - An *Ok Collector Unit* which an *Ok Link* resembling the successful navigation flow.

As expected, the organization of these elements resembles the controller-view-controller pattern aforementioned. In this example, the controller responsible of populating the objects of the response view is transformed in the two selector units shown. Meanwhile the controller responsible of handling the request is modeled as action with the associated operation units presented.

5. Case Study

In order to evaluate this approach, we have developed a complete case study named the Conference Review System (CRS). CRS is a web application implemented by a developer team of our software laboratory. This system is based on the case study proposed in the First International Workshop on Web-Oriented Software Technology⁴. So partial MDWE representations

⁴<http://users.dsic.upv.es/~west/iwwost01/>

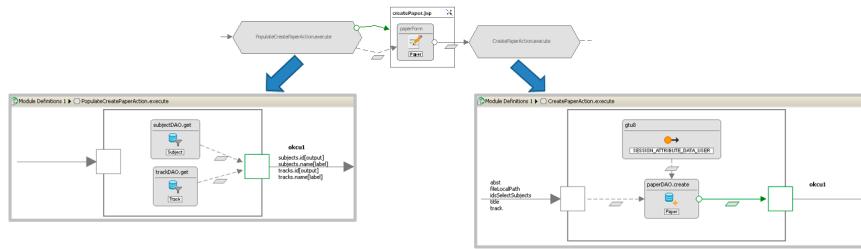


Fig. 4. IFML WebRatio create operation

Table 1. Transformation result summary

Source Element	No.	Target element	Gen.
Page	34	Page	100%
Output Presentation Objects	9	Component View Details	100%
Input Presentation Objects	16	Component View Form	100%
Object Presentation Collection (mapping)	22	Component View Simple List	100%
Object Presentation Collection (DataSet_PA)	8	Component View Simple (filter)	NA
Data Operation Call (type=create)	6	Create Operation	100%
Data Operation Call (type=remove)	4	Delete Operation	100%
Data Operation Call (type=update)	14	Update Operation	100%
Data Operation Call (type=getAll, DataSet_PA)	5	Selector Unit	100%
Session Operation Call (type=set)	1	Set Session Attribute	100%
Session Operation Call (type=get)	12	Get Session Attribute	100%
Collection Operation Call	23	Connect Unit, Disconnect Unit or Reconnect Unit	100%

are available. The implementation technology coincides with the one proposed by the application scenario used in this paper. And the development team has followed a basic collection of code conventions and design patterns.

In order to validate our approach, the reverse engineering generated IFML model has been compared to a manual IFML model representing the same original system (CRS). Table 1 presents a summary of the results obtained. In this table only the most relevant source elements of the transformation are presented. In concrete, those ones directly related to the generation of IFML model elements. 154 elements from the 1655 elements of the source MIGRARIA MVC model. 95% of the expected target elements are successfully generated. As a final step, although a proper effort assesment experiment has not been developed, the generated IFML model was used by a WebRatio experienced engineer to generate a complete specification of the legacy system. As main conclusion our approach decreased about a 70% the development time compared to model the system manually from the scratch.

6. Conclusions and Future Work

This work tackles an important part of the modernization process defined within the MIGRARIA project which faces the evolution of the presentation of a legacy Web system towards a new Web 2.0 RIA client. In this paper we have focused on the process of extracting and representing the information from the legacy system to represent it at a higher abstraction level.

The generation of the IFML model takes as input a conceptual model of the legacy web application (MIGRARIA MVC model), so its reusability depends on the reusability of the reverse engineering process defined to get this model. In this case, two main sources of change are considered: (1) a change of the code conventions and design patterns, and (2) a change of the implementation technology. For the sake of brevity, we discuss only the former one. If the implementation technology remains the same but the code conventions change, it is mandatory to adapt the model transformation chain defined. In new case studies under development (based on real applications) we have observed that most of the times the selected strategy is to add

more steps to the original transformation chain instead of adapting the rules previously defined. Those results may suggest that our transformations rules (and the code conventions considered) are generic and comprehensive enough to be applied in different modernization scenarios without heavy modification.

As main lines for future work we consider the following: (1) providing precise metrics to evaluate the initial coverage of a new case study; (2) effort assesment; and (3) improving the tool support of the reverse engineering process to simplify the engineer's decision making.

Acknowledgements

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References

1. Bernardi, M.L., Di Lucca, G.A., Distanti, D.: The RE-UWA Approach to Recover User Centered Conceptual Models from Web Applications. *Int. J. Softw. Tools Technol. Transf.* 11 (6), 485–501 (2009)
2. Di Lucca, G.A., Distanti, D., Bernardi, M.L.: Recovering Conceptual Models from Web Applications. In: *Proceedings of the 24th annual ACM international conference on Design of communication*. pp. 113–120. ACM Press (2006)
3. Martin, R., Archer, L., Patel, R., Coenen, F.: *Reverse Engineering of Web Applications: A Technical Review*. University of Liverpool (2007)
4. Rieder, M.: *From Legacy Web Applications to WebML Models. A Framework-based Reverse Engineering Process*. Technische Universität Wien (2009)
5. Rodríguez-Echeverría, R., Conejero, J.M., Clemente, P.J., Preciado, J.C., Sánchez-Figueroa, F.: Modernization of legacy web applications into rich internet applications. *Curr. Trends Web Eng.* 7059/2012 (*Lecture Notes in Computer Science*), 236–250 (2012)
6. Rodríguez-Echeverría, R., Conejero, J.M., Clemente, P.J., Villalobos, M.D., Sánchez-Figueroa, F.: Extracting navigational models from struts-based web applications. In: *Proceedings of the 12th International Conference on Web Engineering*. pp. 419–426. Springer, Heidelberg (2012)
7. Rossi, G., Pastor, O., Schwabe, D., Olsina, L. eds: *Web Engineering: Modelling and Implementing Web Applications (Human-Computer Interaction Series)*. Springer, Heidelberg (2007)
8. Tramontana, P., Amalfitano, D., Fasolino, A.R.: Reverse engineering techniques: From web applications to rich Internet applications. In: *15th IEEE International Symposium on Web Systems Evolution*. pp. 83–86. IEEE, Eindhoven, The Netherlands (2013)

Mobile Usability: An Experiment to Check Whether Current Mobile Devices are Ready to Support Frames and iFrames

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Abstract

Frames have traditionally been identified as a usability issue in websites for computers. Literature points out that they may also be a problem for mobile websites but no studies have been carried out to prove it. Since mobile devices have changed a lot in recent years, it is necessary to check whether frames are still a problem for those devices. In this paper we have performed an experiment with twenty-two mobile devices, to test whether the content can be showed in their browsers, as well as their behavior with different configuration of frames and iframes and whether behavior of bookmarks and the back button is correct or not. The results show that frames and iframes should be avoided in mobile devices because they can cause many problems, which are explained in detail in this paper.

Keywords: Frame, Mobile, Navigation, Usability, Web.

1. Introduction

Frames are often used in web pages for displaying at the same time an index frame (usually a menu) and a content frame. When users click on an option of the index frame, a new content will be shown in the content frame. This is an advantage because it is a solution to the problem of needing to keep a context while accessing multiple pages [5], but it also has many

disadvantages that have already been pointed out by many authors in the past. Some of these drawbacks are mentioned below.

When using frames, the URL shown at the top of the browser does not match with the web page that is being shown, because web pages with frames are made of two or more web content pages, which are loaded into the frames, and each of them has a different URL. This is a problem when users want to copy and paste the URL, for example, to include it as a hypertext anchor in other page or email message, because that anchor will not lead readers to the desired view but to the initial state of the frameset [9]. Another problem related to this operation is bookmarking, because it is based on URLs and users will not be able to bookmark the current page and return to it because the bookmark probably points to another version of the frameset [8]. This problem has also been indicated by many other authors such as Nielsen [6], Bevan [1] and the United States Department of Health and Human Services (DHHS) [2]. In HTML 4.0, a new implementation of frames emerged, which is called inline frames (iframes) and which completely replaced frames in HTML 5.0. This new version is supposed to allow bookmarking the main page and navigate as usual, because they are subordinated to the main page [9], i.e., embedded within the current HTML document.

Another issue of frames is that navigation does not work as usual, because the users' view of information on the screen is determined by a sequence of navigation actions instead of a single navigation action [9], i.e., when users press the back button of the browser, the previous loaded frame will be shown, and not the previous visited web site; and this could bewilder users.

Printing is also another problem arising from the use of frames, as many browsers cannot print framed pages appropriately because the print command usually results in the printing of a single frame, and this is especially problematic with scrolling frames, as browsers do not know if only the visible part of the frame should be printed or the whole content, taking up more room than it does on the screen [9]. Other authors in the literature have also pointed out this problem, saying that frames can interfere with printing [1], that printouts become difficult when using frames [8] and that frames pose problems when users attempt to print [2].

Firtman [3] said that "in 1997 some people were happy using frames technique, creating fixed menu bars and dealing with links between frames, until search crawlers came into action and frames became the worst thing you could ever do in a website". The problem for search engines is due to every frame is a different HTML document [3], and therefore they have troubles since they do not know what composites of frames to include as navigation units in their index [9]. This problem has also been pointed out by the DHHS in guideline 6:13 [2].

Another major problem is that not all web browsers support frames [4], so some users may not be able to see a site with frames [9]. This is especially important when using mobile browsers, as they many of them do not support frames [11] or will not allow users to scroll inside a frame or iframe [3], so probably users will not be able to see the whole content. However, these statements were made years ago, mobile devices have changed a lot since then and frames are still used (HTML 5 is a recent technology and it supports iframes), so this should be checked and updated for current mobile devices.

Finally, frames also pose an additional problem related to the small screen of mobile devices: splitting the screen into smaller windows as frames is uncomfortable for users, because the space for the content will be even smaller when a part of the screen is being continuously occupied by a frame.

As aforementioned, HTML definition introduced iframes in version 4.0, as they are supposed to cause fewer problems than frames, which have been definitely removed in HTML 5.0. Since version 5.0 only iframes are supported, but are devices (especially mobile devices) ready to use them, or do not support it? That is one of the questions that the work presented in this article will answer.

Existing guidelines for PC have different opinions about frames because DHHS recommends using frames when certain functions must remain visible on the screen as the user accesses other information on the site [2], but ISO says that frames should be used with care [7]. Both of them warn about potential but different problems: DHHS says that printing or searching problems may occur, and ISO advices about the use of the back button,

bookmarking of pages, or scrolling of information. However, these guidelines are intended to PC and it is not checked whether they are applicable or not on mobile devices.

Furthermore, there is one guideline about frames especially designed for mobile devices, which is guideline 5.4.2 of Mobile Web Best Practices [11]. This guideline says that frames and iframes should not be used because they are generally problematic, but it does not mention any specific problem. Although this guideline is addressed to mobile devices, it is necessary to check whether it is valid for current mobile devices, as it was established in 2008 and, as aforementioned, mobile devices have changed a lot and these guidelines may have changed since then. In addition, some of the above problems have already been solved in the past for Personal Computers (PCs) [10], but some of them may still remain for mobile devices.

On the other hand, as far as we know, there are no experiments testing frames and iframes on mobile devices (smartphones and tablets), and existing guidelines were defined some years ago and are not updated for current mobile devices. This is important because technology changes very fast and usability guidelines should be updated to be adapted to new technologies. For example, some years ago the most common interaction method for these devices was the keyboard, while today are touch screens. Screen size has also changed, and all of this influences how users use these devices and therefore usability guidelines have to be updated. This paper presents an experiment to check whether the aforementioned problems are still present in mobile devices or not, both with frames and iframes, and to give an updated recommendation about frames for mobile web, because all the existing usability guidelines about frames are addressed to PCs or old mobile devices.

Section 2 of this paper presents the experimental design, Section 3 shows the results obtained in the experiment carried out, Section 4 presents the discussion of these results and finally Section 5 presents the conclusions obtained in this work.

2. Method

In this paper we are focusing on how feasible is using frames and iframes to navigate from a mobile device. To do this, an experiment has been carried out with several mobile devices and evaluating four different configuration frames (without scroll and with combinations of scroll) for displaying information from those kind of devices. Both the ability to display the content and the behavior of frames and iframes are studied. The main problems indicated by previous works (i.e. behavior with bookmarks and the back button) have also been studied.

2.1. Subjects

The subjects of the experiment were twenty-two real mobile devices, which had different interaction methods (keyboard and touch screen), operating systems and screen size (Table 1).

Table 1. Mobile devices used as subjects in the experiment.

Device	Screen size	Device	Screen size
HTC Magic	3.2"	Samsung Galaxy Mini	3.2"
BB Curve 9360	2.44"	Samsung Galaxy SIII	4.8"
Nokia Lumia 610	3.7"	Samsung Galaxy Nexus	4.65"
LG L3 E400	3.2"	iPad 2	9.7"
HTC Wildfire	3.2"	HTC Desire	3.7"
BB Torch 9860	3.7"	iPhone 4	3.5"
HTC Radar	3.8"	Samsung Galaxy Young	3.27"
Nokia Lumia 710	3.7"	Samsung Galaxy S	4"
Samsung Omnia W	3.7"	Samsung Galaxy Tab 3	7"
BB Curve 9300	2.46"	Samsung Galaxy S4	5"

Sony Xperia U	3.5"	BQ Pascal Lite C	7"
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The default mobile web browser was used in each device, as most (or all) of them allow installing new web browsers, but we preferred to study the default one because users could use them since they purchase the device, and the results are more consistent using the default one than using a new web browser that may not be available in all platforms.

2.2. Tasks

The tasks performed with each subject were:

1. Checking whether the content could be displayed completely or not.
2. Checking whether the behavior of the frames/iframes was the expected or not.
3. Checking whether the behavior with bookmarks was correct or not.
4. Checking whether the behavior of the back button was the expected or not.

To perform the first task, we evaluated whether all content could be displayed, so if any part of the content could not be displayed, the answer to this task was "no". To perform the second task, we evaluated whether the behavior of the frames/iframes were correct. An incorrect behavior was considered when a frame does not have scrolling but it scrolls for showing the content and when it has scrolling in only one direction but it scrolls in another direction to display the content. The third task was evaluated by adding a webpage loaded in a frame to bookmarks, and then trying to reload it. If the webpage was not properly loaded, then the answer to this task was "no". Finally, to perform the fourth task, we evaluated whether the behavior of the back button was the expected (i.e., if it returned to the previous webpage) or not (i.e., it returned to the previous frame).

2.3. Design

Four different interfaces were designed for the experiment (Fig. 1), each of which had two frames (left and right). The left frame was the same for every interface and did not have scrolling, and the right frame varied for every interface: the first one (called W1) had a frame without scrolling, the second one (W2) had a frame with vertical scrolling, the third (W3) had a frame with horizontal scrolling and the fourth (W4) had a frame with both types of scrolling, i.e., vertical and horizontal.

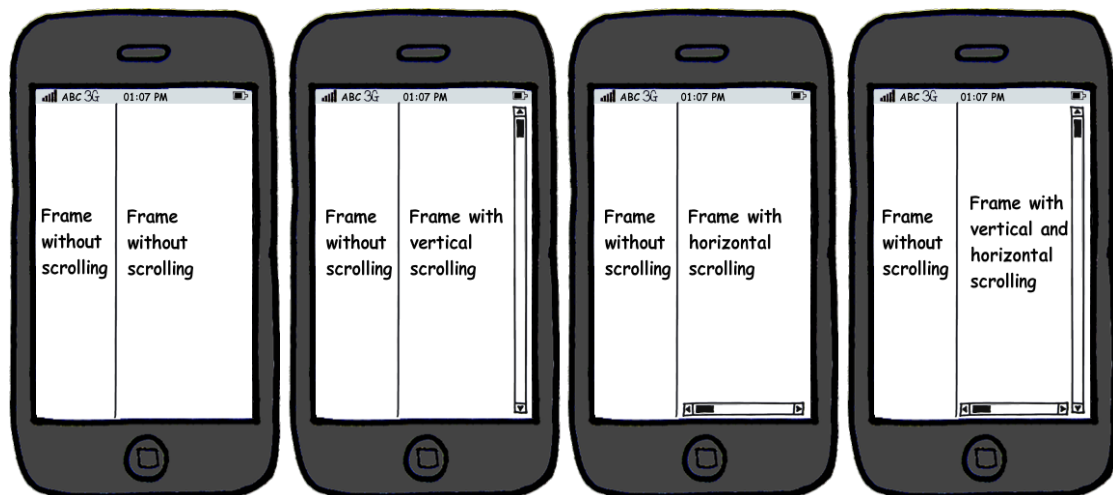


Fig. 1. Prototype of interfaces (W1, W2, W3, W4) designed for the experiment.

The independent variables were the kind of frame tested on each interface (i.e. W1, W2, W3, W4), the device orientation (portrait or landscape) and the frames implementation type (frames or iframes). The experiment had a within-subjects design. The dependent variables were (1) the ability to display the whole content, (2) the correct behavior of the frames in each

case, (3) the correct behavior of frames with bookmarks and (4) the correct behavior of frames with the back button. The dependent variables number 1 and 2 were measured for all interfaces and orientations, and dependent variables number 3 and 4 were measured only for one kind of interface (an additional interface designed, which contained two frames: the left one had a menu and its target was displayed in the right one) and in portrait orientation. This was because two different content pages were necessary to be loaded in order to check the behavior of bookmarks and back button, and interfaces of Fig. 1 only had one page loaded. Therefore, the experiment consisted of 22 subjects x 4 interfaces x 2 orientations x 2 implementations x 2 dependent variables = 704 data plus 22 subjects x 1 interface x 2 implementations x 2 dependent variables = 88 data. In summary, 792 data were collected in total.

2.4. Procedure

The experiment consisted of two phases: preparation and main testing.

In the preparation phase, the interfaces for the experiment were developed and uploaded to a web server, in order to be accessible from all the mobile devices via Wi-Fi connection.

In the main testing phase, all subjects were tested individually. Firstly the experimenter loaded the first interface in the mobile web browser, and then she tried to display the whole content and checked the behavior of the frame. The results (whether the content was fully displayed and the behavior of the frame about scrolling, bookmarks and back button) were written down for further analysis. Then the process was repeated for the remaining cases, i.e., with the other interfaces and orientations, until all the experimental conditions were performed.

3. Results

After the experiment was performed with all the subjects, the data collected were analyzed to extract interesting data.

3.1. Ability to Display the Content

As seen in Table 2, the content in W2 and W3 could be completely viewed in 100% of the devices when using both frames and iframes (please note that when cells contain two numbers, the number in parenthesis takes into account the cases where devices could not be in landscape orientation, i.e., in some cases landscape orientation was not supported by some devices, so the number in parenthesis represents the value over the total number of devices). Interface W4 could be viewed in 100% of the devices when using frames, but around 95% when using iframes. This was due to scrolling did not work in both directions in one of the devices. On the other hand, the content of W1 could not be completely viewed in around 26% on average (between portrait and landscape) in the mobile devices when using frames and around 7% when using iframes. This happens when the device is not able to show the whole content in the screen (due to its small screen size) and it is not possible to scroll (because for the case W1 it was not allowed).

Table 2. Results of the experiment for the first task (displaying content).

		Frames				iFrames			
		Yes		No		Yes		No	
Int.	Orientation	N	%	N	%	N	%	N	%
W1	Portrait	17	77.27	5	22.73	20	90.90	2	9.10
	Landscape	14	70.00 (63.63)	6	30.00 (27.27)	19	95.00 (86.36)	1	5.00 (4.54)
W2	Portrait	22	100	0	0.00	22	100	0	0.00
	Landscape	20	100 (90.90)	0	0.00	20	100 (90.90)	0	0.00

W3	Portrait	22	100	0	0.00	22	100	0	0.00
	Landscape	20	100 (90.90)	0	0.00	20	100 (90.90)	0	0.00
W4	Portrait	22	100	0	0.00	21	95.46	1	4.54
	Landscape	20	100 (90.90)	0	0.00	19	95.00 (86.36)	1	5.00 (4.54)
Total		157	93.45 (89.20)	11	6.55 (6.25)	163	97.02 (92.61)	5	2.98 (2.84)

In general, the content was viewed more times when the devices were in portrait orientation, which suggests that mobile browsers are well designed for navigating in portrait orientation, but not in landscape orientation.

3.2. Behavior

The results for the second task of the experiment (behavior of frames) are shown in Table 3 (please note that when cells contain two numbers, as in the previous table). First of all, it is important to say that "correct behavior" means that a frame having scroll lets to move the part of the webpage having scroll in the direction it is enabled, but not over the whole page, because this is not the default behavior of frames and this could mislead users.

Table 3. Results of the experiment for the second task (behavior of frames).

Int.	Orientation	Frames				iFrames			
		Yes		No		Yes		No	
		N	%	N	%	N	%	N	%
W1	Portrait	9	40.91	13	59.09	5	22.73	17	77.27
	Landscape	8	40.00 (36.36)	12	60.00 (54.54)	3	15.00 (13.63)	17	85.00 (77.27)
W2	Portrait	3	13.64	19	86.36	10	45.46	12	54.54
	Landscape	2	10.00 (9.10)	18	90.00 (81.80)	7	35.00 (31.81)	13	65.00 (59.09)
W3	Portrait	3	13.64	19	86.36	10	45.46	12	54.54
	Landscape	2	10.00 (9.10)	18	90.00 (81.80)	7	35.00 (31.81)	13	65.00 (59.09)
W4	Portrait	3	13.64	19	86.36	10	45.46	12	54.54
	Landscape	2	10.00 (9.10)	18	90.00 (81.80)	6	30.00 (27.27)	14	70.00 (63.63)
Total		32	19.05 (18.18)	136	80.95 (77.27)	58	34.52 (32.95)	110	65.48 (62.50)

When using frames, in around 88% (average between portrait and landscape) of the 20 devices the behavior was incorrect for W2, W3 and W4; and only in around 60% the behavior was incorrect for W1. On the contrary, with iframes, the behavior was worse in interface W1 (around 81% of the devices had an incorrect behavior) than in interfaces W2 (around 60%), W3 (around 60%) and W4 (around 62%).

As in the case of displaying content, the behavior was also better when the devices were in portrait orientation instead of in landscape orientation, and iframes worked (in general) better than frames. There is only one case in which frames had a better behavior than iframes: with interface W1. This was due to the design of the web page, i.e., the right frame had a big content to be shown and no scrolling was allowed in the source code, so mobile browsers have to choose in these cases their behavior: they can show the whole content, ignoring the source code and using scroll to do this; or they can meet the source code and do not allow scrolling, and therefore the whole content will not be displayed. With frames there were more mobile browsers that met the source code than with iframes, and that is why the content was displayed fewer times than with iframes.

3.3. Bookmarks

After performing the third task, we found that bookmarks did not work well in 100% of the devices, as they saved the URL of the main webpage with the default frames or iframes, so if users want to save in bookmarks a webpage different from the loaded by default, they will not be able to retrieve it.

3.4. Back Button

In 100% of the devices the back button did not work as expected, because when using frames and iframes and pressing the back button, all the mobile web browsers showed the previously visited frame/iframe, and not the previous webpage, as it may be expected. This behavior could be disorienting for the user.

4. Discussion

With the experiment shown in this paper we have empirically verified that the most frequently mentioned problems related to frames in PC websites (bookmarking [1], [6, 7, 8] and back button [7], [9]) are still remaining in mobile web browsers. They do not allow properly bookmarking, neither using frames nor even using iframes, which are a newer implementation in HTML and were supposed to bookmark properly in PC [9]. The back button neither worked properly in none of the devices, neither using frames nor using iframes, because when this button was pressed the previous content was shown in the right frame, but not the previous visited website. Therefore we could say that those problems pointed out in guideline 9.3.10 of ISO 9241-151 [2] for PC websites are still valid for existing mobile devices. These problems should be specified in guideline 5.4.2 of Mobile Web Best Practices [11] to help developers to know what problems they may find when using frames or iframes.

On the other hand, we also tested the ability to display the content and the behavior of frames in mobile devices, as some authors indicated that not all web browsers support frames [4], [9], especially mobile web browsers [11], some of which would not allow users to scroll the content within a frame or iframe [3]. Our results support those affirmations, as not all devices were able to display the content or behave as expected, especially in frames and iframes with scrolling.

As tablets are being used increasingly, one limitation of our study is that most of the devices used to carry out the experiment were smart phones, and we should have included more tablets in the sample, but we could not do it because of economic issues. Including pointer devices in the sample (and also a representative set of devices) would have also been interesting, but the same reason applies to why they have not been used.

5. Conclusion

From the first task performed in the experiment, we could conclude that the content can be always displayed if the implementation of a web page with frames or iframes is correct, except when an iframe has both horizontal and vertical scrolling, where some mobile devices can be found that are not able to manage both scrollings at the same time to show the content. The biggest problem found for showing the content was when the implementation was not correct, because the content was bigger than the device screen and the source code did not allow scrolling, so that the content could not be fully displayed. In addition, it is recommended to use mobile devices in portrait orientation when viewing web pages with frames or iframes, as the content can be viewed in more cases when using this orientation.

The results for the second task are even more noteworthy because most of the devices had an incorrect behavior, and behaviors were very varied depending on the mobile device used. Therefore, if a web site uses frames or iframes, mobile users can be misled, since in most cases the behavior is not as expected. This is more pronounced when frames and iframes have scrolling and when using frames rather than iframes, so we could conclude that iframes have

improved their behavior compared to traditional frames. As in the case of displaying content, the behavior was also better when the devices were in portrait orientation rather than in landscape orientation, and it was worse when the implementation was not correct, i.e., when the source code says that no scrolling should be used, but mobile devices do it. Hence, as aforementioned, we recommend using mobile devices in portrait orientation when navigating web sites with frames or iframes.

It has also been shown that bookmarks do not work well in mobile devices, either with frames or iframes, and the back button does not work as expected, as it breaks the traditional concept of navigation. Therefore, these traditional usability issues are still present in new browsers such as those of mobile devices.

According to the results, using frames and iframes does not follow the principle of universal accessibility, since users who have some specific mobile devices will not be able to view the content of the website. Therefore, we could conclude that frames and iframes should be avoided in mobile devices because the content may not be displayed, their behavior may not be that expected, bookmarks do not work well and using the back button neither. If using frames is strictly necessary then developers should be careful when implementing (because otherwise users may not view the content), and should use iframes instead of traditional frames, as they are newer, allow displaying the whole content more times (in average) and their behavior is better (in average). This is a new guideline about frames and iframes for mobile devices and that is not included in any recommendation or standard, so it would be important that designers and developers take this into account when designing and developing mobile websites. It is also important to continue researching new methods of structuring information in mobile websites, avoiding the problems detected in frames and iframes.

Finally, as mentioned above, some problems detected were specific in some devices, so that mobile devices manufacturers should be aware of the importance of solving these issues to improve usability for their users.

References

1. Bevan, N.: Usability issues in web site design. Serco Experience Lab, London (1999)
2. DHHS (US Department of Health and Human Services): Research-Based Web Design and Usability Guidelines. Washington D.C. (2008)
3. Firtman, M.: Programming the mobile web. O'Reilly Media, Inc., Sebastopol (2013)
4. Frick, T., Monson, J.A., Xaver, R.F., Kilic., G., Conley, A.T., Wamey, B.T.: Navigational Structure on the World Wide Web: Usability Concerns, User Preferences, and "Browsing Behavior". In: Proceedings of Selected Research and Development Papers Presented at the National Convention of the Association for Educational Communications and Technology, pp. 111-117. RTS & Associates Inc, Houston (1999)
5. Henninger, S.: An organizational learning method for applying usability guidelines and patterns. In: Proceedings of Engineering for Human-Computer Interaction, pp. 141-155. Springer, Heidelberg (2001)
6. Instone, K.: Usability heuristics for the Web (1997), <http://instone.org/heuristics>. Accessed March 28, 2014
7. ISO 9241-151: Ergonomics of human-system interaction – Part 151: Guidance on World Wide Web user interfaces (2008)
8. Nielsen, J.: Original Top 10 Mistakes in Web Design (1996), www.useit.com/alertbox/9605a.html. Accessed March 28, 2014
9. Nielsen, J.: Why frames suck (most of the time) (1996), <http://www.useit.com/alertbox/9612.html>. Accessed March 28, 2014
10. Nielsen, J.: Top ten mistakes revisited three years later (1999), www.useit.com/alertbox/990502.html. Accessed March 28, 2014
11. W3C: Mobile Web Best Practices 1.0 - Basic guidelines (2008)

Implementing a Mobile Application for Street Lighting Evaluation

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Abstract

Nowadays, energy consumption is on the rise. This is not sustainable in the long run. The highest energy use in Town Councils takes place in street lighting installations. In order to help in this problem, we present a mobile service to evaluate the electrical consumption of these infrastructures. This new tool is able to make an estimation of energy demand of installations; on an easy and intuitive way thanks to an evaluation methodology which reduces the need of a large list of parameters used by other programs. As a result, the developed application also gives users the opportunity to compare the efficiency of the installation evaluated with others previously evaluated to increase energy efficiency. The application was tested with two different experiments to ensure its correct running and to evaluate both the estimation accuracy and usability.

Keywords: Energy Consumption, HTML5, Smartphone, Usability.

1. Introduction

Energy saving has become the most urgent environmental problem to be addressed by all societies. Street lighting is one of the main energy consumption in local governments. It typically accounts for 30-60 percent of greenhouse gas emissions [20]. Nevertheless, evaluation and operation of electric lighting design shows that the improvements could save up to 50% of energy [14]. There are many possibilities to achieve this reduction, such as reducing high illumination level, improving quality of lighting, removing light pollution or changing standards [4]. However, these improvements often require large investments, complicating their implementation.

At present, the average consumption of Spanish lamps is one of the highest in the European Union countries, with an approximate consumption of 157W per lamp, well above United Kingdom, 76W, or Netherlands, 61W [17].

Once the government realized this overuse, the Royal Decree 1890/2008 [16] was established to improve efficiency and energy saving. However, not all the Autonomous

Communities have implemented dimmable lighting systems as Andalusia, where the percentage of installations without this system obligatory is 64% [8].

Another possible cause of the problem about the excess of energy consumption could be the lack of awareness of maintenance managers. To solve this, there are some programs to calculate the efficiency of energy consumption, but all of them have been developed as computer applications and not mobile phone. However, Town Councils do not take advantage of them, sometimes because of the lack of qualified employees or because the program is only linked to a specific manufacturer, limiting a full performance.

Keeping in mind that mobile systems, such as smartphones, have become the primary computing platform for many users [2]. We have developed a mobile application which estimates electrical energy consumption on street lighting installations, independently of manufactures, and gives the opportunity to compare with other.

The purpose of this system is to give users the possibility to make an estimation of the consumption of installation in a simple and intuitive way. To check the correct running of the application developed, it was tested in two different ways: an evaluation of the estimation accuracy with real installations, and a study of the usability of this tool.

2. Related Work

Nowadays, there are plenty programs to evaluate energy consumption in buildings. However, similar systems applied to street lighting are not common and, in most of cases, the level of knowledge required is too high. So far no mobile applications are known. Nevertheless, the study of the existing programs can be used as a base to improve the application scope.

One of the most renowned programs is DIALUX, which allows creating a 3D virtual world where real lighting effect may be recreated. It also gives information related to power consumption of each element to guarantee the compliance of regulations [7]. The strength of this tool is the database with information from the main lighting manufacturers, providing more accurate evaluations.

Another tool is CALCULUX, helping lighting designers to select and evaluate lighting systems [12]. The program allows predicting financial implications; including energy, investment, lamp and maintenance costs for different luminaire arrangements. Although, its main weakness again is the exclusive relation with Philips products.

RELUX is a light calculation program. It is based on the solid angle projection procedure, to calculate street lighting as per different standards in order of the kind of lighting evaluated. In the case of street lighting the normative used is EN 13201[3].

After studying the features of them, it was observed that their complexity was not compatible with mobile devices. In this context, usability and compactness of the information displayed has a significant role.

The main usability hurdles for mobile devices are small screens, awkward input, download delays and mis-designed sites [15]. Knowing these disadvantages, before starting to develop the application, it is necessary to perform a study to reduce as much as possible the information needed to make the evaluation. Therefore, a study was conducted to obtain the minimum requirements to make a correct evaluation.

3. Energy Consumption Analysis

The methodology used to estimate the electrical energy consumption of street lighting systems is as follows: Firstly, it analyzes the main components which affect to the energy consumption. Secondly, it describes how the application calculates the electrical energy consumption.

3.1. Components Influencing Energy Consumption

Street lighting installations are mainly formed by lamps, ballast, street lighting control system and dimmable lighting system. To ensure about the influence of each one in final energy consumption, they have been studied individually.

The most important component in street lighting is lamps. Depending on the technology used, different sorts of lamps can be found: stand mercury vapor, high pressure sodium, low pressure sodium, high pressure ceramic metal halide and led lamps. Each kind has a different response to external factors [22]. After studying them, it was discovered that the most important factor is the lamp voltage, which defines the final lamp power. This factor influences differently depending on the type of lamp.

Analyzing the voltage separately shows how this factor is not constant over time. The fluctuations on voltage may vary the power of the lamp up to 0.5% [19]. In spite of nominal voltage is 220V, the fluctuations may even reach values up to 249V. This overvoltage situation shortens the lifetime of lamps, dissipating more power than its rated power.

To solve overvoltage problems, street lighting installations use dimmable lighting systems, which are able to control the voltage. At present, these systems allow saving energy thanks to the configuration of the input voltage, being capable of reducing it based on some parameters like traffic flow or weather conditions [23]. All these features enable the evolution to adaptive lighting systems where the luminous flux of the installation can be controlled. The minimum luminous flux level was established on 50% because this dimming has no influence on observers and drivers visibility [1].

Another component associated with the consumption is ballasts. This device is required to control the lamp. There are three sorts: electromagnetic, inductive and electronic. In spite of the main difference between them is the electrical energy consumption, there are other differences to be taken into account, such as losses caused by iron and copper or losses in the magnetic choke [18]. If the value of the power associated to this element is unknown, the Royal Decree defines a maximum value depending on the sort of lamp.

The running time of the installation is managed by the street lighting control system. There are two different options in the market: astronomic time switch, twilight switches. The burning hours of the devices is different due to the differences on working criteria on the devices. While astronomic time switch allows controlling the switch on and off according to sunrise and sunset hours [21]. Twilight switches measures the amount of natural light available and turns on and off the lamps on a specific level of light [10].

3.2. How the Application Calculates the Electrical Energy Consumption

After understanding the performance of the components which affect in energy consumption, an estimation of total energy consumption can be calculated. To do this, the methodology used estimates the final consumption of installation as the sum of all of the streetlights. To calculate the energy of each luminaire, knowing the ballast power ($P_{ballast}$) is necessary, but also the nominal lamp power (P_{lamp}), the impact of the current voltage over it (V_{impact}) and the number of burning hours (N_{hours}), as is shown below:

$$E_{consumption} = \left((P_{lamp} * V_{impact}) + P_{ballast} \right) * N_{hours} \quad (1)$$

4. Proposed System

To evaluate the energy consumption, a new application (SOLE - System to evaluate the Outdoor Lighting Energy demand) is proposed in this paper. The application has been developed as a Smartphone application, so that maintenance managers can conduct energy-estimating operations easily and quickly. The main aim of this application is to evaluate street lighting, showing the prediction of energy and number of burning hours. To create energy awareness, the tool also shows a comparative chart in which the average of their power lamps is compared with other evaluated by the system. The application architecture and its use are explained in the following sections.

4.1. Application Architecture

The main problem observed to develop a mobile application is the number of existing platforms in markets. The variety of systems hinders developing native applications valid for all devices due to their differences on programming languages [5].

Developing native applications has, in some cases, a cost associated with the development and deployment in certain platforms. However, mobile applications built on HTML5 allow cut down the development time and cost with the advantage of being portable not only between mobile platforms, also giving the opportunity to develop a webpage, which can make the application available to be used by mobile devices without having to install new programs. Nevertheless they also have some limitations. While HTML5 offers many JavaScript APIs that give access to several device services, the reality is that their implementation in mobile devices is not always complete [9]. Maybe HTML5 applications do not achieve the same performance as native applications, but the lower cost and cross-platform availability of web applications are clear advantages [11]. For these reasons, and after analyzing the needs of the application, we have created a new HTML5-based mobile application where the user can check the energy behavior of a street lighting installation.

The most important factor for mobile users is the battery life [13]. For that reason, and to ensure the computation of the energy evaluation is not too intensive to be performed on a mobile device, the computation is performed in the server. In this way, the changes made on the database or on the calculation methodology do not affect the application behavior.

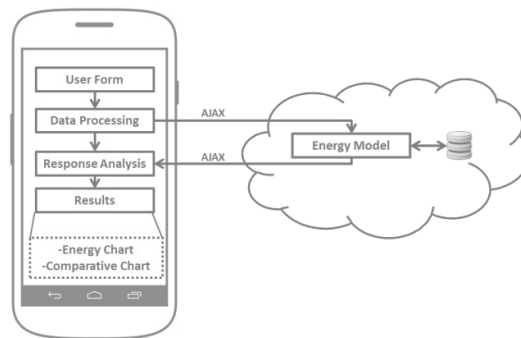


Fig. 1. App Architecture

4.2. Displaying Energy Consumption

The first screen shows an introduction of the tool, where you can find also information related to the aim of the application (figure 2(a)). It is possible to come back to this screen from anywhere of the program thanks to the navigation toggle button placed at the top of the screen.

When users start the installation evaluation of the installation, the first thing to do is to register all the features of the equipment devices (city, lamps and so on) by means of the form showed on figure 2(b). As it is known, the screen size may hinder the input of data. For that reason, the form was divided into three different parts. Thereby the user has to pass through them to enter all the information.

When the information is set, the application sends the information to the server and waits for the energy evaluation. After receiving the server's response, the user obtains the results. The intention is that the incorporation of simple interactive graphics, which are supplemented by small portions of relevant information, gives users the opportunity to check the data [6]. As it happens with the input form, the result has been divided into two different screens to simplify the use of the tool. To switch between these options, two buttons are placed, one for each section of results:

- In the first section, two charts with the information about the energy consumption and the burning hours can be observed. If the user introduces real consumption values, these data will be shown in the same chart together energy estimation (Figure 2(c)).

- The last section shows a comparison between the average of power per lamp of the infrastructure and the average of other installations of the same province which has been previously evaluated by the system. Besides the chart, the distribution of lamps according to the kind of technology used is shown (Figure 2(d)).

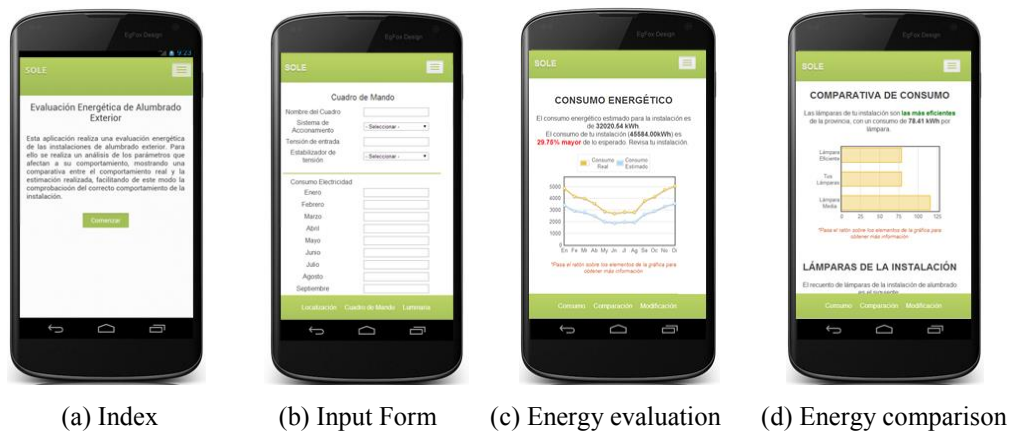


Fig. 2. Application screenshots

5. Results and Discussion

Two experiments were conducted to evaluate the application from the following viewpoints:

- **Capability to evaluate energy consumption:** Could the application estimate energy consumption of street lighting installations?
- **Usability for sustainable operations:** Is the application easy and interesting enough to be used as an energy evaluation tool?

5.1. Capability to Evaluate Energy Consumption

To answer the first question, it was obtained information related to street lighting installations in 4 different municipalities (Villaluenga de la Sagra, Tielmes, Tardajos and Rabanales) in order to check the application. The collection of information related to energy consumption was obtained thanks to energy bills. It is worth stressing the absence of dimmable systems in all the installations evaluated. Once the information was collected, the main drawback observed in most cases was the lack of information related to the number of burning hours, or the information about the ballast power. In these cases the application solves the problem giving an approximation of these values thanks to the study made previously about each device.

As a result, an average error produced on complete simulations up to 5% was observed. On the other hand, when the data has lack of information about the installation, the error could increase up to 10%. That error may be due to different factors such as fluctuations on voltage or the characteristics of components. Figure 3 shows a chart with a real comparison between the energy estimation and the real energy value on the municipality of Tardajos, Burgos.

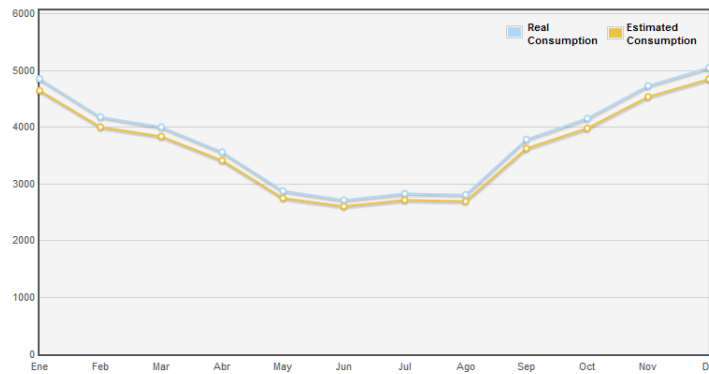


Fig. 3. Differences between estimated and real energy consumption in the municipality of Tardajos, in the province of Burgos

5.2. Usability for Sustainable Operations

The next experiment was made in order to check the level of users' acceptance of the tool, where 8 subjects tested the tool. To be sure about the understanding of the developed application, the selected users have different levels of knowledge about street lighting.

During the experiment, a sheet with different parameters of an installation was given to users, who had to introduce the information in the application. To analyze how users insert the information, the sheet had more information than required on the application form. The experiment was carried out using two devices with different characteristic with the purpose of obtaining more information about the influence of the screen size on the usage of the tool. Each user performed the experiment only with one of the devices. The devices used were:

- 7 inches tablet (BQ Pascal Lite C).
- 3.5 inches smartphone (Samsung Galaxy Ace).

Once the experiment finished, the users had to fill out a questionnaire with several questions to evaluate and give their opinion about the application.

Thanks to the questionnaire, we have realized that difficulty of use increases when the device has a small screen. The main reason is the need of use the keyboard, which occupies most of the screen; and the presence of a list of buttons at the bottom of the screen, which hampers displaying the form fields. In spite of that, it is important to highlight how users qualify the complexity of use as medium (3), even with low knowledge about street lighting. The 60% of the respondents highlight how the interface is helpful to follow the steps to complete the experiment.

When they were asked about the result of the evaluation, 75% of the respondents indicated as high point the quality of the charts, which gives the opportunity to display information by month just touching the value points. Moreover, the interviewed stand out that this developed tool should raise the energy awareness. Figure 4 shows the main results of the questionnaire made following the Likert scale.

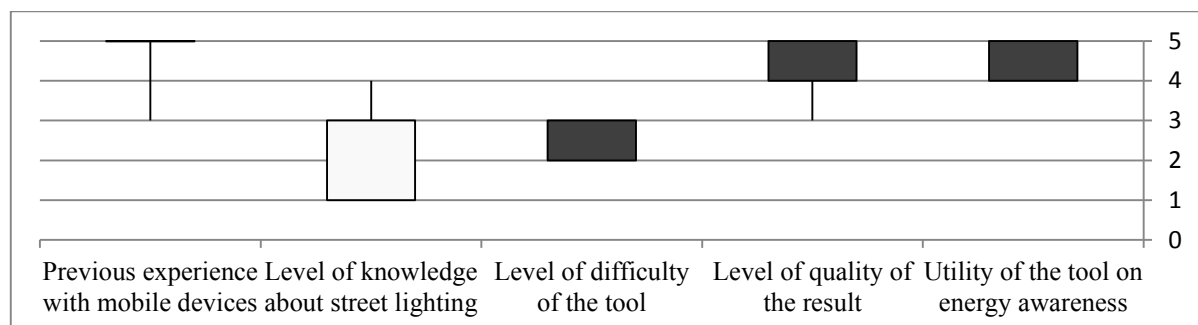


Fig. 4. Results of the questionnaire evaluated using a Likert scale (1-Low, 5-High)

6. Conclusion

High energy consumption of street lighting systems has propitiated the development of programs to evaluate them. However, their complexity makes difficult their use by inexperienced users. These programs create a simulation of a detailed scenario to be able to perform the evaluation, needing the input of a long list of parameters, most of them without impact on energy consumption.

The main benefit is the contribution of an unique mobile application, known as SOLE (System to evaluate the Outdoor Lighting Energy demand), which simplifies the evaluation of street lighting energy consumption. The result is a manageable and intuitive application that estimates the electrical energy consumption and the number of burning hours without the influence of a specific manufacturer. It should be noted that the comparison chart among installations was the better evaluated in the form because users realize of their real situation.

Throughout the experiment conducted to check the usability of the tool, we observed how an intuitive interface may help users to solve the drawback of a low level of knowledge on street lighting installations.

Finally, we would like to point out how the size of the screen was the main drawback to be solved on the developing stage. As a result on the last test we realized that the complexity of the application increases when users use a device with small screen. The main reason is the need to use the keyboard and a list of buttons at the bottom of the screen, thus hampering the display of the fields.

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References

1. Bacelar, A.: The influence of dimming in road lighting on the visibility of drivers. *J. of Light & Visual Environment*. 29 (1), 4-49 (2005)
2. Bajad, R. A., Srivastava, M., Sinsha, A.: Survey on Mobile Cloud Computing. *J. Engineering Sciences & Emerging Technologies*. 1 (2), 8-19 (2012)
3. Bhavani, R.G., Khan, M.A.: Advanced Lighting Simulation Tools for Daylighting Purpose: Powerful Features and Related Issues. *J. Trends in Applied Sciences Research*. 6 (4), 345-363, (2011)
4. Boyce, P. R., Fotios, S., Richards, M.: Road lighting and energy saving. *J. Lighting Research & Technology*. 41 (3), 245 – 260 (2009)
5. Charland, A., Leroux, B.: Mobile application development: web vs. Native. *Communications of the ACM*. 54 (5), 49-53 (2011)
6. Costello, G.J., Clarke, R., Donellan, B., Lohan, J.: Development of a Prototype Knowledge Discovery Portal for Energy Informatics. In: *Proceedings of the 20th International Conference on Information Systems Development*, pp. 129-141. Springer, Edinburgh (2011)
7. Gómez-Lorente, D.: A new methodology for calculating roadway lighting design based on a multi-objective evolutionary algorithm. *J. Expert systems with applications*. 40 (6), 2156-2164 (2013)
8. Guía de ahorro y eficiencia energética en municipios (2011) (Guide of saving and energy efficiency in municipalities), (in Spanish). http://www.agenciaandaluzadelaenergia.es/sites/default/files/guia_de_ahorro_y_eficiencia_energxtica_web_defl.pdf. Accessed March 10, 2014

9. Hemel, Z., Visser, E.: Declaratively Programming the Mobile Web with Mobil. In: Proceedings of the 11th International conference on Object oriented programming systems languages and applications, pp. 695-712. ACM, New York (2011)
10. Howell, E.K.: Photoelectric controls for street lights. *J. Electrical Engineering*. 80 (10), 780-785 (1961)
11. Juntunen, A., Jalonen, E., Luukkainen, S.: HTML 5 in Mobile Devices -- Drivers and Restraints. In: Proceedings of the 46th Hawaii International Conference on System Sciences, pp. 1053-1062. IEEE, Wailea (2013)
12. Kostic, M., Djokic, L., Pojatar, D., Strbac-Hadzibegovic, N.: Technical and economic analysis of road lighting solutions based on mesopic vision. *J. Building and environment*. 40 (1), 66-75 (2009)
13. Kumar, K., Yung-Hsiang, L.: Cloud Computing for mobile users: can offloading computation save energy? *Computer*. 43 (4), 51-56 (2010)
14. Loe D. L.: Quantifying lighting energy efficiency: A discuss document. *Lighting Research & Technology*. 35 (4), 319-329 (2003)
15. Nielsen, J., Budiu, R.: *Mobile usability*. New Riders, United States (2013)
16. Real Decreto 1890 (2008). Reglamento de eficiencia energética en instalaciones de alumbrado exterior. (In Spanish) (Royal Decree 1890. Energy Efficiency for Outdoor Lighting Installations). <http://www.boe.es/boe/dias/2008/11/19/pdfs/A45988-46057.pdf>. Accessed March 10, 2014.
17. Sánchez de Miguel, A.: Differential Photometry Study of the European Light Emission to the Space. In: Proceedings of World Conference in Defence of the Night Sky and the Right to Observe the Stars, pp. 379-383 Las Palmas (2007).
18. Shu-Hung, H., Ngai-Man, H., Yan, W., Wai Tam, P., Hui, S.Y.: Comparison of Dimmable Electromagnetic and Electronic Ballast Systems—An Assessment on Energy Efficiency and Lifetime. *J. IEEE Transactions on Industrial Electronics*. 54 (6), 3145-3154 (2007)
19. Street Lighting Load Research Report 2 (2013). <http://www.elexon.co.uk/wp-content/uploads/2012/03/StreetLighting-Load-Research-Report-2-2013.pdf>. Accessed March 10, 2014
20. Street Lighting Strategy (2011). http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/Lighting/Street_Lighting/Draft-streetlight-Strategy.pdf. Accessed March 10, 2014
21. SunriseSunset, <http://www.sunrisesunset.com/> Accessed March 10, 2014.
22. Yan, W., Hui, S.Y.R., Chung, H.S.H.: Energy saving of large-scale high intensity discharge lamp lighting networks using a central reactive power control systems. *J. IEEE Transactions on industrial electronics*. 56 (8), 3069-3078 (2009)
23. Zotos, N., Stergiopoulos, C., Anastasopoulos, K., Bogdos, G., Pallis, E., Skianis, C.: Case study of a dimmable outdoor lighting system with intelligent management and remote control. In: Proceedings of the International Conference on Telecommunications and Multimedia, pp. 43 – 48. IEEE, Chania (2012)

An Exploratory Study on the Adoption of Mobile Advertising in China

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Abstract

With the development of mobile technology, mobile advertising has become popular worldwide. It seems that almost every user who owns a mobile device receives mobile advertisements from various service providers. However, most consumers hold negative attitude toward mobile advertising. Therefore, this research aims to investigate the factors which influence consumers' adoption of mobile advertising. Based on literature review from previous research, a research model was proposed. This research model was empirically evaluated using survey data collected from 302 receivers of mobile advertising. According to the analytical results of our study, consumers' attitude toward mobile advertising and incentives explain about 80% of consumers' intention to receive mobile advertisements. Besides, entertainment, credibility, personalization and irritation all have direct effects on consumers' toward mobile advertising, and the effect from entertainment is quite strong. Furthermore, both theoretical and practical implications of this study are discussed.

Keywords: Mobile Advertising, Entertainment, Credibility, Irritation, Personalization, Incentives, Consumers' Attitude.

1. Introduction

With the development of mobile technology, mobile advertising has become popular worldwide. This new advertising media has been employed by many multinational companies, such as McDonald's, Microsoft and Google, etc. To maximize the chances to communicate with a captive audience, advertisers are beginning to funnel money into mobile advertising. After several false starts, mobile advertising has now truly taken off and is forecast to account for 37% of all growth in global ad expenditure this year, and 31% in 2014, according to a recent report by ZenithOptimedia. Besides, according to iResearch, the money spent on mobile advertising increased by 151% in China during March and September in 2013.

It is obviously that Chinese practitioners have paid enough attention to mobile advertising, however, most previous studies revealed the public attitude towards advertising in western countries [3, 4]. Mobile services have been the fastest diffusing technology in history, but acceptance of mobile services has varied between different services [6, 7]. Therefore, more attention should be paid to investigate public attitude towards mobile advertising in China. A critical question thus arises. What factors are most predictive of how consumers would respond to mobile advertising? Based on analysis of prior literature on related fields, a research model was developed to investigate the adoption of mobile advertising. The objective of this paper is to empirically examine how well the proposed research model is able to explain mobile advertising adoption in China.

The remainder of this paper is organized as follows: Section 2 discusses the theoretical background of this study. The research model and hypotheses are presented in Section 3. The research method and results of this research are provided in Section 4. This is followed by a discussion of the findings in Section 5. Practical implications of this study are discussed in Section 6. Section 7 concludes this research and suggests directions for future research.

2. Literature Review

2.1. Attitude towards Internet Advertising

Although Internet has emerged for a relatively short time, its penetration and impact seems to be significant. Different from the attitude towards traditional advertising, the attitude towards Internet advertising in general was mixed. In [17], Schlosser et al. found that nearly one third of the respondents held positive attitude, one third held negative attitude and remaining one third held neutral view towards Internet advertising. According to the previous research [5], informativeness, entertainment and irritation of advertisements were critical predictors of their value and were important to the effectiveness of Web advertising. They would influence consumers' attitude toward Internet advertising.

Table 1. Literature review on mobile advertising adoption.

Literature	Research purpose	Findings
Noor et al. (2013) [13]	Analyze consumers' attitude towards mobile advertising and their intention to purchase the advertised products and services.	The relationships between consumers' attitude towards mobile advertising, subjective norms, perceived behavioral control and their intention to purchase products and services are significant.
Hung et al. (2012) [10]	Investigate factors influencing the perception of mobile advertising in different cultures (a comparison between Japan and Austria).	The results suggest that infotainment and credibility are key factors predicting advertising value among Austrians and the Japanese. However, our findings show that Japanese customers are more irritated by mobile advertising than are Austrian respondents.
Chowdhury et al. (2010) [3]	Study the factors affecting consumer attitudes toward SMS-based advertisements in Bangladesh.	The findings show that if mobile advertisers can present mobile ads pleasingly, with appropriate information, consumers will not be annoyed and there is a fair possibility that they will gradually like the ads. Furthermore, credibility has found to be the most significant of the factors affecting respondents' attitude toward mobile ads.
Drossos et al. (2007) [4]	Investigate the significance of a number of factors associated with SMS advertising effectiveness.	The findings indicate that incentive, interactivity, appeal, product involvement, and attitude toward SMS advertising in general directly influence attitude toward the advertisement, attitude toward the brand, and purchase intention.
Hanley et al. (2006) [9]	Study factors affect mobile advertising acceptance among college students.	Results show that college students would consider accepting ads on their cell phones if specific cell phone ad delivery conditions were met or free cell phone products and services or monetary incentives were offered.
Haghirian et al. (2005) [8]	Study costumers' attitude toward advertising via mobile devices among Austrian users.	Users' attitude toward mobile advertising is negative and ads value and message content have the most impact on the attitude.

2.2. Mobile Advertising

As the field of mobile advertising is just at the beginning, it appears that there are only a few studies about mobile advertising employed theoretical and methodological approaches when compared with the literature of traditional and Internet advertising. Some studies have explored factors affecting consumers' adoption of mobile advertising, and some of these studies are summarized in Table 1.

This research aims to complement and extend existing research by focusing on customers' adoption of mobile advertising. It is a continuing effort in studying the potential factors affecting the acceptance of mobile advertising.

3. Research Model and Hypotheses

Based on the literature review, we proposed a research model illustrated in Fig. 1.

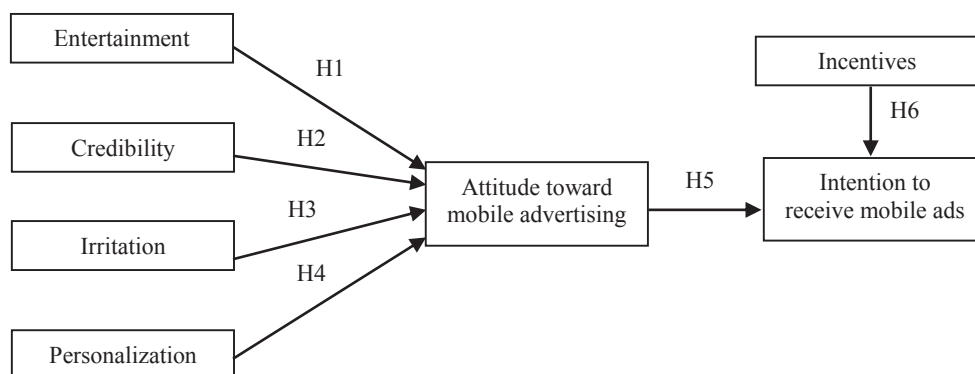


Fig. 1. The research model.

3.1. Entertainment

Entertainment element in advertising can fulfill consumers' needs for aesthetic enjoyment and emotional release [5]. Besides, Saadeghvazir et al. found that the entertainment of mobile advertising leads to positive attitude toward mobile advertising [16]. Therefore, we proposed the following hypothesis:

Hypothesis 1: The entertainment of mobile advertising has a positive effect on users' attitude toward mobile advertising.

3.2. Credibility

Credibility of an advertisement is influenced by different factors, especially by the company's credibility. Advertising credibility play an important role which create value of web advertising. In terms of trust in privacy and the laws of mobile advertising, Merisavo et al. found that credibility positively influenced the acceptance of mobile advertising in Finland [12]. On the basis of the former research, the following hypothesis was proposed:

Hypothesis 2: The credibility of mobile advertising has a positive effect on users' attitude toward mobile advertising.

3.3. Irritation

Irritation in advertising can be termed as an advertisement that creates annoyance, unhappiness, and brief intolerance. Altuna et al. found that irritation comprised the only negative dimension of consumer attitudes towards mobile advertising [1]. Therefore, we hypothesized:

Hypothesis 3: The irritation of mobile advertising has a negative effect on users' attitude toward mobile advertising.

3.4. Personalization

Personalization is one of the main features of mobile advertising. Rao and Minakais found that personalized advertising would also enhance consumer satisfaction [15]. This indicates that personalization would improve consumers' attitude towards mobile advertising. Accordingly, the following hypothesis was proposed:

Hypothesis 4: The personalization of mobile advertising has a positive effect on users' attitude toward mobile advertising.

3.5. Attitude

The relationship between attitude and intention is also supported in the field of mobile marketing. For example, Tsang et al. also found that consumers' attitude toward mobile advertising affected their consumer intentions to receive mobile advertisements directly [18]. Therefore, we proposed the following hypothesis:

Hypothesis 5: Consumers' attitude toward mobile advertising has a positive effect on their intention to receive mobile advertisements.

3.6. Incentives

Incentive based advertising is an approach that provides specific financial rewards to consumers who agree to receive advertisements into their mobile phones [14]. For example, mobile phones companies may reward consumers with free connection time for listening to voice advertisements. Iddris found that advertisers create the value to message by sending incentive based advertisement [11]. On the basis of the former research, the following hypothesis was proposed:

Hypothesis 6: Providing incentives for receiving mobile advertisements has a positive effect on consumers' intention to receive mobile advertisements.

4. Data Analysis

Empirical data was collected by conducting a survey, in form of a written questionnaire online and offline from October 15 to December 15, 2013. The survey yielded 346 responses both online and offline, 302 of them were usable. The participants were mainly college students. The primary reason of choosing college students as the major participants is that in comparison to other age groups, college students are more likely to use mobile devices frequently, view news and mobile advertisements, and do shopping online.

The first part of the questionnaire was about the demographic questions. 29.8% of the participants were male, and 70.2% were female. All the participants were between 18 and 25 years old, and 98.0% of them have the bachelor degree at least. All the participants had received mobile advertisements, and 95.0% of them had read mobile advertisements. 48.3% of the respondents indicated that they most frequently received SMS-based mobile advertisements.

In China, 3G and WiFi are the two most common wireless network technologies that provide wireless Internet access and services to users. Some areas in big cities (e.g., Beijing, Shanghai) are even fully covered by WiFi. Unlike the developed countries, mobile commerce hardly reaches low-income earners that constitute the majority of the population in China. But many from the young generations are comfortable with using some existing basic mobile services. This may help them attempt to try some advanced mobile services in the future. As mobile communication technology is developing very fast and the mobile commerce market in China is growing, more and more advanced mobile services will be available on the

business market. Given that China has the largest number of mobile phone subscribers in the world, it is believed that mobile commerce has a potentially exceptional future in China.

The second part of the questionnaire was set to test the hypotheses proposed above. Developed from the literature, the measurement questionnaire consisted of 20 items¹. A seven point Likert scale, with 1 being the negative end of the scale (strongly disagree) and 7 being the positive end of the scale (strongly agree), was used to examine participants' responses to all items in this part. In addition, data were analyzed using the structural equation modeling (SEM).

4.1. Measurement Model

In this study, we examined goodness-of-fit of the measurement model by using six widely-used fit indices: the chi-square/degrees of freedom (χ^2/df), the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), the comparative fit index (CFI), the normed fit index (NFI), and the root mean square error of approximation (RMSEA). Table 2 shows that all the fitness measures are within acceptable range. Therefore, we consider the measurement model is acceptable, and the measures indicate that the model fit the data.

Table 2. Fit indices for the measurement model.

Measures	Recommended criteria	Measurement model
Chi-square/d.f.	<3.0	1.913
GFI	>0.9	0.913
AGFI	>0.8	0.884
CFI	>0.9	0.954
NFI	>0.9	0.909
RMSEA	<0.08	0.055

In [2], Bagozzi and Yi proposed the following three measurement criteria: Factor loadings for all items should exceed 0.5, the CR should exceed 0.7, and the AVE of each construct should exceed 0.5. According to the results, the factor loadings range from 0.699 to 0.941, and the CR values range from 0.829 to 0.945. In addition, the AVE of all constructs exceeded 0.5 with the minimum of 0.619. As the three values of reliability are above the recommended values, the scales for measuring these constructs are deemed to exhibit satisfactory convergence reliability.

The measurements of discriminant validity are presented in Table 3. It is easy to find that the variances extracted by the constructs are more than the squared correlations among variables. The fact reveals that constructs are empirically distinct. As the convergent and discriminant validity measures are quite well, the test of the measurement model is satisfactory.

Table 3. Discriminant validity.

Variables	Entertainment	Credibility	Irritation	Personalization	Attitude	Incentives	Intention
Entertainment	0.850						
Credibility	0.182	0.619					
Irritation	0.171	0.030	0.678				
Personalization	0.138	0.101	0.035	0.715			
Attitude	0.452	0.190	0.151	0.185	0.845		
Incentives	0.060	0.070	0.033	0.081	0.103	0.677	
Intention	0.413	0.259	0.129	0.163	0.540	0.131	0.792

(Note: Diagonals represent the average variance extracted, while the other matrix entries represent the square correlation).

¹ The measurement items are available at: <http://www.idi.ntnu.no/~shanggao/ISD/Items.pdf>

4.2. Tests of the Structural Model

The structural model was tested using Amos 20.0, which is an add-on module for SPSS. The results of the structural model are shown in Fig. 2.

The R2 (R square) in the figure denotes to coefficient of determination. The standardized path coefficients between constructs are presented, while the dotted lines stand for the non-significant paths. As a result, the six hypotheses were supported. In addition, all the hypotheses were statistically significant. The positive effects of entertainment and credibility on attitude were relatively strong, as shown by the path coefficients of 0.51 and 0.25 ($P < 0.001$). The other path coefficients of irritation and personalization were statistically positively significant at $P < 0.01$. The paths from entertainment, credibility, irritation and personalization explain 71% of the observed variance in attitude toward mobile advertising. Thus, Hypotheses 1, 2, 3 and 4 were supported. The effect of attitude toward mobile advertising on intention to receive mobile advertisements is quite strong, as indicated by the path coefficient of 0.89 ($P < 0.001$). The other path coefficient from incentives to intention to receive mobile advertisements is statistically significant at $P < 0.05$. Besides, 80% of the observed variance in intention to receive mobile advertisements can be explained by the two paths. Therefore, Hypotheses 5 and 6 were supported.

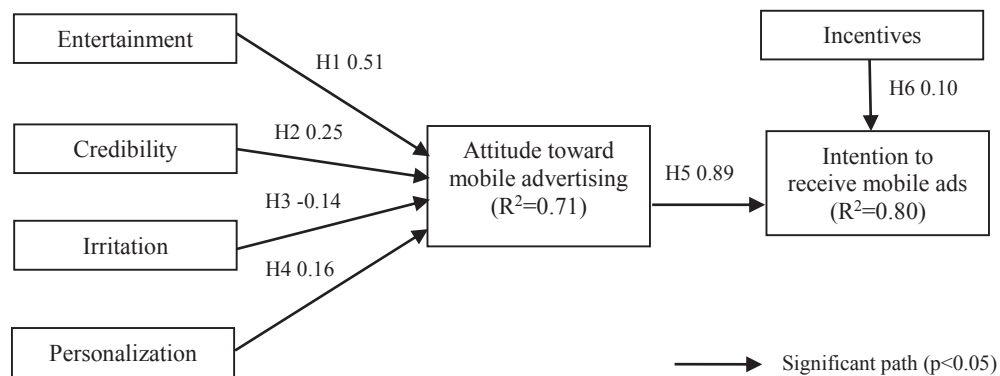


Fig. 2. Results of structural modeling analysis.

5. Discussion

In our study, we found all the six hypotheses were supported. As the empirical data illustrated, the respondents held negative attitudes about receiving mobile advertisements. This may be because they found mobile advertisements irritating intimate nature of mobile phones. It indicated that consumers' attitude would be favorable if the mobile advertisements were sent with permission.

Entertainment was the most significant of the factors affecting respondents' attitudes, followed by credibility, personalization and irritation. The effect of entertainment has been confirmed in the first hypothesis. This is consistent with the previous studies. For example, Faraz et al. found that the entertainment of mobile advertisements was significantly related to consumers' attitude toward mobile advertising [16]. The empirical findings indicated that if mobile advertisements were funny, and contain pictures, sound, video or other forms to attract consumers' attention, they were more likely to be accepted by the consumers. The results presented that credibility also results in positive attitude toward mobile advertising. Similar results were found in other studies, such as Tsang et al. found that credibility affected consumers' attitude toward mobile advertising directly [18]. It seems that famous and well-known companies have a good chance of making mobile advertising campaigns successfully.

According to the result of the fourth hypothesis, personalization has positive effect on consumers' attitude toward mobile advertising. Today, consumers would more likely to

receive advertisements with personalized information. One of the main reasons people criticize advertising may be attributed to irritation. According to the results in our study, irritation has negative effect on consumers' attitude toward mobile advertising. Mobile advertisements may disturb consumers' usage of mobile devices. Thus, the providers of mobile advertisements should get consumers' permission in advance. In addition, consumers' intention to receive mobile advertisements is also affected by the incentives associated with the advertisements. Although consumers might hold negative attitudes toward mobile advertising, sometimes they were willing to accept those advertisements in case that some incentives were associated.

However, we are also aware of some limitations of this work. Firstly, the participants of our study were mainly college students. This sample might not be fully representative of the entire population. Secondly, all the data were collected using self-report scales in the research. This may lead to some caution because common method variance may account for some of the results.

6. Implications

This research made contribution to find factors that consumers' adoption of mobile advertising in China. The results illustrated that consumers' intention to receive mobile advertisements was also guided by their attitude. From a practical perspective, the findings in our study implied that practitioners should concern about factors that affect consumers' adoption of mobile advertising. The results showed that entertainment has the strongest effect on consumers' attitude toward mobile advertising. Thus, if more creative and interesting mobile advertisements are provided, consumers' attitude toward mobile advertising could become more positive. Practitioners may use the findings of this study to plan their business campaign to their potential consumers. For example, they can personalize mobile advertisements according to consumers' profiles, and they can also provide financial rewards to attract consumers.

Further, mobile advertising services providers should improve their understanding of trust-related concerns and personal preferences and characteristics of the target users in order to fulfill the users' expectations. For instance, practitioners can send mobile advertisements with appropriate information at proper time in order to avoid unnecessary interruptions and disturbances to potential consumers.

7. Conclusion and Future Research

This study examined the factors which affect consumers' adoption of mobile advertising in China. A research model with six research hypotheses was proposed in this research. All the hypotheses were positively significant supported. The results indicated that entertainment, credibility, personalization, and irritation affect consumers' attitudes toward mobile advertising directly. Meanwhile, incentives and consumers' attitudes toward mobile advertising have positive effects on consumers' intention to receive mobile advertisements. Thus, practitioners should concern all the factors that affect consumers' adoption of mobile advertising.

Continuing with this stream of research, we plan to the research model's validity in other empirical contexts, such as mobile advertisements on a specific mobile application. Future research is also needed to empirically verify the research model with larger samples in China.

References

1. Altuna, K.O., Konuk, A.F.: Understanding consumer attitudes toward mobile advertising and its impact on consumers' behavioral intentions: a cross-market comparison of United States and Turkish consumers. *International Journal of Mobile Marketing*. 4 (2), 43-51 (2009)

2. Bagozzi, R. P., Yi, Y.: Specification, evaluation, and interpretation of structural equation models. *Journal of the academy of marketing science*. 40(1), 8-34 (2012)
3. Chowdhury, H. K., Parvin, N., Weitenberner, C., & Becker, M.: Consumer attitude toward mobile advertising in an emerging market: An empirical study. *Marketing*. 12(2), 206-216 (2010)
4. Drossos, D., Giaglis, G. M., Lekakos, G., Kokkinaki, F., & Stavraki, M. G.: Determinants of effective SMS advertising: an experimental study. *Journal of Interactive Advertising*. 7(2), 16-27 (2007)
5. Ducoffe, R.H.: Advertising value and advertising the Web. *Journal of Advertising Research*. 36(5), 21-35 (1996)
6. Gao, S., Krogstie, J., Siau, K.: Developing an Instrument to Measure the Adoption of Mobile Services. *Mobile Information Systems*. 7(1), 45-67 (2011)
7. Gao, S., Krogstie, J., Siau, K.: Adoption of mobile information services: An empirical study. *Mobile Information Systems*. 10(2), 147-171 (2014)
8. Haghirian, P., Madlberger, M.: Consumer attitude toward advertising via mobile devices-An empirical investigation among Austrian users. (2005)
9. Hanley, M., Becker, M., Martinsen, J.: Factors influencing mobile advertising acceptance: will incentives motivate college students to accept mobile advertisements? *International Journal of Mobile Marketing*. 1(1), 50-58 (2006)
10. Hung, C.-L., Chou, J. C.-L., Ding, C.-M.: Enhancing Mobile Satisfaction through Integration of Usability and Flow. *Engineering Management Research*. 1(1), p44 (2012)
11. Iddris, F.: Mobile advertising in B2C marketing. Unpublished Masteral Thesis, Lulea University of technology. Retrieved February. 1(2008), 1653-0187 (2006)
12. Merisavo, M., Kajalo, S., Karjaluoto, H., Virtanen, V., Salmenkivi, S., Raulas, M., & Leppäniemi, M.: An empirical study of the drivers of consumer acceptance of mobile advertising. *Journal of Interactive Advertising*. 7(2), 41-50 (2007)
13. Noor, M., Nazri, M., Sreenivasan, J., Ismail, H.: Malaysian Consumers Attitude towards Mobile Advertising, the Role of Permission and Its Impact on Purchase Intention: A Structural Equation Modeling Approach. *Asian Social Science*. 9(5) (2013)
14. Pietz, M., Storbacka, L.: Driving advertising into mobile mediums: Study of consumer attitudes towards mobile advertising and of factors affecting on them. Umeå University. (2007)
15. Rao, B., Minakakis, L.: Evolution of mobile location-based services. *Communications of the ACM*. 46(12), 61-65 (2003)
16. Saadeghvaziri, F., Hosseini, H. K.: Mobile advertising: An investigation of factors creating positive attitude in Iranian customers. *African Journal of Business Management*. 5(2), 394-404 (2011)
17. Schlosser, A. E., Shavitt, S., Kanfer, A.: Survey of Internet users' attitudes toward Internet advertising. *Journal of Interactive Marketing*. 13(3), 34-54 (1999)
18. Tsang, M. M., Ho, S.-C., Liang, T.-P.: Consumer attitudes toward mobile advertising: An empirical study. *International Journal of Electronic Commerce*. 8(3), 65-78 (2004)

Analyzing the Importance of Marking Links to Special Targets in Mobile Web

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Abstract

Literature points out the importance of indicating when a link opens a different website in a new window, since this is the default behavior that users expect, but this problem has not been specifically studied in mobile devices yet. This paper explains a study that was carried out with 20 different mobile devices and 19 users. We compared the usability of opening links in the same window or in a new one, informing or not informing the user about the target, as well as the convenience of using icons or text to inform about the target of a link. Results show that 95% of the devices used for the experiment had browser multi-window support, and we conclude that mobile users prefer to be previously informed when a link opens in a new window, and that the preferred method for informing them is using an icon instead of a text.

Keywords: Usability, HCI, Mobile Devices, Mobile Web, Navigation, Empirical Study.

1. Introduction

The affordable access to mobile technology and mobile Internet has contributed to the increase of mobile users and Web traffic through these devices [5]. Therefore, the design of mobile Web content has increasingly gained in importance and mobile usability is of growing relevance, as mobile Web access presents interoperability, accessibility and usability issues due to factors such as small screen size or the way of interacting with the device [10].

Standards and recommendations providing guidance on increasing usability when designing Web user interfaces [13] may not be directly applied to web mobile interfaces because of the different characteristics of these devices [1], [17]. Different initiatives address the issues related to the design of digital content for mobiles in order to establish guidelines and recommendations to generate this content in a usable way for mobile devices [3], [9], [11], [17, 18]. However, there is not a standard yet to follow and Mobile Web Best Practices by W3C “Mobile Web Initiative” [22] may be outdated because they do not consider the advances in mobile technology in the last years. A comprehensive understanding and experimenting with mobiles will help in formulating guidelines and recommendations or even contribute to standardization by migrating solutions from other established standards, by adapting them or by including new ones.

One of the topics considered in Web design are hyperlinks, which allow linking some content with another one, enabling the navigability Web feature. From the point of view of PCs, there have been many efforts to establish guidelines and recommendations (about their size, meaning, etc.) to create these hyperlinks [7], [13]. As mentioned above, many authors stated that traditional usability guidelines may not be applicable to mobile devices. Therefore, in the particular case of guidelines for hyperlinks whose targets open in a new window, they also may not be applicable to the mobile Web, because windows management may be uncomfortable in mobile devices and even sometimes these devices do not support multiple windows, so the user should be warned when a hyperlink opens in a new window [22].

We are interested in determining the effects of warning users about opening new windows when they open links in their mobile device's web browsers. This work tries to answer two questions: (1) are mobile devices able to manage more than a browser window at the same time? and (2) if a hyperlink opens in a new window, is it necessary for the user to be previously warned? To answer these questions, this paper presents a set of experiments carried out with different mobile devices and users with different types of hyperlinks (notifying and not notifying their target). The results will contribute to evolving mobile device usage, as well as mobile web design and development, thus helping both designers and developers to consider this issue in their developments.

Section 2 of this paper shows the related work to this research, Section 3 explains the details of the experiments carried out, Section 4 presents the results, and finally Section 5 discusses the results and concludes the work.

2. Related Work

Warning the users that a link is going to be opened in a new window or tab is a common recommendation in guidelines and standards establishing usability recommendations for hyperlinks in general web pages design [7], [13] and it is an issue addressed in usability of mobile devices [4], [22].

The ISO 9241-151 Ergonomics of human-system interaction – Part 151: Guidance on World Wide Web user interfaces [13], specifically designed for general purpose web pages, provides in guideline 9.4.10 “Marking links opening new windows” that links that open new browser windows or pop-up windows should be clearly marked.

The initiative Usability.gov, Web design and Usability Guidelines by the US Department of Health and Human Services [7], also provides a set of guidelines for general purpose web pages (known as “HHS guidelines”), and guideline 7:1 “Provide Navigational Options” indicates that when a link opens a new browser window the back button is disabled, eliminating the user's past navigation (Back-button problem). This can be confusing to the user because he/she might not know how to get back to the previous pages [15]. Continuing with the HHS guidelines, guidelines 10:12 “Indicate Internal vs. External Links” and 2:1 “Do Not Display Unsolicited Windows or Graphics” discuss distractions and annoyances that a user might perceive when opening a new window, especially if it is an unsolicited pop-up. W3C [22] also supports this idea, since the guideline 13 says that pop-ups or other windows should not appear and should not change the current window without informing the user.

However, when using mobile devices, the user visually interacts with only one application at a time, using just one window [2]. In [4] a set of usability guidelines applicable to mobile devices are proposed, and although they do not recommend any specific guideline for this problem, they comment that working with a single window in mobile devices is uncomfortable and complicated. Furthermore, many devices do not support more than one browser window, so opening a link in a new window may have unpredictable results on a mobile device [22]. This is one of the reasons why traditional usability guidelines may not be appropriate for mobile devices [17] and further research has to be carried out to analyze whether it makes sense to open links in new windows in mobile web.

Opening links automatically in a new window is both confusing and disruptive for some users, as they are likely to expect the new webpage will load in the current window. Furthermore, it breaks one of the fundamental principles of the user interface design, that is,

users should always be in control of the interface they are interacting with [14], [19]. Nielsen [16] commented that, in exceptional circumstances, non-Web documents could be opened in a new window, but users should be warned in advance that a new window would appear. We can find studies for web browsing in PCs, pointing out the importance of indicating when a link opens a different (external) website from which the users are visiting [20], [23] or the navigation difficulties when popup windows appear [21] but, as far as we know, this issue has not been investigated thoroughly in the specific case of mobile web browsing.

3. Research Methodology

The experiment comprised two parts: first, an analysis on different mobile devices was carried out to check whether they were able to manage multiple browser windows. As results showed that most mobile devices could work with them, the second part was performed, which aimed to study the importance of informing the user when opening links in a new browser window.

3.1. Part 1: Experiment With Mobile Devices

The first part of the experiment addressed the question: “Do mobile devices support multiple browser windows?”. In order to answer it, a simple web page was designed that contained only two links: one that opened the target in the same window and another one that opened the target in a new window. Then, the behavior of both links was tested on a set of twenty mobile devices of various makes and models, with different operating systems, interaction methods (touchscreen, keyboard, and stylus) and screen sizes.

3.2. Part 2: Experiment With Users

The guideline to be tested is 9.4.10 “Marking links opening new windows”, included in ISO 9241-151 [13]. Therefore, the null hypothesis adapted to mobile devices would be “Links that open new browser windows or pop-up windows should be clearly marked on mobile devices”.

The experiment compared the performance of users when web pages included or lacked notifications about opening links in new windows. To analyze the usability, metrics for effectiveness, efficiency and satisfaction factors were considered [12].

Two web pages were designed, each of which contained only a series of links (there was no more text on the web page). The targets of the links in the first web page were not indicated. The second web page had two different types of notification (with text or with icon), because there could be a significant difference depending on the method used [24]. The icon may also have an influence [6], so we chose the icon used by the official Transport for London web page¹, because a previous study demonstrated this is a usable web page [8].

Subjects

Nineteen subjects participated in the experiment (13 male, 6 female). Regarding the age distribution, 47.37% was between 18 and 24 years, 36.84% was between 25 and 34 years, and 15.79% was older than 35 years. As to the subjects' self-rating on their experience in using mobile devices, 42.11% were experts, 47.37% were intermediate, and 10.53% were novice.

Apparatus

To carry out the experiment, six mobile devices of different makes were used, with various operating systems and different interaction methods². In all cases the default web browser of

¹Transport for London. <http://www.tfl.gov.uk/>.

²Specifically, the devices used were an Apple iPhone 4 (with iOS 4.3.3), a Samsung Omnia W (with Windows Phone 7.5), a Sony Xperia U (with Android 2.3.7), a BlackBerry Curve 9360 (with RIM 7.0), a BlackBerry Torch 9860 (with RIM 7.0 and touchscreen) and a Nokia Asha 302 (with Symbian S40).

the device was used and no additional software was installed. A custom-made support held a webcam to record the mobile's screen and the user's interaction (Fig. 1).



Fig. 1. Custom-made device used to record user interactions.

Design and Tasks

A within-subject design experiment was used. The task was to ask the users to open a requested link in the same window or in a new one. The metrics to measure for *effectiveness* were the number of errors made and whether the user was able to correctly finish the task or not. The number of errors was the number of times the link was opened in a destination other than the requested. To measure *efficiency*, the time users took to successfully open each link was recorded, and if a user failed, the time was measured until he/she gave up. Finally, after performing the experiment, users filled out a *satisfaction* survey where the comfort was assessed for each mobile device for opening links in new windows.

Procedure

The treatments of the experiment were randomly assigned to each user, so that it could mitigate the possible biases introduced by other factors. All subjects were tested individually in a quiet research lab, being conducted by the experimenter, who told them what link had to open and where in each case. All users performed the experiment once with each configuration (i.e., links without informing about their target and links informing about it) and each mobile device (six different devices). For each of these cases, all possible combinations were tested: on the one hand, a link that opens by default in the same window had to be opened (1) in the same window and (2) in a new window; and on the other hand, a link that by default opens in a new window also had to be opened (3) in the same window and (4) in a new window. That is, 48 videos ($2 \times 6 \times 4 = 48$) were taken in total for each user, and later analyzed. After the experiment, each user answered the satisfaction survey.

4. Results

The results obtained are presented below for each part of the experiment.

4.1. Part 1 of the Experiment: Experiment With Devices

The results of the first part of the experiment was that 19 out of 20 mobiles (95%) used in the test supported multiple browser windows. This contradicts the W3C indications [22], because mobile devices have been evolving in recent years, by adding new functionalities.

4.2. Part 2 of the Experiment: Experiment With Users

In the following lines, the measurements taken for each usability factor will be discussed. Please note that in the results analysis, statistical significance refers to $p < 0.05$.

Effectiveness and Efficiency

Effectiveness and efficiency was measured considering: (1) task completion, (2) number of errors and (3) the time taken to perform the task in the following cases:

- Open in the same window a link that by default opens in the same window (to simplify, from now on this operation will be named “Same-same”).
- Open in a new window a link that by default opens in the same window (“New-same”).
- Open in the same window a link that by default opens in a new window (“Same-new”).
- Open in a new window a link that opens by default in a new window (“New-new”).

In addition, for the cases in which a link opened by default in a new window (last and penultimate cases), the difference between informing with a text and informing with an icon was also studied. Below are the results for each of the cases above.

Results on Task Completion

In the “Same-same” case, 100% of the tasks were fully completed, both when informing about the target of the link and when not informing. In the “New-same” case, 82% were fully performed when informing about the target of the link, and 79.65% when not informing about it. In the “Same-new” case, 65.48% of the tasks were fully completed when the target of the link was not notified, whereas 77.68% of the tasks were fully completed when the target was notified. Finally, in the “New-new” case, 80.70% of the tasks were fully completed when the target was not indicated and 82.46% when it was.

Although there was not statistical significance in “Same-same”, “New-same” and “New-new” cases, the statistical analysis indicates that there is statistical significance in the case “Same-new” ($\chi^2=7.891$, $df=3$, $p=0.048$), so it suggests that marking the target of links affects positively in opening links in the same window when they open by default in a new one.

Results About the Number of Errors

The basic statistics about the number of errors in the tasks are summarized in Table 1. The analysis shows a statistical significance in the cases “New-same” ($z=-2.07$, $p=0.04$) and “Same-new” ($z=-5.11$, $p=0.00$). In these cases, informing about the target of the link reduces the number of errors. This was not found to be significant in the case “New-new” ($z=-1.76$, $p=0.08$) and no analysis could be performed in the case “Same-same” because data were zero in all cases, so we assume that there is no statistical difference in that case.

Table 1. Basic statistics of the number of errors when opening links.

	Not informing about the target			Informing about the target		
	Average	SD	Median	Average	SD	Median
Same-same	0.000	0.000	0.000	0.000	0.000	0.000
New-same	0.540	0.780	0.000	0.366	0.569	0.000
Same-new	1.221	1.223	1.000	0.696	0.909	0.000
New-new	0.237	0.537	0.000	0.307	0.500	0.000

Results About the Time

Table 2. Basic statistics of the efficiency (time in seconds) when opening links.

	Not informing about the target			Informing about the target		
	Average	SD	Median	Average	SD	Median
Same-same	5.386	9.720	3.000	4.065	3.828	3.000
New-same	15.640	20.630	7.000	6.960	3.201	6.000
Same-new	27.600	25.940	23.000	18.500	17.150	12.500
New-new	9.180	14.050	5.000	5.860	7.093	4.000

Table 2 summarizes the results of the task completion time when informing or not about the target of the link. The average time was always lower when informing about the target, but no significance difference was found in the case “Same-same” ($z=-0.41$, $p=0.68$). In the remaining cases there was statistical significance: in “New-same” ($z=-2.25$, $p=0.02$), “Same-new” ($z=-4.07$, $p=0.00$) and “New-new” ($z=-3.09$, $p=0.00$). So, informing about the target of the link is advisable in the last cases, as it reduces the task completion time.

Results About the Type of Notice (Icon or Text)

To analyze which type of notice is more appropriate to inform users about the target of the link, only the cases with links opening their targets in new windows were considered (“Same-new” and “New-new”). All targets were indicated with a text or an icon and the task completeness, number of errors and task completion time was measured.

In the case “Same-new”, 68.75% of the tasks were fully completed using text and 89.58% using an icon. The difference was significant ($\chi^2=7.894$, $df=1$, $p=0.005$), so using icons to indicate the target of links is preferred instead of text. In the case “New-new”, 81.63% of the tasks were successfully completed when the notice was a text, and 83.07% when it was an icon; but there was no statistical significance between text and icon ($\chi^2=0.04$, $df=1$, $p=0.841$).

About the number of errors, in the “Same-new” case the average was 0.794 ($SD=0.970$) for text, while it was 0.571 ($SD=0.816$) for icons. In the case “New-new”, the average for text was 0.449 ($SD=0.5796$) and 0.200 ($SD=0.4031$) for icons. The statistical analysis suggested that there is statistical significance between using text or icons to indicate the target of links when they are opened in a new window ($z=-2.50$, $p=0.0125$); but not when they are opened in the same window ($z=-1.28$, $p=0.2034$).

Finally, there was no statistical difference between using text or icons in the task completion time, nor in the “Same-new” case ($z=-0.50$, $p=0.6178$) or in the “New-new” case ($z=-0.62$, $p=0.5389$); although the average time was lower for icons in the “New-new” case than for text (4.508 vs 7.650 seconds), and the time for text was slightly lower in the “Same-new” case than for icons (17.73 vs 19.49 seconds).

Satisfaction

The subjects were asked the following questions in the survey after the experiment:

1. Knowing that the target of a link will be opened in a new window, when would you click on it?
2. Would you like to be previously informed when the target of a link opens in a new window when clicking on the link?
3. How would you prefer to be informed when the target of a link opens in a new window when clicking on the link?

The answers to the first three questions were quantitatively measured with predefined answers. An additional open question was added about the general opinion of users about informing or not informing when a link opens its target in a new window on a mobile device.

The average results to question 1 for all devices were: 64.91% answered “Only if I was interested in the link”, 30.70% answered “Only if strictly necessary” and 4.39% answered “Otherwise”. For question 2, 15.79% answered “Never”, 73.69% answered “Always” and 10.52% answered “Otherwise”. On the other hand, answers to question 3 were: 100% said that they preferred to be informed by an icon for all mobile operating systems except Symbian, where 84.21% of the users preferred to be informed by an icon and 15.79% otherwise (not text). In average (for all operating systems, including Symbian), 97.37% preferred to be informed by an icon and 2.63% otherwise (nor icons or text).

Regarding the open question, 47.37% answered that users should be informed when a link opens its target in a new window, because otherwise they may be confused on those devices that do not clearly show the number of open windows, inasmuch as opening a link in a new window is not the default behavior or because the user may not want to open many windows.

This makes navigation more comfortable, especially on mobile devices as users may not know exactly where they are and windows management is more difficult.

5. Discussion and Conclusions

Most mobile devices currently available in the market (in the experiment, in particular, was 95%) support multi-window. Therefore, it makes sense to analyze the usability of different issues of mobile web browsing. In this work we were interested in experimenting whether links that open new browser windows should be clearly marked on mobile devices.

Results showed that task completion was higher when informing about the target of the link, and the difference was significant when a link that by default opens in a new window is opened in the same window. There was also statistical significance in the number of errors and/or efficiency when a link opens in a new window (either opening it in the same window or in a new one), so we can say that in mobile devices it is preferable to inform when a link opens by default in a new window. Furthermore, this is reinforced by the results of the satisfaction survey, of which we obtained (question 2) that users (73.69% of average) prefer to be always previously informed when they are using a mobile device and a link opens by default in a new window.

There was statistical significance between using icons or text to inform about the target of a link in task completion (case “Same-new”) and in the number of errors (case “New-new”), always in favor to icons. Therefore, in mobile devices it would be advisable to use an icon instead of a text to inform about the target of a link when it opens a new window. It is important to highlight that the icon used should be easy-to-understand.

The analysis of effectiveness, efficiency and satisfaction showed that it is always better to inform previously about the target of the link and also users clearly prefer to be informed when they are using mobile devices and they are going to open a link whose target opens in a new window. Therefore, we can confirm the initial hypothesis: “Links that open new browser windows or pop-up windows should be clearly marked on mobile devices”.

Our results are consistent with the web guidelines 9.4.10 of ISO 9241-151 [13] and 2:1 of HHS Guidelines [7], which means that this guideline (marking links opening new windows) is also applicable to mobile devices, and not only for PC websites. This can be due to the mobile devices evolution and the inclusion of multiple window support, which contradicts recommendations given by Ballard [2] and W3C [22]. Although commonly only one window occupies the whole screen of a mobile device, the behavior is similar to multi-window in PC, because most mobile web browsers make users aware of the number of windows opened. On the other hand, our results support guideline 13 of the Mobile Web Best Practices [22], suggesting that usability of opening links in mobile devices has not changed in recent years, likewise it does not change with respect to PCs. Therefore, we could conclude that links opening new windows should always be marked, regardless of the device used, as it seems to be a guideline that remains over time.

The main limitations of the study are the lack of results segmented by operating system due to the number of devices used and the age of participants is not balanced. Therefore, further experiments with more participants and mobile devices will be conducted to segment the results for each operating system and age groups.

As every day more and more people use the Internet, and also mobile devices, the work presented here has a special relevance for making easier the task of mobile web browsing. To do this, web designers and developers should take into account the recommendations presented in this paper.

References

1. Albers, M., Kim, L.: Information Design for the Small-screen Interface: An Overview of Web Design Issues for Personal Digital Assistants. *Tech. Commun.* 49 (1). 45-60 (2002)

2. Ballard, B.: *Designing the mobile user experience*. John Wiley & Sons, Chichester (2007)
3. Buchanan, G., Farrant, S., Jones, M., Thimbleby, H., Marsden, G., Pazzani, M.: Improving mobile internet usability. In: *Proceedings of the 10th International Conference on World Wide Web*, pp. 673-680. ACM, Hong Kong (2001)
4. Budiu, R., Nielsen, J.: *Usability of Mobile Websites and Applications: Design Guidelines for Improving the User Experience of Mobile Sites and Apps*. Nielsen Norman Group, Fremont (2011)
5. Chen, T.M.: How networks changed the world. *IEEE Netw.* 25 (6), 2-3 (2011)
6. Curry, M.B., McDougall, S., de Bruijn, O.: The effects of the visual metaphor in determining icon efficacy. In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, pp. 1590-1594. SAGE Publications, Chicago (1998)
7. DHHS (US Department of Health and Human Services): *Research-Based Web Design and Usability Guidelines*. Washington D.C. (2008)
8. Garcia-Lopez, E., Garcia-Cabot, A., de-Marcos, L., Oton, S., Hilera, J.R.: Semiautomatic Evaluation of Websites Usability. In: *Proceedings of the Fifth International Conference on Advances in Computer-Human Interactions*, pp. 165-169. IARIA, Valencia (2012)
9. Gong, J., Tarasewich, P.: Guidelines for handheld mobile device interface design. In: *Proceedings of the 2004 DSI Annual Meeting*, pp. 3751-3756. Boston (2004)
10. Harper, S., Yesilada, Y., Goble, C.: Building the Mobile Web: rediscovering accessibility?. *Univers. Access in the Inf. Soc.* 6 (3), 219-220 (2007)
11. Hubert, R.: Accessibility and usability guidelines for mobile devices in home health monitoring. *ACM SIGACCESS Access. and Comput.* (84), 26-29 (2006)
12. ISO 9241-11:1998. Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on Usability (1998)
13. ISO 9241-151:2008: Ergonomics of human-system interaction – Part 151: Guidance on World Wide Web user interfaces (2008)
14. Nielsen, J.: Heuristic evaluation. In: Nielsen, J., Mack, R.L. (eds.) *Usability Inspection Methods*, pp. 25-64. John Wiley & Sons, New York (1994)
15. Nielsen, J.: Usability 101: Introduction to usability, <http://www.nngroup.com/articles/usability-101-introduction-to-usability> (2003). Accessed March 19, 2014
16. Nielsen, J.: Open New Windows for PDF and other Non-Web Documents, <http://www.nngroup.com/articles/open-new-windows-for-pdfs> (2005). Accessed March 19, 2014
17. Nielsen, J., Budiu, R.: *Mobile usability*. New Riders, Berkeley (2012)
18. Seong, D. S. K.: Usability Guidelines for Designing Mobile Learning Portals. In: *Proceedings of the 3rd International Conference on Mobile Technology, Applications & Systems*, pp. 25. ACM, Bangkok (2006)
19. Shneiderman, B., Plaisant, C.: *Designing the user interface. Strategies for effective human-computer interaction* (5th ed). Addison-Wesley, Boston (2010)
20. Spool, J., Scanlon, T., Schroeder, W., Snyder, C., DeAngelo, T.: *Web Site Usability: A Designer's Guide*. Morgan Kaufmann, Los Altos (1999)
21. Storey, M.A., Phillips, B., Maczewski, M., Wang, M.: Evaluating the usability of Web-based learning tools. *Educ. Technol. & Soc.* 5 (3), 91-100 (2002)
22. W3C Mobile Web Best Practices 1.0: Basic guidelines (2008)
23. Weinreich, H., Lamersdorf, W.: Concepts for improved visualization of Web link attributes. *Comput. Netw.* 33 (1), 403-416 (2000)
24. Williams, T.R.: Text or graphic: An information processing perspective on choosing the more effective medium. *J. of Tech. Writ. and Commun.* 23 (1), 33-51 (1993)

At the Edge of the Cloud: Improving the Coordination of Proactive Social Devices

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Abstract

Today's Internet-connected devices, such as tablets and mobile phones, have excellent computing power, which creates a possibility for complex, cooperative multi-device platforms. However, coordinating these devices typically requires implementing the coordination process separately in an application specific fashion, which takes focus away from the actual application development. For this purpose we have introduced Social Devices middleware, which allows developers to easily coordinate proactive interactions on a heterogeneous set of devices. Since the proactivity sets its own elements to the coordination, in this paper we introduce our research for coordinating Social Devices. Moreover, as cloud-based solutions typically assume established and fast Internet-connectivity, we also describe how we have complemented the coordination paradigm with Personal Area Network (PAN) based coordination. Social Devices applications can now adapt and choose between cloud and Bluetooth Low Energy based coordination as the JavaScript-based coordination logic can be executed on both, device and server side.

Keywords: Social Devices, Mobile Cloud, Proactive Interactions, JavaScript as a Coordination Language, iBeacon-based coordination

1. Introduction

In recent years, smart devices have become increasingly capable and connected. They are used for everyday purposes: for entertainment, for socializing with friends, and for sharing life events. Continuous connectivity enables the devices to utilize cloud services and perform tasks at the background. Additionally, new sensors are emerging and these devices can be used for tracking user activities and context. However, the cloud services are yet typically utilized by the user using the device, not by the device itself. Thus, cloud or social media services do not support seamless cooperation and interoperability of the devices but rather collaboration of the people. Vendors like Apple or Samsung have created their own standards for sharing resources among devices, like streaming music and videos for instance. These solutions, however, are usually initiated by users and typically require manual efforts to coordinate the devices and their resources. Moreover, these solutions are vendor specific and may eventually lead to vendor locks.

To support cooperation and interoperability in a heterogeneous set of devices we have introduced concept of *Social Devices* and its initial implementation named *Social Devices Platform (SDP)* [11]. The system infrastructure is *mobile cloud* based, abstracting the physical differences of the devices. The concept of mobile cloud here refers to a system where different types of devices are connected with some technology, and hence communicate with each other either directly or through a communication service. Social Devices support the heterogeneity and different resources of each device by regarding them as capabilities; The capabilities describe

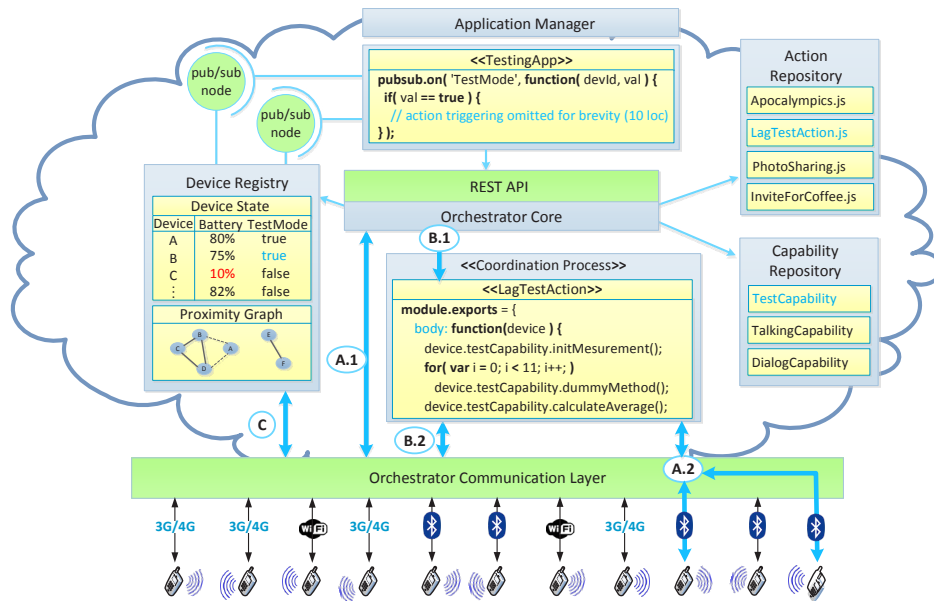


Fig. 1. Social Devices middleware running LagTest action.

what a device can do: the device may, for instance, have *TalkingCapability* installed enabling it to translate text to speech. Interactions between devices and people in Social Devices are described with a concept of *action*. An action contains the coordination logic, and hence defines how the devices interact with each other as well as with people. The actions are then proactively triggered by Social Devices applications, based on changes in devices' context. The current Social Devices middleware has been depicted in Fig. 1.

Initially, Social Devices concept was implemented as a cloud service where the communication between the service and the devices was based on Comet-technology (HTTP long-polling), and the coordination language was Python. While cloud-based orchestrating offered a good starting point for the coordination of the devices, our goal from the beginning was to move towards more flexible system architecture and coordination paradigm where also devices within each others proximity could directly coordinate each others by utilizing various communication technologies, such as Personal Area Networks (PAN). In this paper we report our research of coordinating Social Devices, and describe how we ended up using Socket.IO and Bluetooth Low Energy (BLE) as communication technology, and JavaScript as a coordination language.

The rest of the paper is structured as follows. We start with motivating and presenting some related work in Section 2. Then, in Section 3, we describe the device coordination inside Social Devices ad-hoc mobile clouds, and evaluate the different technologies we have used. In Section 4 we present some future work, and finally, in Section 5 we draw some conclusions.

2. Motivation and Related Work

Currently coordinating devices typically requires implementing the coordination process separately in an application specific fashion. Due to this, the applications running on separate devices are not aware of each other, which make it hard to implement seamlessly cooperating systems. The current situation is unsustainable and the lack of seamless user experience has lead to manifestos like *Manifesto for Experience of Things* [9] and *Liquid Software Manifesto* [14]. The approaches for coordinating multiple devices have mainly been focusing on information presentations (e.g. [6, 8, 10]), or for multimedia resource synchronization (e.g. [13]). How-

ever, our work is different, since with Social Devices we are not aiming to offer only automated services or new kinds of interfaces. For example, in [6], we find similarities in the approach for coordinating the devices, but the aim is different. As [3, 6, 10] focus on generating user interfaces and coordinating them on the devices, the system philosophy is more user-centric than ours. We, in contrast, aim to make devices interact and socialize independently, and make the operations visible for the users. When the majority of approaches focus on coordinating the devices in predefined locations, such as smart spaces or homes, our focus is in coordinating the devices wherever they are in the proximity of each other in any location. Several approaches have also been proposed for the modelling and specification of collective actions (e.g. [2]) and for coordinating computational resources (e.g. [1, 4, 5]). We are revitalizing the idea by applying it to mobile clouds, where actors correspond to individual devices forming the cloud, and whereas a centralized entity is responsible for coordinating the execution of mobile devices. In previous research, the closest relative to our PAN-based coordination approach is constituted by coordination languages for mobile agents (e.g. [12]). However, the PAN-based coordination works differently, since we are treating complete mobile devices as agents.

3. Elements of Coordinating Social Devices

The initial approach of coordinating Social Devices was implemented as a cloud service where the communication was based on Comet-technology. Basically, with Comet-based implementation the client maintained HTTP/TCP connection to the server until the server responded with a remote method call. After receiving the HTTP response the client executed the method call and connected again by sending method call response. The coordination language was Python as the coordination service was Django/Python based and the script language worked well in this centralized approach. In the following we describe why we chose to use JavaScript as a coordination language, and how Socket.IO and Bluetooth Low Energy measurably improved coordinating proactive interactions.

3.1. Minimizing Lag and Communication Latency with PAN-based Coordination

The Social Devices concept is meant to support all types of applications that can be proactively triggered in various situations. Consequently, there are also differences how well different interactions tolerate lag. Many of the Social Devices actions are not too critical about the latency or lag, as they are meant to happen in background mainly offering users support in their daily activities by automating things and informing what is currently going on. On the other hand, many actions are much more critical as they require real-time communication and fast interacting with other entities. A self-evident example of these requirements are games where multiple Social Devices take part and need to be coordinated according to the behaviour of other devices. To support faster coordination and situations where Internet connection cannot be utilized, we implemented the coordination process with Bluetooth 4 sockets (RFCOMM) for Android. In this paradigm one of the devices that participates to the interaction is selected to take the role of the coordinator (Fig. 1, phase #A.1), and hence it commands other devices as well as itself (Fig. 1, phase #A.2).

Social Devices are coordinated by invoking their capability methods by a coordinating entity. Basically this means that before a device can be commanded to start next process or update a running process, the coordinating entity needs to receive response from some other device. In a way this requires the device coordination to be synchronous, although the processes running on the devices can be asynchronous. As with any distributed systems, the communication latency between system entities becomes a relevant thing to consider while defining the interactions for Social Devices. The latency in communication affects heavily on the lag that a user typically experiences. In Social Devices the total lag consist of the following:

$$L_{total} = \Delta r_{self} + p + \left(\sum_{i=0}^n (g + \Delta c_i + P(x) + \Delta r_i + p) \right) + g + \Delta c_{self} \quad (1)$$

In the equation Δr_{self} and Δr_i reflect the latency of relaying the return value from device to the coordinator, p is the time spent in parsing the return value and passing it to the action body on the coordinator, g is the time spent in generating a method call, Δc_{self} and Δc_i reflect the latency in communicating the method calls to the receivers, and n is the number of capability calls invoked on the other devices before invoking the next method call on the measuring device. $P(x)$ reflects time spent on executing the capability method on a device, and thus, always depends on the function and the implementation of the method call.

To compare communication latency with Comet and Bluetooth (BT) 4 based coordination (and later on with Socket.IO and Bluetooth Low Energy) we minimized the method processing time, $P(x)$, and implemented a *TestCapability* containing a *dummyMethod* that only saved a time delta between two method calls when it was called by the coordinating entity. In *LagTestAction* (see Fig. 1) the *dummyMethod* was invoked eleven times in a row on one device, resulting to ten time delta values, which were then used to calculate the average time delta to reflect how long it takes to coordinate a device. No other method calls were invoked in between the *dummyMethod* calls. Consequently, the average lag in these measurements mainly consists of the communication latency, and also invoking, parsing and generating the method calls and their responses as described in equation (2).

$$\bar{L} = \frac{1}{n} \sum_{i=0}^n (\Delta r_i + r + g + \Delta c_i), n = 10 \quad (2)$$

The results in Table 1 show that the latency in communication clearly affects to the lag, and that the difference between Comet and BT 4 based coordination paradigms is prominent. On average, the latency is 10 to 20 times longer with Comet-based coordination, depending on the used internet connection. Moreover, this asymptotic difference in the lag becomes even more substantial if we consider that the reaction time of a human is typically around 150 to 200 ms for auditory and visual stimulus, and hence, it could be assumed that soon after this time has passed people start wondering why the system is not working properly.

The measurements results also reveal that the used Internet connection in Comet-based coordination has a strong influence on the latency in coordination. The average lag with 3G connection is almost one second, and twice as slow as with wlan connection. Basically this means that Comet-based coordination over 3G connection is too slow in cases where people participate to the interaction or otherwise intensively follow the interaction of the devices. On the other hand, with a decent wlan connection (or very fast 3G or 4G) the 0.45 second lag can still be tolerable in cases which don't require or offer intensive user input or output.

Compared to BT 4 based coordination there also seems to be more variation in the communication latency in Comet-based coordination, as even a fast Internet connection can become slow at times. Whereas the standard deviation in BT 4 based results is about 2 ms, with Comet-based coordination it is between 23 to 70 ms. This kind of fluctuation in coordination speed may confuse and frustrate users if they cannot be sure if the action execution has ended.

3.2. Improving Cloud-based Coordination with Socket.IO

Although the measurements clearly show that the device coordination with BT 4 sockets is much faster, not all the devices yet support Bluetooth, and thus we decided to try improving the cloud-based coordination with Node.js and Socket.IO technologies. Node.js is a server-side JavaScript platform built on Google's V8 JavaScript Engine. Socket.IO, on the other hand, is a new, officially non-standardized protocol for relying events between client and server, typically

Table 1. Communication latency in device coordination in milliseconds.

Δt_i	Comet (HTTP)			Socket.IO			BT 4	BLE
	wlan1	wlan2	3G	wlan1	wlan2	3G	Android	iOS
1	402	471	976	77	83	429	55	59
2	418	421	953	91	83	421	57	71
3	371	493	972	73	84	448	57	43
4	400	406	973	72	73	530	58	67
5	453	476	1078	74	77	579	60	63
6	434	469	966	75	79	420	57	62
7	395	433	958	70	74	422	61	46
8	393	446	1153	71	136	458	56	48
9	412	450	970	80	77	432	57	55
10	415	441	940	69	83	438	56	70
$\overline{\Delta t}$	409.3	450.6	993.9	75.2	84.9	457.7	57.4	58.4
σ	22.88	26.85	67.36	6.46	18.39	53.70	1.84	10.06

utilizing WebSockets as a communication protocol (Phases #B.1 and #B.2 in Fig. 1 represent the current cloud-based coordination). Both of these technologies are especially designed to support fast input/output operations, and hence the new coordination layer also offers an efficient way for the devices to update their contextual information to the Device Registry (Fig. 1, phase #C) and further notify applications through publish/subscribe interface.

The Table 1 shows that the coordination speed in cloud-based coordination was improved substantially, and is now 2-6 times faster, and almost as fast as with BT 4 sockets while using good quality wlan connection. A notable point is also that Socket.IO-based coordination with a wlan connection is faster than human reaction time, which makes it possible to utilize it in applications that require intensive interaction. Based on our experiences, and supported by the measurements standard deviation, the Socket.IO-connection seems to be more stable and only rarely drops compared to the Comet-technology. Also, as Fig. 2 shows, the interaction initialization now takes less time with the new implementation of the communication layer, mainly because of the faster communication. This supports the proactive nature of Social Devices applications, as some interactions are very critical about this. For instance, when people meet or pass by each others, the need for interaction between their devices may be over within seconds.

3.3. JavaScript as a Coordination Language

In the original Social Devices system the interactions were defined with Python programming language as this platform was Django-based cloud service. However, different mobile platforms, like Android and iOS for instance, natively use different programming languages, and hence cannot directly execute Python. As a solution, automated translation from Python to other programming languages could be applied, but most likely these solutions would be very error prone. Moreover, the actual deployment of the code would still be an issue. In the first experiment of using BT 4 sockets for PAN-based coordination, we used class loader to dynamically load Java byte code from Android application package files (.apk) as we deal with deploying new device capabilities to Android in our current implementation. However, this solution only worked with Android, and the Social Devices concept is designed to support all types of devices.

In Worldwide Developers Conference (WWDC) 2013 Apple introduced its officially sup-

ported JavaScriptCore.framework for executing JavaScript code on iOS 7 and OS X. This allows creating virtual machines or contexts where JavaScript code can be executed, and also allows invoking native Objective-C methods from the JavaScript code. Android has similar support for running Google's V8 engine on Android devices, although this is not currently part of the official SDK and needs to be separately compiled to the application. As the new communication layer was implemented with Node.js, and JavaScript support on the device-side also seems to be emerging, it was a natural choice for the new coordination language. The jump from Python to JavaScript was easy as they both are dynamically typed languages that can be used for scripting. The end result is that we can now run exactly the same interaction definitions on both, server and device sides. However, generating the device communication stub is done differently. Whereas with the cloud-based coordination the device stub utilizes Socket.IO sockets for sending and receiving events to the clients, with the PAN-based solution the device stub invokes a native Objective-C method on iOS that can communicate directly with the devices nearby. JavaScript seems to fit extremely well for this type of heterogeneous multi-device coordination purposes as the developers can implement the actions that directly run with both approaches. What is more, the support for JavaScript gets better all the time, which makes it possible to implement the PAN-based coordination on many other platforms as well.

3.4. iBeacons and Bluetooth Low Energy

The first implementation of PAN-based coordination that was based on Bluetooth 4 sockets had two major problems. *Firstly*, it required pairing of the participating devices. Fortunately, the pairing only needs to be done once between each device, and thus would not be that big concern with user's own devices. However, the idea of Social Devices is also to support proactive interactions with friends' devices, as well as with non-personal and public devices, and thus pairing with these devices would have to be conducted before the device can be utilized for the first time. The extra work for the user would have been against principles of Social Devices as one of the main ideas is to reduce the manual tasks that currently requires users' attention. Additionally, based on our measurements even though the devices were already paired, it took approximately 3.6 seconds to discover and establish connection between two devices. What is more, receiving the initialization command and retrieving participant device information from Device Registry it took about 6.3 seconds to start running the interaction with the BT 4 socket based approach. With cloud-based approach, on the contrary, the pairing is never needed, and hence the action execution can be started more freely with previously unknown entities.

Secondly, although the BT 4 socket based communication between Android devices worked pretty well, there was no common way of making the communication work with other platforms, like iOS for instance. The problem with Bluetooth has always been that many devices support only some of the overspecialized subprotocols/services that merely allow communication with specific peripherals, but do not allow developers to specify their own communication protocols.

As the iOS has had Bluetooth Low Energy (BLE) support since version 5, we decided to try out this protocol for device coordination. BLE essentially works a bit different than its predecessors as it allows developers to define their own services. These services are then described with characteristics that can either be readable or writeable. The biggest advance is that BLE does not require pairing the devices, but instead allows them to communicate freely if they know each others protocols. The downside with BLE is that currently a device can act only in one role at a time, either as *central* or *peripheral*. However, this not an issue with Social Devices as the role of the coordinator is chosen by the server, or the Social Devices application logic to be exact, and hence the coordinating device is commanded to acts as BLE central, and the other participants are commanded to act as peripherals. As the measurement results in Table 1 show the coordination with BLE is as fast as with Bluetooth 4 sockets.

In WWDC 2013 Apple also introduced iBeacons. Whereas iBeacons (at least currently) is

nothing more than Apple's brand for BLE discovery this kind of branding may drive developers to start implementing proximity-based applications which, on the other hand, may improve the support for BLE as it is currently only supported by the iOS devices and the latest Android 4.3 devices. As from the beginning of developing Social Devices concept (since 2011) we have utilized various versions of Bluetooth discovery to detect other Social Devices nearby, and measured their distance with *Received Signal Strength Indication (RSSI)* values, we have encountered four major issues. *Firstly*, the biggest concern with Bluetooth discovery on Android devices has been that Bluetooth discovery at random times interferes with wlan, and breaks the phone's Internet connection. This happens when the two radios happens to work on the same frequency as Bluetooth changes it channel rapidly. With iOS and BLE discovery we have not experienced this kind of issues. *Secondly*, doing the discovery has been quite slow, although there has been some research of making the query faster (e.g. [7]). With BLE the discovery is very fast taking only few hundred milliseconds. *Thirdly*, many platforms, such as iOS and older Android versions only allow making the device discoverable for a short period of time. *Finally*, doing traditional discovery constantly drains the battery of the discovering device. However, although BLE offers some improvements, the discovery power consumption can still be an issue.

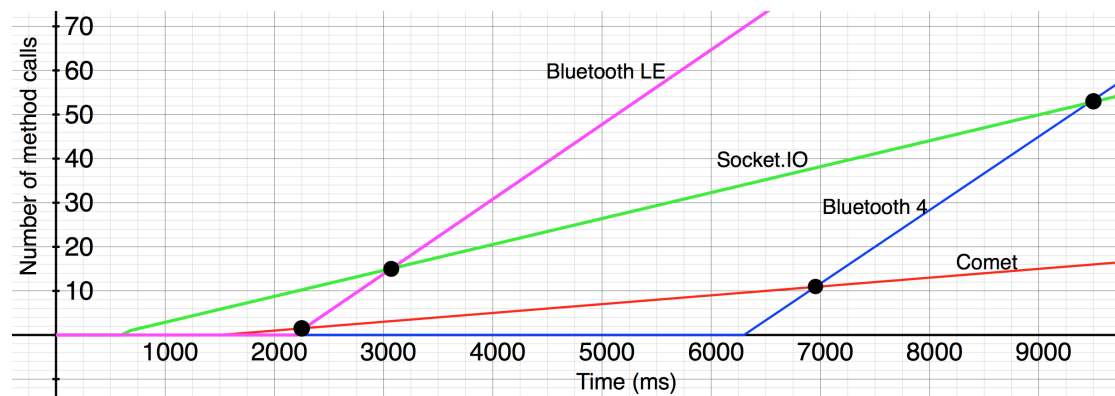


Fig. 2. Theoretically composed diagram of device coordination with different protocols.

4. Future Work

Although Bluetooth definitely offers faster coordination, the big downside is that only few devices yet support Bluetooth LE. While the support is slowly emerging to Android phones, many other devices like smart televisions and Internet of Things smart objects typically offer Internet connectivity only. In this sense cloud-based coordination can currently harness wider spectrum of Social Devices. On the other hand, some smart objects offer BLE connectivity only, and hence supporting also these may help to extend the edge of Social Devices mobile clouds. Moreover, we are currently implementing a hybrid model where during the execution of the action the devices with no BLE support could be coordinated through cloud. Furthermore, at some point we also plan to study peer-to-peer coordination, where the coordination would be distributed to each participant device, and where a token would then be used to allocate capability execution turns on each participant device.

5. Conclusions

In this paper we introduced our research of coordinating Social Devices, and how we have improved the original cloud-based coordination paradigm to better support proactive interactions between devices and people. The improvement in coordination speed has been depicted in

Fig. 2; The composed diagram shows that due to Socket.IO and Bluetooth LE the coordination is now substantially faster, and the interactions can take place in less time. Moreover, Bluetooth LE allows PAN-based communication without pairing the devices, which supports Social Devices goal to make simultaneous usage of multiple devices more seamless. At the same time, Bluetooth LE makes discovering nearby devices fast, which again improves the proactiveness of the system. Finally, using JavaScript as a coordination language allows flexibly deploying the coordination logic from cloud to device to support situations where fast coordination is required.

Acknowledgements

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References

1. Aaltonen, T., Helin, J., Katara, M., Kellomäki, P., Mikkonen, T.: Coordinating Aspects and Objects. *Electr. Notes Theor. Comput. Sci.*, 68 (3), 248–267 (2003)
2. Back, R.-J., Kurki-Suonio, R.: Distributed Cooperation with Action Systems. *ACM Transactions on Programming Languages and Systems*, 10 (4), 513–554 (1988)
3. Broll, G., Rukzio, E., Paolucci, M., Wagner, M., Schmidt, A., Hussmann, H.: Perci: Pervasive Service Interaction with the Internet of Things. *Internet Computing, IEEE*, 13 (6), 74–81 (2009)
4. Chapman, B., Haines, M., Mehrota, P., Zima, H., van Rosendale, J.: Opus: A Coordination Language for Multidisciplinary Applications. *Sci. Prog.*, 6 (4), 345–362 (1997)
5. Ciancarini, P.: Coordination Models and Languages as Software Integrators. *ACM Computing Surveys*, 28 (2), 300–302 (1996)
6. Elting, C.: Orchestrating Output Devices: Planning Multimedia Presentations for Home Entertainment with Ambient Intelligence. In: *Proceedings of the 2005 Joint Conference on Smart Objects and Ambient Intelligence: Innovative Context-aware Services: Usages and Technologies*, pp. 153–158. ACM, New York, NY, USA (2005)
7. Jiang, J.-R., Lin, B.-R., Tseng, Y.-C.: Analysis of Bluetooth Device Discovery and Some Speedup Mechanisms. *J. Elec. Eng.*, 11 (4), 301–310 (2004)
8. Kray, C., Krüger, A., Endres, C.: Some Issues on Presentations in Intelligent Environments. In: Aarts, E., Collier, R.W., van Loenen, E., de Ruyter, B. *Ambient Intelligence*, pp. 15–26, Springer, Heidelberg (2003)
9. Manifesto for Experience of Things, <http://seamlessli.github.io/mfiteot/>. Accessed June 5, 2014
10. Myers, B.A., Nichols, J., Wobbrock, J.O., Miller, R.C.: Taking Handheld Devices to the Next Level. *Computer*, 37 (12), 36–43 (2004)
11. Mäkitalo, N., Pääkkö, J., Raatikainen, M., Myllärniemi, V., Aaltonen, T., Leppänen, T., Männistö, T., Mikkonen, T.: Social Devices: Collaborative Co-located Interactions in a Mobile Cloud. In: *Proceedings of 11th International Conference on Mobile and Ubiquitous Multimedia*, pp. 10:1–10:10, ACM, New York, NY, USA (2012)
12. Peschanski, F., Darrasse, A., Guts, N., Bobbio, J.: Coordinating Mobile Agents in Interaction Spaces. *Science of Computer Programming*, 66 (3), 246–265 (2007)
13. Rekimoto, J.: Multiple-Computer User Interfaces: "Beyond the Desktop" Direct Manipulation Environments. In: *Proceedings of CHI '00 Extended Abstracts on Human Factors in Computing Systems*, pp. 6–7, ACM, New York, NY, USA (2000)
14. Taivalsaari, A., Mikkonen, T., Systä, K.: Liquid Software Manifesto: The Era of Multiple Device Ownership and Its Implications for Software Architecture. In: *Proc. of 38th Annual International Computers, Software & Applications Conference*, pp. 66–67, IEEE (2014)

Managing CALIPSOneo Project: Learning from Trenches

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Abstract

The model-driven engineering paradigm is a paradigm that combines the power of concepts and its relations, using abstracts models in order to offer suitable mechanisms for software development. In fact, software engineering community has applied MDE in different contexts of software engineering, getting suitable results. Despite these mechanisms, both global coordination and effective management of big software projects are not always easy task. Lack in communication lines, configuration plan execution and risky management are activities that have been executed by development teams in order to assure the quality of results, an essential point for a project to succeed. The paper's aim is to present an approach based on the NDT methodology in order to solve these problems pulsar and how it has been applied in a real project called CALIPSOneo.

Keywords: Model-Driven Engineering, Software Process Management, Product Lifecycle Management.

1. Introduction

Model-Driven Engineering (MDE) [18] paradigm is being used by the research community in the last years, obtaining suitable results during for software development. For this, MDE is focused on concepts and how these concepts evolved (using abstracts models) in the life cycle of a product.

Over the last decade, software engineering community has applied MDE in different contexts of software engineering, getting suitable results. For instances, it was used in the context of the web engineering, in methodologies such as UWE (UML Web Engineering) [23] or WebML (Web Model-Languages) [24]; in the context of software testing, with approaches such as [25, 26]; in software product lines, such as [27]; or even in more specific contexts like software architecture, with the approach WebSA [28]. These researches have produced suitable results that could be considered an inspiration source for the industrial community. However, very few experiences were reported from the enterprise [29]. In addition, the situation is not different big software project in which a global effective management is necessary.

Global coordination and effective management of a big software project are not always easy tasks. The lack in lines of communication [30], configuration plan execution and risk management are activities that development teams carry out in order to assure quality of results.

The paper's aim is to present a quality and effective solution based on tools and framed into methodological framework. To illustrate the feasibility of our approach, it has been applied to a real aeronautical project called CALIPSONeo. Airbus EADS CASA¹ developed this project in collaboration with the University of Seville (Spain), Polytechnic University of Madrid (Spain) and T-Systems². The project presented some relevant characteristics like a heterogeneous and distributed team (from Madrid, Seville and Barcelona; Spain), a new technology for the team and, even, for final users that required the application of concrete and effective techniques for its right management.

This paper evaluates in practice the application of classical techniques, after being improved with four main factors:

- 1) The application of the MDE Paradigm, as a key factor for software development and quality management, using the NDT (Navigational Development Techniques) [4] methodology and its tool case, NDT-Suite [7][14]. NDT has been successfully applied in a large number of real projects. Nevertheless, it was adapted and applied in a new context, the aeronautical one, which entails modifying the methodology and its management policies.
- 2) The use of effective tools for project management.
- 3) The use of effective management documentation based on ECM (Enterprise Content Management) solutions, such as Alfresco [1]. According to AIIM (Association for Information and Image Management) [22], ECM consists of strategies, methods and systems used to capture, manage, store, preserve, and deliver content and documents related to organizational processes. ECM systems and strategies facilitate the management of an organization's unstructured information, wherever that information exists.
- 4) The use of collaborative communication tools, such as WebEX [2], in order to improve communications among all stakeholders. Quality communication allows effectively conveying and receiving messages to and from others.

The paper is structured as follows: Section 2 offers a global vision of NDT. Section 3 introduces the problem which has been our catalyst to carry out this research (for this purpose, we have relied on a real project: CALIPSONeo). Section 4 and Section 5 describe our proposal and then the results obtained after being applied to CALIPSONeo project, respectively. Finally, Section 6 states some conclusions and future work.

2. NDT: Navigational Development Techniques

Navigational Development Technique (NDT) [4] is a Model-Driven Web methodology that was initially defined to deal with Web development requirements. NDT starts with a goal-oriented phase of requirements and establishes a set of transformations to generate analysis models. NDT has evolved in the last years and offers a complete support for the whole life cycle. Nowadays, it covers viability study, requirements treatment, analysis, design, construction or implementation as well as maintenance and test phases, such as software development phases. Additionally, it supports a set of processes to bear out project management and quality assurance and sustain different life cycles, for instance, sequential, iterative and agile processes. As an advantage, NDT can be applied in the enterprise environment. Today, many companies in Spain work with NDT and the associated tools for software development. This is possible due to the fact that NDT is completely supported by a set of free tools, grouped in NDT-Suite [7] [14]. This suite enables the definition and use of every process and task supported by NDT and offers relevant resources for quality assurance, management and metrics with the aim of developing software projects. NDT is based on the Model-Driven paradigm. It selects a set of metamodels for each development phase (requirements, analysis, design, implementation, construction, test and maintenance) in order

¹ Airbus Defence and Space website: <http://www.airbusmilitary.com/>

² T-Systems' website: <http://www.t-systems.es/>

to support each artefact defined in the methodology. All concepts in every phase of NDT are modeled and formally related to other concepts by means of associations and/or OCL [12] constraints. Besides, NDT proposes a set of QVT Transformations (Query/View/Transformation) [16] among each metamodel in every phase, that may enable to get one phase results from the previous one. Nevertheless, transferring this idea to the enterprise environment is not possible. Companies do not actually use metamodels, transformations and other elements, thus technology seems too abstract for them.

After assessing different possibilities, some UML-profiles were developed for each NDT metamodel. These UML-profiles were defined in a UML-based tool named Enterprise Architect [19]. Then, the first tool for NDT-Suite, NDT-Profile, was developed. The remaining NDT-Suite tools are based on this profile and offer a range of different uses when applying NDT, as it is described below:

1. **NDT-Profile** is a specific profile for NDT, developed by means of Enterprise Architect. This tool offers the chance of having all the artefacts defining NDT easy and quickly as they are integrated within the tool called Enterprise Architect.
2. **NDT-Driver** [8] is the key tool to execute transformations among NDT models. It implements a set of automated procedures that enables to perform all MDE transformations among the different models of NDT previously described. The data source to use this tool is a project developed with NDT-Profile.
3. **NDT-Quality** [9] is a tool that automates most of the methodological review of a project developed with NDT-Profile. It checks the quality of using NDT methodology in each phase of a software life cycle and the quality of traceability of MDE rules of NDT.
4. **NDT-Prototype** is a tool designed to automatically generate a set of XHTML prototypes, from the Navigation models described in the Analysis phase, of a project developed with NDT-Profile.
5. **NDT-Glossary** [6] consists in implementing an automated procedure that generates the first instance of the glossary of terms of a project developed by means of NDT-Profile tool. This tool is useful for the validation of requirements captured during the Requirements phase of the project.

In addition, NDT-Suite has more tools: NDT-Report, NDT-Checker or NDT-Counter. You can see the purpose of these tools on IWT2 website.

As it can be concluded, NDT has become a complete approach offering high support for software project development by exploiting the power of the Model-Driven paradigm. In the last years, NDT has evolved again and now, in order to offer a suitable and a global solution for the real application of NDT, a global framework named NDTQ-Framework [17] was developed. NDTQ-Framework comprises a set of processes involving development processes, management processes, quality processes, testing processes and security processes. This environment is based on different reference models like CMMi (Capability Maturity Model Integration) [3] and ITIL (Information Technology Infrastructure Library) [13] and its application in real projects are certificated under different standards like ISO 27001 [11], ISO 9001:2008 [10], UNE EN 16602 and ISO 14000. This paper does not aim to present NDTQ-Framework in detail, but you can download more information from IWT2 website³.

3. Motivating scenario: CALIPSONeo project

In the last ten years, NDT is being used in a high number of real projects developed by different companies, either public or private. As a result, they have provided us with an important feedback. One of these projects is CALIPSONeo (advanCed Aeronautical soLutIons using Plm proceSses & tOols) [5], which has been developed in Airbus EADS CASA by multiple and different teams. From the experience of this project we know that requirements are difficult to conciliate in projects involving multiple teams. This paper proposes improving the NDT methodology to solve these problems during requirements conciliation.

³ IWT2's website: <http://www.iwt2.org/>

CALIPSONEO is an ambitious project based on PLM (Product Lifecycle Management) [31]. Its main objective is the design of a new PLM methodology to conform to a PLM collaborative design and the required development of the software that satisfies that concept. This methodology allows defining, simulating, optimizing and validating the aeronautical assembly processes in a 3D virtual environment before these processes are implemented in a real shop floor. CALIPSONEO is subdivided into three individual subprojects, in order to effectively manage the work needed to complete it. They are: MARS (autoMATED shop-floor documentation updating System), PROTEUS (PROcess sTructure gEneration and Use) and ELARA (gEnerALization to assembly oriented authoring Augmented ReALity). Figure 1 shows one schema of the whole system with the MARS, ELARA and PROTEUS projects represented.

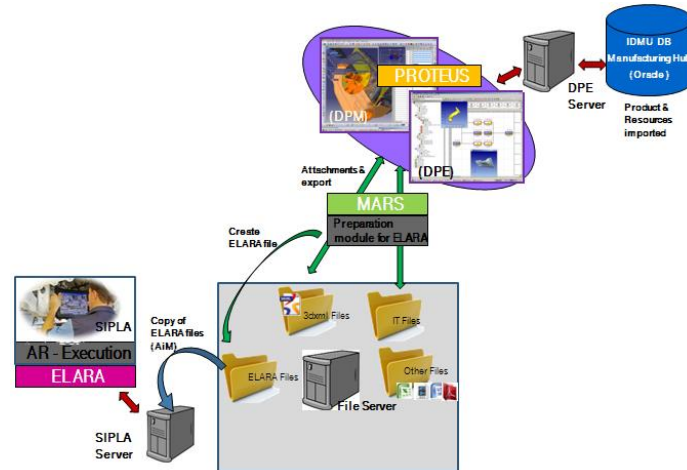


Fig. 1. General scheme of the CALIPSONEO project

These subprojects are totally different not only about their content or functionality, but the team evolved within. However, subprojects must be coordinated and correctly integrated because they have common actors who demand ordinary functionality.

PROTEUS was performed by a team which expertise is focused on the ‘real PLM context’, i.e., how an engineer will work with the environment to develop a manufacturing task. Engineers will use PROTEUS to define assembly operations, even using a 2D interface (DELMIA PROCESS ENGINEER or DPE) or 3D interface (DELMIA PROCESS MANAGER or DPM). On this assembly tasks, the engineer must take into account the products and resources used to perform the process. The process will be analyzed to optimize their times, costs, and use of resources. For this purpose, PROTEUS is responsible for the Product, Process and Resources structure definition as well as the interrelations to create an iDMU (industrial Digital Mock Up) [20].

MARS is in charge of exploiting iDMU using the manufacturing process defined by the engineer using PROTEUS and uses it to obtain automatically the documentation (Work Instruction) needed at shop floor for the airplane assembly. A Work Instruction is a 2D or 3D document with the detailed instructions for the shop floor worker, being easily for him to perform the assembly task. The connection between PROTEUS and MARS was extremely high, sharing the same environment (DELMIA PROCESS MANAGER) and depending for the process made in PROTEUS by the engineer.

Finally, the central objective ELARA must achieve is to develop a system which should provide workers in assembling tasks, with augmented reality technology, still valid on any airframe, using either the 3D information included in iDMU or the information coming from MARS. The final result will be an industrial prototype to be used in the assembly process of FanCowl product in A320Neo program.

The three projects described are very different, and the teams that work in them are also very different. Not only for the task have they had to perform, but also the distance between teams an important fact to take into account. It is harder to work, depending of teams from

others states or countries. Taking into account that the three projects depends one on the other (ELARA depends of MARS and MARS depends of PROTEUS), they were performed in parallel, that means, the specification of the projects have to be very well described according to ensure the proper communications of them.

About the technologies used, on PROTEUS, the main tools used were database storage to communicate the information across both interfaces, the 2D (DPE) and the 3D (DPM). MARS handles scripting and programming in .NET⁴ to export the information from DPM to Microsoft Word documents. Also MARS uses the information from DPM to generate 3D work instructions, rendered in 3DViaStudio Player. ELARA uses Augmented Reality and mobile technologies. As we can see, every project has a different expertise, so the teams evolved in the project were also very different, making this project, CALIPSOneo, a multidisciplinary project, increasing the effort needed to perform a proper communication between teams.

4. Approach

Our approach can be addressed by means of three different areas: (i) project planning and meetings; (ii) project management; and (iii) deliverables storage and working space. This section describes each of these areas and their interactions with the developed project.

Firstly, in large or small projects in which there are different teams working remotely and collaboratively, both **project planning and meetings** must be flexible and with the least possible cost, but weekly meetings are also necessary to control the project progress.

This monitoring is a complex task when there are geographical locations constraints. For example, in our project (CALIPSOneo) team leaders were in different Spanish cities (T-Systems from Barcelona, Polytechnic University of Madrid from Madrid and, University of Seville and Airbus EADS CASA from Seville). Our proposal includes using professional collaborative tools for meeting. For example, in our project we used WebEx [2] which provides a web environment for teleconferences, being able to share documents and desktops as well as controlling other computers remotely. Chiefly, these meetings were carried out through AT&T [32], but they were quickly replaced due to the integrated calls WebEx included. WebEx allows connecting to conferences using the computer audio and microphone, which makes this tool very useful.

Secondly, in our proposal we have had into account the **project management** in order to achieve both global coordination and effective management of big software projects. we propose to use web tools (such as Redmine [33]) to project management. In addition, these tools should provide integration mechanisms to facilitate communication with methodological project environment in order to link the methodological process tasks with project planning.

The next area handled the **project's deliverables storage and working space** for the development team. One of the main requirements of the project was the use of a common repository for documents storage. These documents encompassed minutes of the meetings, external documentation (like users manuals or references), final deliverables for the project and 'in work' documents. For this purpose, we propose to use Alfresco [1] to manage final documentation and Subversion to manage 'in work' documentation. Additionally, Alfresco includes a version control for all the documents, which was very useful for managing the versions of the deliverables generated throughout the project.

In relation to deliverables storage and 'in-work' documents, we recommend the use of Subversion because it can be set up in every computer, providing a local copy of all 'in-work' documents for each participant in the project. That will avoid that many people use the same document. Once the file is finished, it cannot be modified and it is stored into Alfresco by using versioning systems.

⁴ <http://www.microsoft.com/net>

5. Results

The projects were successful in general. However, it is known that always that a new methodology or a new workflow is introduced, the learning curve is very high and the susceptibility to use it is not the same for every participant in the project. Below we will analyze each of the three main pillars described in Section 4 (project planning and meetings, deliverables storage and working space, and task management), pointing out each advantage and disadvantage as well as the proposed solution for future work.

With regard to meetings, the selected tool, WebEx, was a great option, providing a common dashboard and the possibility of sharing content or control other computers remotely. One of the main advantages of this tool was the ability to use an external phone for calling or the computer audio system. This characteristic was very useful for holding a meeting via laptop, without depending on a physical phone.

In relation to project planning, at first, each project leader of CALIPSONEO used a different management tool. Some team leaders used Microsoft Project for scheduling. This tool was used about the entire project, but not using the whole performance of the same; it was only useful for Gantt Diagram visualization. Other team leaders use Microsoft Excel or xMind [34] for the same purpose. The main goal was showing the progress achieved during the week in the meeting, so the tool ceased to be important. This variety of tools became confusing, since a different tool was used in each project meeting concerning CALIPSONEO project. Moreover, these types of tools are not collaborative, i.e., new versions were stored every week into the documental repository, Alfresco. As a result, a huge amount of versions for project planning was produced, being complicated to access them.

However, this working method proved unworkable in collaborative environments. Consequently and following our proposal, we used Redmine which provides integration mechanisms. Using this functionality, we were able to establish MDE mechanisms to transform different models of NDT (which were specified in NDT-Profile) in tasks which could be planned and managed within Redmine.

This is one of the core-points on which we are working for future projects. The use of a web-based tool; based on Redmine, being easy to show the project's goals and task on time using a Gantt Diagram.

Next point is the use of the documental repository, Alfresco. Alfresco was the most used tool during the project storing even final documents, or project's deliverables, and 'in work' documents. The main advantage of Alfresco was also its greatest fail. This tool provides the user an easy way to upload files, which quickly became a box without order in which everyone stored its files without any criteria. Alfresco provides a version control for each file it stores, making easy to rollback to any previous version. One of the main errors was to upload the same file in different versions, by adding at the end of the file the deliverable version, increasing the number of files for each deliverable and making difficult to find the last one. Another problem related to Alfresco was that many people used the same file. This posed a lack of coordination due to the physical separation of the people involved in the project. As a result, each company working with a file duplicated it, by adding its name. After a period previously defined, the file was combined, merging the work run by all the enterprises in a unique file. This work is performed by one person and it usually takes a few days to finish it, therefore it is possible to make mistakes.

Once all the pros and cons achieved during the project have been reviewed, we summary the working methodology used for multidisciplinary projects, involving worldwide working teams.

Regarding meetings, we have used Redmine in addition to WebEx, since this tool can show the progress of the project quickly. This reduces the wasted time in meetings. In addition, Redmine provides a Wiki and Forum section, which makes easier share knowledge and solve problems between people in different countries in an agile manner. Despite e-mail can be an alternative, its lack of agility and response times are not viable in a collaborative context. Redmine can manage all the tasks to carry out together with the project's schedule.

NDT methodology, used to ensure the quality of the product developed, was extremely difficult to apply due to the amount of local copies of the same file. Enterprise Architect file, which is the base tool for NDT-Methodology was created for each subproject mentioned in section 3. Each company worked with a local copy, and after a scheduled period of time, the responsible member integrated all the local copies into a file, called master file. Once the master file was created, the working teams kept on working until the next scheduled integration period.

This work plan will be replaced by Subversion, integrated into Enterprise Architect. This will enhance collaborative work and avoid scheduled periods for merging changes.

This proposal will be implemented on the next projects so as to solve problems found on CALIPSOneo and stress positive features.

6. Conclusions and Future Work

This paper has presented a practical evaluation of a set of good practices and management policies. These policies are based on three main pillars represented by: Model-Driven paradigm with NDT and NDT-Suite approach; documental management policies, with an effective use of Alfresco; and collaborative tools, in order to assure the right development of the project.

The paper has shown how the right application of these good practices and policies constitutes an effective mechanism for quality assurance. However, it is very important to stick out that the right tools support has been essential and very critical for the successful result of our project. In CALIPSOneo, despite each member of the team knew the rules, the suitable tools helped each member to follow his/her work. There were daily and weekly controls and corrective activities were executed very frequently. The cost that these controls can suppose in a software project, if no-suitable tools are offered, is higher in many situations.

CALIPSOneo has laid the foundations for a set of works developed in liaison with Airbus Defense and Space that currently involves two new projects, EOLO (factoriEs Of the future. industrial develOpment) [20] and Geolia (first Generation of aErospace iDMU cOncept impLementation And deployment) [21]. Management policies used in CALIPSOneo are extended in these new projects, which are being carried out at present with new members. Other tools, such as Redmine, have been added in this new period according to our policies so as to improve some aspects that were not well supported in previous projects, such as workload or daily planning.

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References

1. AIIM: The Global Community of Information Professionals, <http://www.aiim.org/>, Accessed April 2014
2. Alfresco, <http://www.alfresco.com>, Accessed April 2014
3. AT&T, <http://espanol.att.com/>, Accessed April 2014
4. Bertolino, A., Gnesi, S.: PLUTO: A Test Methodology for Product Families. In: Van der Linden, F.J. (ed.) 5th International Workshop on Software Product-Family Engineering. LNCS, vol. 3014, pp 181-197. Springer, Heidelberg (2004)
5. Chrissie M.B., Konrad M., Shrum S.: CMMI® for Development: Guidelines for Process Integration and Product Improvement. Editorial Pearson Education (2011)
6. CISCO: WEBEX, <http://www.webex.es/>, Accessed April 2014

7. EOLO, http://investigacion.us.es/sisius/sis_proyecto.php?idproy=25048, Accessed April 2014
8. Escalona, M.J., Garcia-Garcia, J.A., Mas, F., Oliva, M., Del Valle, C.: Applying model-driven paradigm: CALIPSONEO experience. Proceedings of the Industrial Track of the Conference on Advanced Information Systems Engineering, pp. 25-32. CEUR, València (2013)
9. Escalona, M.J., Aragón, G.: NDT. A model-driven approach for web requirements. IEEE Transactions on software engineering 34(3), 377-390 (2008)
10. García-García, J.A., Alba, M., García-Borgoñón, L., Escalona M.J.: NDT-Suite: A Model-Based Suite for the Application of NDT. In: Brambilla, M., Tokuda, T., Tolksdorf, R. (eds.) 12th International Conference on Web Engineering, LNCS, vol. 7387, pp. 469–472. Springer, Heidelberg (2012)
11. García-García, J.A., Victorio, J., García-Borgoñón, L., Barcelona, M.A., Dominguez-Mayo, F.J., Escalona, M.J.: A Formal Demonstration of NDT-Quality: A Tool for Measuring the Quality using NDT Methodology. The 21st Annual Software Quality Management (SQM) conference (2013)
12. García-García, J.A., Escalona, M.J., Cutilla, C.R., Alba, M.: NDT-Glossary. Proceedings of the 13th International Conference on Enterprise Information System, pp. 170-175. SciTePress, Beijing (2011)
13. García-García, J.A., Cutilla, C.R., Escalona, M.J., Alba, M., Torres, J.: NDT-Driver: A Java Tool to Support QVT Transformations for NDT. In: Pooley, R., Coady, J., Schneider, C., Linger, H., Barry, C., Lang, M. (eds.) Information Systems Development: Reflections, Challenges and New Directions, pp. 89-101. Springer Science+Business Media, New York (2013)
14. Geolia, http://investigacion.us.es/sisius/sis_proyecto.php?idproy=25051, Accessed April 2014
15. Gutierrez, J.J., Nebut, C., Escalona, M.J., Mejías, M., Ramos, I.: Visualization of use cases through automatically generated activity diagrams. In: Czarnecki, K., Ober, I., Bruel, J-M., Uhl, A., Völter, M. (eds.) 11th International Conference on Model Driven Engineering Languages and Systems. LNCS, vol. 5301. pp. 83-96. Springer, Heidelberg (2008)
16. ISO/IEC: ISO 9001:2008 Quality management systems, Requirements. International Organization for Standardization (2008)
17. ISO/IEC: ISO/IEC 19507:2012 Information technology - Object Management Group Object Constraint Language (OCL). International Organization for Standardization, formal/2012-05-09 (2012)
18. ISO/IEC: ISO/IEC 27000:2009 Information technology, Security techniques, Information security management systems & Overview and vocabulary. International Organization for Standardization (2009)
19. IWT2: NDT-Suite, www.iwt2.org, Accessed April 2014
20. Mas, F., Gomez, A., Menendez, J.L., Rios, J.: Proposal for the conceptual design of aeronautical final assembly lines based on the iDMU concept. In: Bernard, A., Rivest, L., Dutta, D. (eds.) 10th IFIP WG 5.1 International Conference on Product Lifecycle Management for Society, pp. 10-19. Springer, Heidelberg (2013)
21. Melia, S., Gómez, J.: The webSA approach: applying model driven engineering to web applications. Journal of Web Engineering 5(2),121-149 (2006)
22. Mohagheghi, P., Gilani, W., Stefanescu, A., Fernandez, M.A.: An empirical study of the state of the practice and acceptance of model-driven engineering in four industrial cases. Empirical Software Engineering 18(1), 89-116 (2013)
23. OMG. Documents Associated with Meta Object Facility (MOF) 2.0 Query/View/Transformation. Object Management Group (2008), <http://www.omg.org/spec/QVT/1.0/>
24. PMI (Project Management Institute) Inc. A Guide to the Project Management Body of Knowledge, Fourth Edition (2008)

25. Ponce, J., García-Borgoñon, L., García-García, J.A., Escalona, M.J., Domínguez-Mayo, F.J., Alba, M., Aragon, G.: A Model-Driven Approach for Business Process Management. *Covenant Journal of Engineering & Technology* 1(2), 32-52 (2013)
26. Redmine, <http://www.redmine.org/>, Accessed April 2014
27. Robles, E., Grigera, J., Rossi, G.: Bridging Test and Model-driven Approaches in Web Engineering. In: Gaedke, M., Grossniklaus, M., Díaz, O. (eds.) 9th International Conference on Web Engineering. LNCS, vol. 5648, pp.130-150. Springer, Heidelberg (2009)
28. Schmidt, D.C.: Model-Driven Engineering. *IEEE Computer* 39(2), 25-31 (2006)
29. SparxSystems, Enterprise Architect, <http://www.sparxsystems.com>, Accessed April 2014
30. Stark, J.: Product Lifecycle Management: 21st Century Paradigm for Product Realisation. Springer, Heidelberg (2011)
31. Tjassing, R., Kolthof, A., De Jong, A., Verheijen, T., Pieper, M., Van Bon, J., Van der Veen, A.: Fundamentos de ITIL, Volumen 3. Van Haren Publishing (2008)
32. UWE (UML-based Web Engineering), <http://uwe.pst.ifi.lmu.de/>, Accessed April 2014
33. WebML (Web Model Language), <http://www.webml.org>, Accessed April 2014
34. XMind, <http://www.xmind.net/>, Accessed April 2014

A Novel Method for the Comparison of Graphical Data Models

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Abstract

This paper proposes a methodical approach for data model comparisons based on the graph theory. The proposed new approach is a Graphical Model Comparison Algorithm (GMCA) which includes a procedure, methods and an algorithm that can be used for comparing two data models for similarities. The comparison is based on the structural similarity of graphs representing data models that contain some semantically similar data objects.

Keywords: Data Model Comparison, Graph Theory, Semantic Similarity, Structural Similarity.

1. Introduction

Development and implementation of information systems is reliant on modeling. Two factors – reusability and integration play a significant role in the process of system implementation [9]. Various process, data, and business models are used to align software and organizational structures. In the case that software and organizational structures do not align well, software customization or the redesign of the organizational structure are reasonable alternatives. In order to reuse and implement existing data structures and applications, the compliance of referent and target implementation domains must be achieved, which is best checked by the use of corresponding models. Similarly, for integration, the compatibility of implementation co-domains and interoperability of their information systems must be checked on the appropriate models.

The research presented in this paper proposes that the alignment, compliance, compatibility, and other related properties of business problem domains and their IT co-domains, (which are used in different contexts), can be identified, checked and proven by using the similarity of their corresponding models. Given their importance and stability, we will focus on the data structures and models.

Similarities between IT systems can be defined through the examination of their relevant characteristics. One of these characteristics can be expressed as a measure of the semantic and structural resemblance of data objects used in different IT systems. Why is the semantic and structural resemblance of data objects of interest? Firstly, data objects are related to business rules; since many business domains and systems share similar business rules, they handle similar data sets, which are subsequently used in a similar way in various organizations. This proposition is relevant to the reusability of IT systems. Secondly, rapidly changing technology and business environments call for the continuous improvement of IT systems at various levels: technical, data, process, and business. The existing IT systems need to be upgraded, thus, making the integration possibilities of new and existing data structures very important. Thirdly, graphical data models of IT systems, which comprise relationships between the data objects (thereby representing the business rules), are necessary and useful for identifying and analyzing data relations. Since the structure, constraints, and operations representing data

objects or concepts in data models are similar to that of the nodes and edges in graphs, it can be assumed that a comparison of data models based on graph theory is possible.

There are a few formal methods that can be considered as suitable for the graphical comparison of data models [10], [12]. Additional studies have compared the conceptual models of data using descriptive logic [4], and the application of the B-method for comparing relational UML [7]. The concept for the presentation of data models using graphs was researched by many authors [1,2], [5,6] however, there is a lack of any published algorithm or tool to support graphical representation of a data model. On the other hand, some research has focused on investigating and developing models for measuring semantic distance to quantify the distance between two data values using a graph-based approach [8], or determining semantic and schematic similarities between objects in databases, based on a contextual analysis [3].

Influenced by these ideas, the research presented in this paper proposes a new methodical approach. This approach includes procedures that can be used as a tool for comparing two data models for their similarities based on their structure and accounting for the semantic similarity of some data objects.

The fundamental concept is to compare the graphical models as they are (i.e. as graphical representation), without their prior conversion to formal specifications. This implies the use of their basic shape as graphs and the application of graph theory. Despite the development of graph theory and its applications, preliminary research has shown that there are no adequate “ready-to-use” methods and algorithms for this specific purpose. Thus, a new method and algorithm for comparison of graphical data models needs to be defined and implemented.

The new methodological approach explained in this paper is manifested in the fact that the models are compared simultaneously by two criteria: the semantically and structurally, but in one pass through the algorithm and application of the algorithm in a selected tool. Structural comparison is performed only over the contextually/semantically similar elements with the help of directed arcs that describe the use of foreign keys (in relational terms).

2. Graphical Model Comparison: Methods and Process

Before discussing the methods and procedure, the limitations of this method must be explained. These limitations are concerned with the input graphical models for comparison and can be expressed by the following question: When does the comparison of graphical models make sense?

First of all, it should be determined whether graphical models are conceptually comparable, i.e., if they are of the same type and generated on the basis of the same representation concepts. If not, they must be transformed via modeling methods into models that meet this condition. Although our research is based on the Entity-Relationship (E-R) method of graphical representation, the implications and conclusions of our research can be applied to other methods of data modeling with similar concepts and notation.

The next step is to analyze whether models are semantically comparable, i.e., if they contain synonyms or semantically analogous data concepts. Models of a similar shape may describe different matters, which are incomparable, such as the production of fishing nets and the issuance of a loan. In this example, the comparison makes no sense because both models have no semantic analogy. If data models refer to comparable problem domains, then they contain pairs of semantically similar objects. These pairs must be determined first as a prerequisite for further structural analysis.

Determination of the semantic similarity between terms, i.e. semantic relatedness, is essential for various tasks, such as clustering, information retrieval, and synonym extraction, and extends across numerous fields. There are several approaches and methods of determining semantic similarity, but also software tools, which is especially important in order to automate the whole process.

Given the small number of concepts that contain data models (<100 data objects), it is sufficient to use an intuitive method of visualizing the semantic similarity of terms, such as mind map or concept map.

Data models with the previously described pairs of semantically similar data objects (entity types) can be compared in order to explore and establish the structural similarity between them. This method makes sense if the two diagrams have at least two pairs of semantically similar types of entities and at least one relationship between them.

The basic procedure for the application of this method is below:

1. Define pairs of semantically similar data objects from the data models selected for comparison.
2. Translate E-R data models to directed graphs.
3. Create adjacency matrices from directed graphs.
4. Use semantically similar object pairs as permutations for enumerating vertices and extracting adjacency sub matrices.
5. Compare sub matrices and find matching values in matching rows and columns.
6. Interpret matching values as structurally similar relationships.

The process of comparison should include transforming the data models into directed graphs, comparison charts, and the conclusion based on determining the structural similarity between the elements of the graphs.

If it is determined that structural similarity of the directed graphs exists, then it is assumed that the models from which they were derived are also structurally similar.

Based on this assumption, a comparison process and an algorithm for comparing models to identify structural similarities is developed and implemented.

The comparison process is carried out in three phases with a total of 18 specific steps. The process is described in Figure 1. As shown in Figure 1, the steps are interconnected in such a way that the results of one or more steps are used in the next step. The next section gives a brief overview of the Graphical Model Comparison Methodology with an illustration of the algorithm on two graphical data model examples.

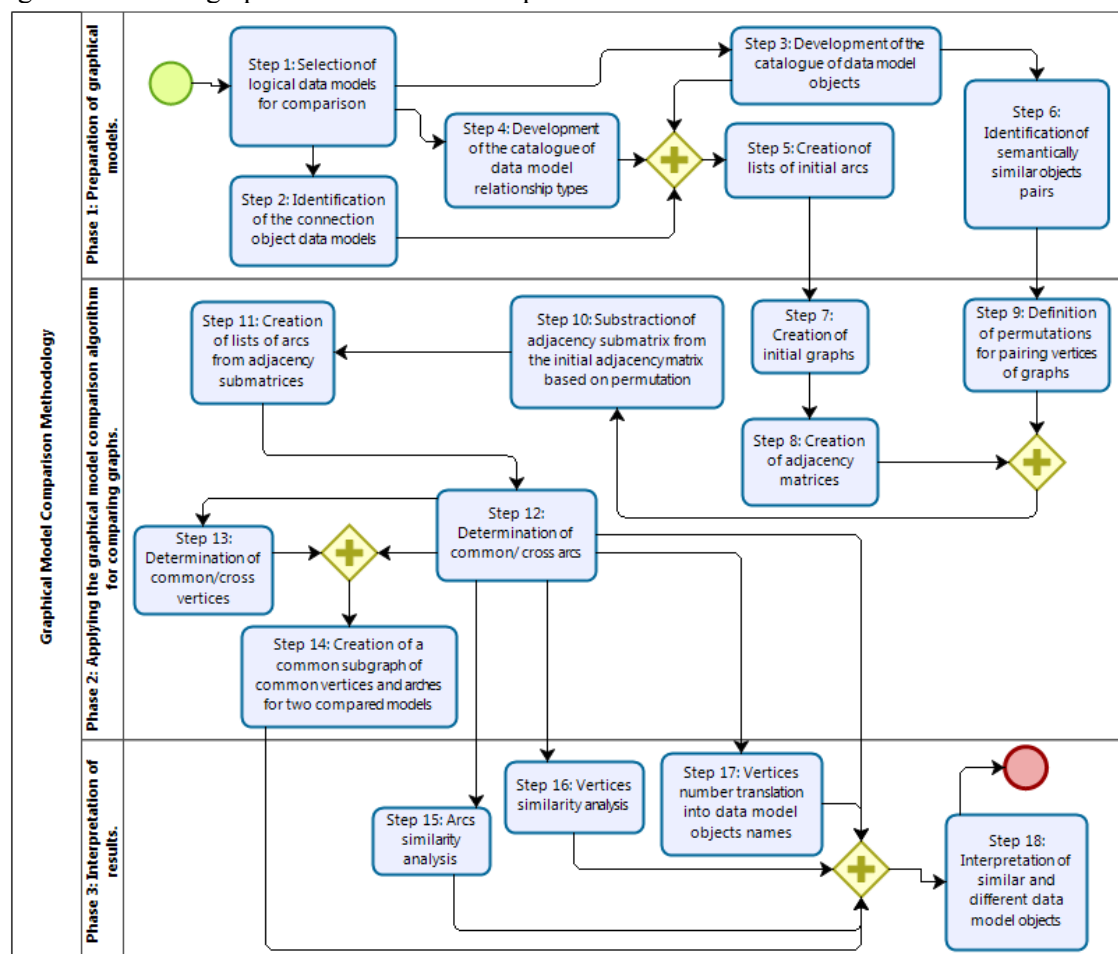


Fig. 1. Graphical Model Comparison Process

3. Illustration of the comparison algorithm on two graphical data model examples

Based on the methodology for comparison of graphical data models, an algorithm named Graphical Model Comparison Algorithm (GMCA) was developed and applied. The applicability of the GMCA to Entity-Relationship data models and related data models which are based on binary relations and graphic notation was tested. The algorithm was written in an open source mathematical tool called wxMaxima [11].

3.1. Phase 1: Preparation of graphical models

In order to show how the algorithm works, each step of the methodology is explained and illustrated with an example comparing two data models. The initial phase of the comparison procedure for determining structural similarity two data model examples were selected (Figures 2 and 3). The first phase consists of following steps: selection of logical data models for comparison, identification of the connection object data models, development of the catalogue of data model objects, development of the catalogue of data model relationship types, creation of lists of initial arcs, and identification of semantically similar objects pairs.

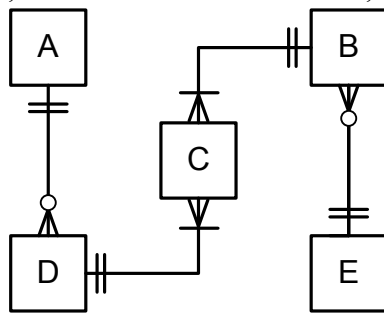


Fig. 2. Example data model 1

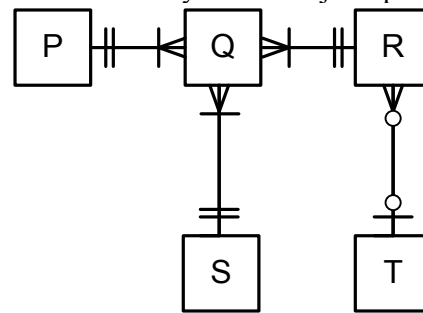


Fig. 3. Example data model 2

For each data model, a list of relationships between objects must be created containing the elements in the following format: [[Source object, target object], relationship type]. Source object refers to the object whose instances are referenced in the target object instances as many times as it is stated in the relationship type.

Data models can contain different relationship types. A subset of common relationship types (1 to many, 1 to 1, many to many) which have been identified as possible relationship types in selected data models, are coded by a number. Assigned codes for relationship types are following: relationship type (0,1):(0,M) is coded by the number 1; relationship type (1,1):(0,M) is coded by 2; relationship type (0,1):(1,M) is coded as 3; and relationship type (1,1):(1,M) is coded by the number 4. This code will be used to describe the weight of arches in the directed graphs.

In order to make the graphs comparable, first identify the pairs of objects which have a semantic similarity, e.g., if object B in data model 1 represents a Client and object R represents Buyer in data model 2, then it can be assumed that these two objects could represent a semantically similar concept in two different data models. In the same way, other semantically similar object pairs are presupposed. These pairs are listed in Table 1. Each pair is coded by a number in the first column. This code number will be used to define permutations of vertices.

Table 1. List of semantically similar pairs of objects

Pair number	Object from data model 1	Object from data model 2
1	E	T
2	D	P
3	C	Q
4	B	R

3.2. Phase 2: Applying the graphical model comparison algorithm for comparing graphs

List of connection from data models 1 and 2 will be used to create and compare lists of vertices and arcs describing graphs derived from data models. These lists are inputs for the algorithm, which will be used to determine the structural similarity of data models.

The second phase of the comparison consists of eight steps, which allow the creation of initial data model corresponding directed graphs (Figures 4 and 5), the creation of adjacency matrices, definition of permutations for pairing vertices of graphs, subtraction of the adjacency submatrix from the initial adjacency matrix based on permutation, the creation of lists of arcs from adjacency sub matrices, determination of common/cross arcs, determination of common/cross vertices and finally the creation of a common subgraph of common vertices and arcs for two compared models (Figure 6).

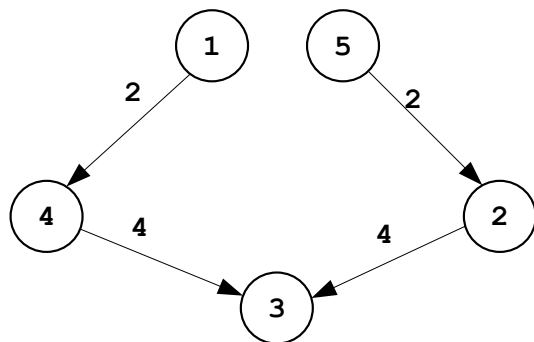


Fig. 4. Graph 1 created from data model 1

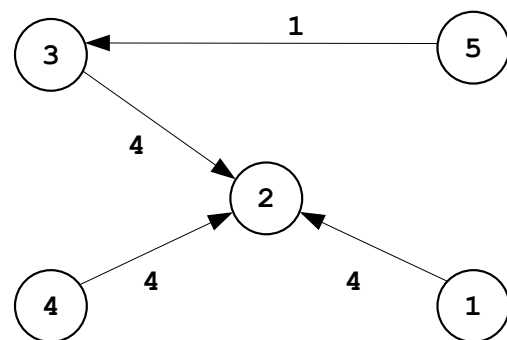


Fig. 5. Graph 2 created from data model 2

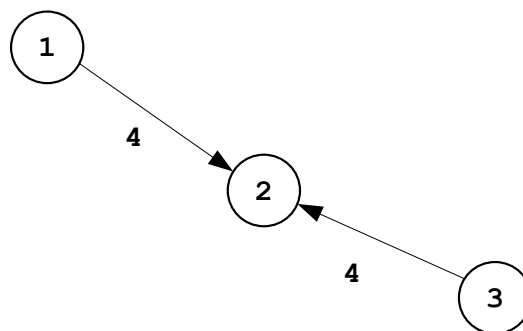


Fig. 6. Common subgraph of common vertices and arcs for two compared models

3.3. Phase 3: Interpretation of results

In this phase, the results are interpreted. This phase consists of four steps: Arcs similarity analysis, vertices similarity analysis, vertices number translation into data model objects' names and the Interpretation of similar and different data model objects. This last step of the methodology refers to the interpretation of the data object similarity by listing data objects for which structural similarity is recognized (if their corresponding vertices are in the common subgraph) and those that are not included in the set of similar data objects.

Comparison results for two compared models are represented by Figure 6 and the matrix from graph intersection are following.

$$\begin{bmatrix} 0 & 4 & 0 \\ 0 & 0 & 0 \\ 0 & 4 & 0 \end{bmatrix}$$

with following measures:

RES: Arc similarity from 1st graph/data model to 2nd :50
 RES: Arc similarity from 2nd graph/data model to 1st :50
 RES: Vertices similarity from 1st graph/data model to 2nd :60
 RES: Vertices similarity from 2nd graph/data model to 1st :60
 SIM: Vertices of 1st graph/data model in intersection:[4,3,2]
 SIM: Names of vertices of 1st graph/data model in intersection:
 [D,C,B]
 DIFF: Vertices of 1st graph/data model NOT in intersection:[1,5]
 DIFF: Names of vertices of 1st graph/data model NOT in intersection:
 [A,E]
 SIM: Vertices of 2nd graph/data model in intersection:[1,2,3]
 SIM: Names of vertices of 2nd graph/data model in
 intersection:[P,Q,R]
 DIFF: Vertices of 2nd graph/data model NOT in intersection:[4,5]
 DIFF: Names of vertices of 2nd graph/data model NOT in intersection:
 [S,T]

4. Conclusion

The alignment, compliance, compatibility and other related properties of business problem domains and their IT co-domains, which are used in different contexts, can be identified, checked and proven by using the similarity of their corresponding data models. This paper presents an overview of a methodology and proposes a process for comparing the structural similarity of two data models with semantically similar elements.

The fundamental idea is to compare the graphical models as they are (i.e. as graphical representation), without their prior conversion to formal specification. This means that it is not important which notation (E-R notation or any other) is being used to show relations between objects, but it is essential to include in the comparison the pure existence of relations (to answer the question are two objects related, and is this relation directed). Due to the fact that different types of relations can be seen between objects (e.g. 1:M is a type of relation in E-Rs) the relationship types are being coded for the purpose of the comparison and it cannot be seen as a restriction of the algorithm. Basically, if a relationship between two objects can be described as a directed arc (one or two arcs for bidirectional relations) then there is no need for model translation into another notation). This concept implies the use of their basic shape as graphs and the application of graph theory.

Preliminary research has shown that there are no adequate “ready-to-use” methods and algorithms for this specific purpose. To meet this need a novel method and algorithm was developed, the Graphical Model Comparison Algorithm (GMCA). In order to show how the algorithm works, the algorithm was illustrated with an example of the comparison of two data models.

It is the conclusion of this research that it is possible to determine the similarity of two data models, based on the semantic similarity of pairs of data objects they contain and structural similarity of graphs, by using the proposed procedure and GMCA.

The secondary results of the application of GMCA are differences between compared models.

The applicability of GMCA to Entity-Relationship data models and the related data models which are based on binary relations and graphic notation has currently been confirmed.

During the process of conducting this research, areas that require further studies have been revealed including:

- The comparison of different versions of the same model;
- Performance indicators of the algorithm (like complexity, scalability and run-time);
- Comparison of the “as is” and “to be” models of various kinds;

- Development of a procedure for comparison of more than two data models, based on the GMCA.

Additionally, this research suggests that the application of the methodological approach to process models (which has partially been tested and shown in other papers like “Comparison of simple graphical process models” in *Journal of Information and Organizational Sciences*), state machines, and other models based on the graphic notation, is a subject for future research.

References

1. Choudhury, S., Chaki, N., Bhattacharya, S.: GDM: a new graph based data model using functional abstraction. *Journal of Computer Science and Technology*. 21(3), 430-438 (2006)
2. Gyssens, M., Paredaens, J., Van Gucht, D.: A graph-oriented object database model. In: *Proceedings of the 9th ACM SIGACT-SIGMOD-SIGART symposium on Principles of database systems (PODS '90)*, pp. 417-424. ACM, New York, NY, USA (1990)
3. Kashyap, V., Sheth A.: Semantic and Schematic Similarities between Database Objects: A Context-based approach. *The VLDB Journal – The International Journal on Very Large Data Bases*, 5(4), 276-304 (1996)
4. Keet, C.M.: A formal comparison of conceptual data modeling languages. *13th International Workshop on Exploring Modeling Methods in Systems Analysis and Design (EMMSAD'08)*, Vol-337, pp. 25-39. Montpellier, France (2008)
5. Kim, P.: E-model: event-based graph data model theory and Implementation, PhD Thesis. Georgia Institute of Technology, Atlanta Georgia, USA (2009)
6. Majundar, A.K., Bhattacharya, I., Saha, A.K.: An object-oriented fuzzy data model for similarity detection in image databases. *IEEE Transactions on Knowledge and Data Engineering*, 14(5), 1186-1189 (2002)
7. Mammar, A., Laleau, R.: From a B formal specification to an executable code: application to the relational database domain. *Information and Software Technology*, 48(4), 253-279 (2006)
8. Roddick, J.F., Hornsby, K., De Vries, D.: A unifying semantic distance model for determining the similarity of attribute values. In: *Proceedings of the 26th Australasian computer science conference - Volume 16 (ACSC '03)*, Michael J. Oudshoorn (Ed.), pp. 111-118. Australian Computer Society, Inc., Darlinghurst, Australia (2003)
9. Saha, B., Stanoi, I., Clarkson, K.L.: Schema Covering: a Step Towards Enabling Reuse in Information Integration. In: *Proceedings of ICDE Conference 2010*, pp. 285-296, IEEE, Long Beach, CA (2010)
10. Vatanawood, W., Rivepiboon, W.: Formal Specification Synthesis for Relational Database Model. *International journal of intelligent systems*, 19, 159-175 (2004)
11. wxMaxima, (<http://andrejv.github.com/wxmaxima/index.html>, Accessed October 10th 2011)
12. Yugopuspito, P., Araki, K.: Transformational Object-Relational Database Model in Formal Methods. *Transactions of Information Processing Society of Japan*, 42(5), 71-80 (2001)

A DSL for EER Data Model Specification

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Abstract

In this paper we present a domain specific language (DSL) for Extended Entity-Relationship (EER) data model approach, named EERDSL. EERDSL is a part of our Multi-Paradigm Information System Modeling Tool (MIST) that provides EER database schema specification at the conceptual level and its transformation into a relational data model, or a class model. EERDSL modeling concepts are specified by Ecore, one of the commonly used approaches to create meta-models. In the paper we present both textual and graphical notations of EERDSL. Since only few modeling constraints may be described at the level of abstract syntax, we use Object Constraint Language (OCL) to specify complex validation rules for EER models.

Keywords: Domain Specific Language, Extended Entity-Relationship Data Model, Databases, Information Systems, Ecore, Object Constraint Language.

1. Introduction

As the information technology constantly grows and evolves, new possibilities for its incorporation in information systems (ISs) continue to appear. There are many ways and approaches that may be deployed to improve the process of IS development. Some of them deploy domain specific languages (DSLs) [17], computer-aided software engineering (CASE) tools or Model Driven Software Development (MDSD) tools. Our focus is on the usage of DSLs based on model driven approaches. In our previous research we developed Integrated Information Systems Studio Tool (IIS*Studio) [1,13,14,15]. IIS*Studio is a software tool that provides a model driven approach to IS design. IIS*Studio, as a software tool assisting in IS design and generating executable application prototypes, currently provides: (i) Conceptual modeling of database schemas, transaction programs, and business applications of an IS; (ii) Automated design of relational database subschemas in the 3rd normal form (3NF); (iii) Automated integration of subschemas into a unified database schema in the 3NF; (iv) Automated generation of SQL/DDDL code for various database management systems (DBMSs) [1]; (v) Conceptual design of common user-interface (UI) models; (vi) Automated generation of executable prototypes of business applications; (vii) Modeling check constraints and untypical

functionalities of business applications [14]; and (viii) Reverse engineering of relational databases to form type (FT) models [2]. Our focus in research is on the design and generation process of a database and application software of an IS.

One of the main motives for developing IIS*Studio is in the following. For many years, the most favorable conceptual data model is widely-used Entity-Relationship (ER) data model with its extensions. Majority of existing CASE tools provide as the first step creation of an ER database schema. The next step in the design process is the ER database schema transformation into the relational database schema. Such scenario has many advantages, but also there are serious disadvantages [12].

In order to provide design of various platform independent models (PIMs) by IIS*Studio, we created a number of modeling, meta-level concepts and formal rules that are used in the design process. We have also developed and embedded into IIS*Studio, tools that apply such concepts and rules. They assist designers in creating formally valid models and their storing as repository definitions. The main features of IIS*Studio may be found in [6].

There is a strong need to have PIM concepts specified formally in a platform independent way. PIM concepts need to be fully independent of repository based specifications that typically may include some implementation details. Our research is based on the Meta Object Facility (MOF) 2.0 [18] to formally describe IIS*Studio PIM concepts. As we could not find standardized implementation of MOF, we decided to use Ecore meta-meta-model, which is provided by Eclipse Modeling Project (EMP) [8]. Besides, created meta-model can be used for the software tool verification in EMP environment and providing software documentation in a formal way. It also represents an abstract syntax for IIS*CDesLang – a textual domain specific language presented in [6], [16]. EMP is the Eclipse environment that provides software development process based on model driven approach (MDA). With the improvement of EMP, we decided to implement some of the existing IIS*Studio functionalities, as the next logical step in the evolution of IS development methods, using this technology. Besides the IIS*Studio functionalities, we have decided to support database schema design based on the Extended Entity-Relationship (EER) data model, as a commonly used, traditional approach. Therefore, we have developed a DSL for the specification of EER database schema specifications, named EERDSL. Although there is a plethora of EER modeling tools, we have decided to develop our own DSL, as we need to integrate EER and FT approaches. The FT approach is supported by a DSL developed using Ecore in the Eclipse environment. The highest level of integration is only possible if EERDSL is also developed using Ecore, allowing the usage of the same repository used by the FT approach. As EER approach is present in almost every book on databases, we believe that our DSL may also be used for educational purposes, such as learning about: (i) EER concepts and developing a database specification at the conceptual level; and (ii) MDSD approach by means of the EER approach the students are familiar with, since it is extensively taught in the previous database courses. FT and EER approaches of our new Eclipse-based tool both provide conceptual database schema modeling. The tool is named Multi-paradigm Information System modeling Tool (MIST). In MIST, both approaches may be used simultaneously. We developed transformations that provide EER models to be transformed into FT models. For both FT and EER models, we provide in MIST a transformation into a relational data model. In this paper we present MIST tool with a focus on EERDSL. EERDSL provides database schema modeling at the conceptual level using graphical and textual notation. EERDSL modeling concepts are represented by the graphical notation proposed by Thalheim in [25]. We have specified textual notation in our own way as there is no standard for it.

Apart from Introduction and Conclusion, the paper is organized in four sections. Related work is elaborated in Section 2. In Section 3 we present the architecture of MIST. In Section 4 we give a presentation of EER meta-model implemented in EMP environment. In Section 5, we give a concrete syntax specification of EER concepts. We present textual and graphical notation of EERDSL, with an example of EERDSL usage.

2. Related Work

EER is one of the commonly used approaches for the database schema design at the conceptual level. PowerDesigner [23], ERWin [4], SmartDraw [22], Oracle Designer [21], or Cameo Data Modeler [5] for MagicDraw are commercial CASE tools that support EER approach. These tools support only graphical notation according to one of the well-known notations, such as Chen's [7], Elmasri-Navathe's [9], Barker's [3], or Merise [24]. Also, all of the aforementioned CASE tools are built as the stand-alone tools. The EERCASE tool presented in [11] is integrated with the Eclipse environment. It provides all of the EER concepts represented with Elmasri-Navathe's graphical notation.

Our tool is integrated with the Eclipse environment. EERDSL component of our tool provides database schema specification using concepts from the EER approach. The concepts are represented by graphical notation represented by Thalheim. Apart from graphical notation, provided by all of the aforementioned tools, our tool also provides EER database schema modeling with a textual notation. As there is no standard for EER textual notation, we have specified textual notation in our own way.

3. The Architecture of MIST

In Fig. 1, we present the architecture of the MIST tool. The tool contains following components: FTDSL, Synthesis, Business Application Generator, EERDSL, EER2Rel, EER2Class, SQL Generator, Java Generator, and R2FT.

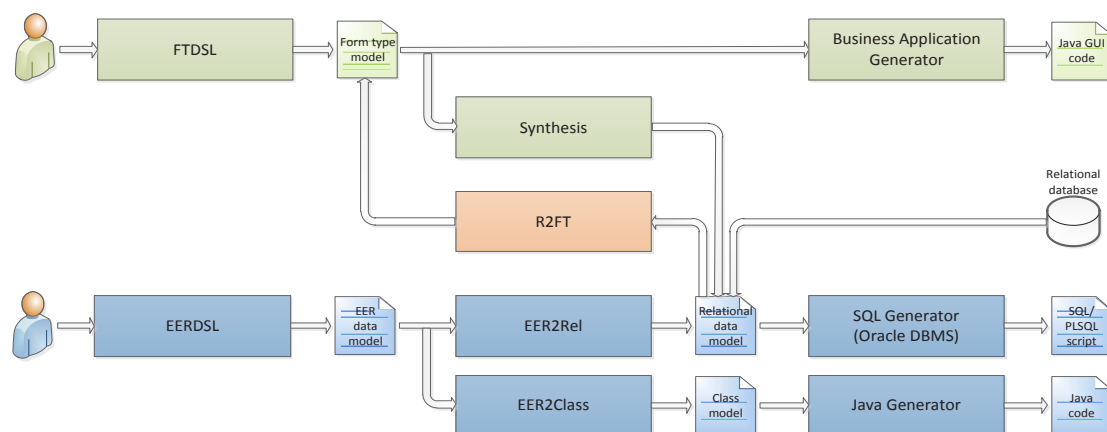


Fig. 1. MIST architecture

FTDSL component comprises a textual domain specific language having the abstract syntax specified by Ecore meta-meta-model. FTDSL allows a designer to model an IS at a conceptual level using FT concepts. IS model based on the FT concept includes not only the database schema of an IS, but also business applications and their graphical user interfaces (GUIs). After the process of the conceptual IS modeling, an IS designer may generate a model of a relational database schema, using the synthesis algorithm. The Synthesis component is an improved synthesis algorithm presented in [12], [19]. The improved synthesis algorithm takes a Universal Relation Schema (URS) expressed by FT concepts as an input and produces a relational database schema as an output. The MIST tool contains the Business Application Generator component, as the FTDSL component may be used to specify business applications of an IS. This component takes an FT model as an input and produces Java code of a modeled business application as an output. As the FT specification is enriched with GUI details, the generated application prototype may be executed and used to perform basic operations over the database.

In order to provide a conceptual specification of an IS database model, MIST comprises EERDSL component. EERDSL includes both graphical and textual domain specific languages. EERDSL abstract syntax is specified by Ecore meta-meta-model. The most IS designers favor one of the well-known EER graphical notations for the database modeling process. The other group of IS designers are more familiar to modeling based on the modeling concepts represented in a textual way. In order to support both groups

of the designers, we developed the DSL that provides database modeling in both ways. The IS designer is able to use both model representations at the same time. By this, two different viewpoints over the same model are provided in MIST. EER module provides the generation of the relational database model and the class model from EER database model.

EER2Rel component of MIST provides transformation of EER model to the relational data model. Models being transformed conform to the EER meta-model and relational meta-model, respectively. The relational data model may be further used in the process of SQL code generation. For this purpose, the SQL Generator component is developed.

EER2Class component of MIST provides a transformation of an EER model to a class model. The class model may be used to generate code in some of the object-oriented programming languages. Our Java Generator component is used to generate Java code from the provided class model.

In order to provide reverse engineering of a relational database model to the FT model, R2FT component has been developed. The component comprises a transformation specification from the relational data model to the FT model. Also, this component may be used to transform an EER database model to the FT model through the relational data model.

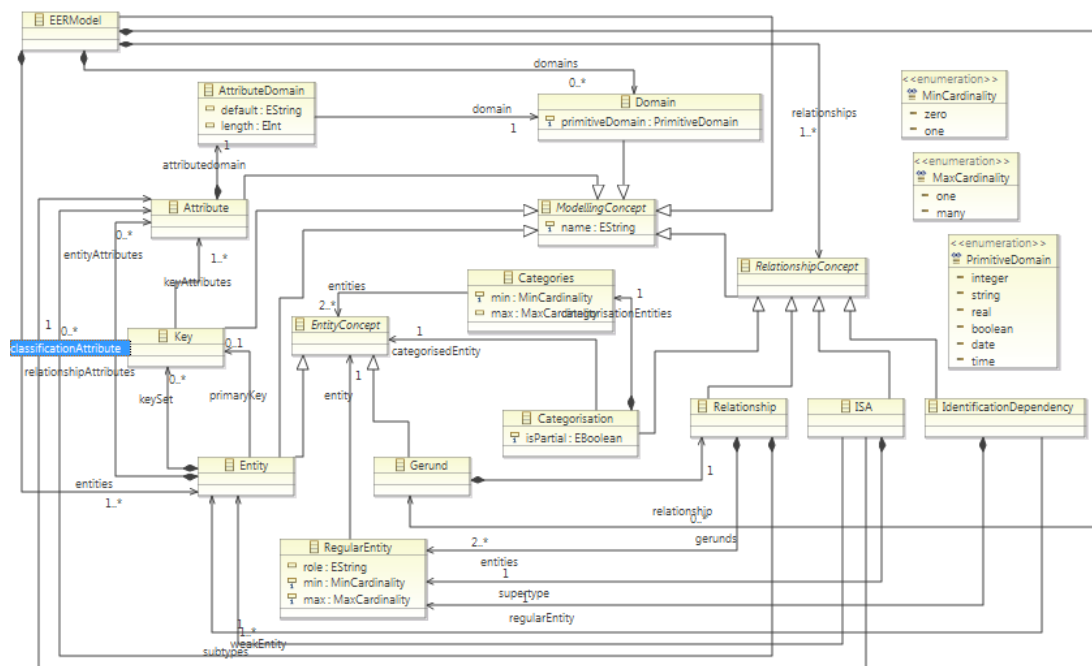


Fig. 2. The EER meta-model

4. Extended Entity-Relationship Meta-Model

In this section we present concepts of our EER PIM meta-model specified by Ecore meta-meta-model. Modeling concepts in the EER data model are: entity, n-ary relationship, IS-A relationship, identification dependency relationship, categorization relationship, gerund, attribute, key, and domain. In the rest of this section, we present the names of meta-model and model concepts in brackets and *italic*. The root concept in our meta-model presented in Fig. 2 is the model (*EERModel*). Each EER model comprises zero or more entities (*Entity*). *Entity* concept is used to model a class of real observed entities in the specified IS. In some approaches, the *Entity* concept is named *Entity Type* concept. Each entity may contain zero or more attributes (*Attribute*). The *Attribute* concept is used to model a property of selected real entities in the designed IS.

A domain (*Domain*) represents a set of allowed values that an attribute may have. Each domain is based upon a primitive domain (*PrimitiveDomain*), such as integer, string, real, boolean, date, and time. Each attribute is associated with exactly one domain

(*AttributeDomain*). For each attribute, length and default value may be specified. Therefore, in order to provide domain reusability, domains may be specified once at the level of EER model, and further reused and restricted at the level of attributes. An entity specification requires a specification of the set of keys (*Key*). Each key is specified as a set of attributes of the entity. Only one key is declared as the primary key.

The EER data model provides modeling different relationship types. Relationships between entities are classified as: n-ary relationship (*Relationship*), identification dependency relationship (*IdentificationDependency*), IS-A relationship (*ISA*), and categorization relationship (*Categorisation*). N-ary relationship represents an association between two or more entities. For each entity in the n-ary relationship (*RegularEntity*) its role, minimum (*MinCardinality*) and maximum (*MaxCardinality*) cardinalities need to be specified. A minimum cardinality may have one of two values: one or zero, while a maximum cardinality may be provided with the values of one or more. For each n-ary relationship, a designer may specify attributes. *Gerunds* are used to specify the rules, by means of just selected entity instance combinations of some entities may be used in relationships with other entity's instances. The main features of different relationship types may be found in [25].

In order to express more complex constraint rules in EER models, we use Object Constraint Language (OCL) [20]. By OCL we specify constraints that cannot be expressed by means of Ecore modeling concepts. First we have to specify OCL invariant that enables checking if the primary key is defined at the level of an *Entity*. Only when an entity is a subtype in an IS-A relationship, the primary key may be unspecified. At the level of the *ModellingConcept* class, an OCL invariant supports checking the uniqueness of all its instances. In an IS-A relationship, the classification attribute is selected from the set of supertype entity attributes. In the *Categorisation* class, OCL invariant supports checking the difference between category and categorization entities. At the level of identification dependency relationship, an OCL invariant checks if weak and regular entities are different. The following OCL invariant enables checking if the sequence of attributes in the key belongs to the set of the attributes of that entity:

```
invariant invalidAttributInKey:
    if(not keySet.keyAttributes->isEmpty()) then
        if(entityAttributes->notEmpty()) then
            entityAttributes->includesAll(keySet.keyAttributes)
        else
            entityAttributes->notEmpty()
        endif
    else
        keySet.keyAttributes->isEmpty()
    endif;
```

5. EERDSL Textual and Graphical Notations

A specification of the concrete syntax is one of the important steps in development of a DSL. Our goal is to develop a DSL in support of the IS design process. Therefore, we have specified a meta-model that defines the structure and semantics of necessary concepts of our EERDSL language. Such meta-model specification represents, at the same time, the abstract syntax of EERDSL, aimed at conceptual modeling of database schemas.

There are numerous tools for the DSL development. We have used our meta-model specified by Ecore in EMF as an abstract syntax specification. By means of Eclipse plug-ins named Xtext [26] and Eugenia [10], we have generated the concrete syntax of EERDSL. In this section we present only a part of the concrete syntax grammar rules.

EERDSL textual notation is generated in the XText plug-in. It is expressed by Extended Backus–Naur Form (EBNF). In this section, we present textual notation rules for the selected EER PIM concepts only.

Production rule for defining an *EERModel* is:

```
EERModel returns EERModel:
'EERModel' name=EString '{'
('domains' '{' domains+=Domain ( "," domains+=Domain)* '}' )?
```

```
'entities' '{' entities+=Entity ( "," entities+=Entity)* '}'
('gerunds' '{' gerunds+=Gerund ( "," gerunds+=Gerund)* '}' )?
'relationships' '{' relationships+=RelationshipConcept ( ","
relationships+=RelationshipConcept)* '}' '}';
```

This rule specifies a name of a model (*name*), possible domains (*domains*), different entities (*entities*), gerunds (*gerunds*), and relationships (*relationships*) created in the context of a model.

Eugenia plug-in provides generation of a graphical notation. The EERDSL graphical notation is expressed by graphical symbols that provide graphical language representations. In Table. 1, we present the symbols of the EERDSL graphical notation only for the main EER PIM concepts. All concepts are represented with widely used graphical notation presented by Thalheim in [25].

Table 1. EERDSL graphical notation symbols

Entity	Attribute	Domain	Gerund
N-ary relationship	IS-A relationship	ID relationship	Categorization relationship

In Fig. 3, we present a fragment of a model specified using a textual and graphical notation of EERDSL. It represents a part of faculty EER database schema, named *FacultySystem*. In the left part of the Fig. 3, a textual model is presented, while in the right part, a graphical notation is depicted. First, we have created an instance of the *EERModel* concept, named *FacultySystem*. In the example shown in Fig. 3, model *FacultySystem* comprises four domains: *integer*, *varchar*, *date*, and *time*. We have also specified entities: *Student*, *Teacher*, *Subject*, *Chair* and *Faculty*. Each student has attributes: *studentID*, *studentsYear*, *studentName*, and *studentSurname*. *KeyStudent* represents the primary key of *Student* entity, comprising attribute *StudentID*. *Subject* entity has attributes: *subjectID* and *subjectName*. *KeySubject* is the *Subject* primary key composed of the attribute *subjectID*. Teachers of a faculty are modeled by the *Teacher* entity, having the attributes *teacherTitle*, *teacherID*, *teacherName*, and *teacherSurname*. A relationship between teachers and subjects taught is modeled by *TeachesClasses*. Each teacher teaches one or more subjects, while a subject is taught by one or more teachers. The relation between students and subjects is modeled by the *Takes* relationship. Each student may attend one or more subjects, while a subject may be attended by zero or more students. Relationship *Grades* models students' grades given by teachers. As only a teacher that teaches a subject may grade students attend that subject, relationship *Grades* must relate relationships *Takes* and *TeachesClasses*. Therefore, relationships *Takes* and *TeachesClasses* are created as gerunds. Each student that attends a subject may be graded by exactly one teacher teaching the subject. A teacher teaching a subject may grade zero or many students on the subject. Each grading has *examDate* and *grade* attributes. Relationship between teachers and chairs is modeled by *WorksAt* relationship. Each teacher works at exactly one chair, while at one chair may work one or more teachers. Each chair is identified by its name and the faculty's *facultyID* attribute. Therefore, a relationship *IsPartOf*, between *Chair* and *Faculty*, is modeled by the identification dependency relationship.

```

EERModel FacultySystem {
  domains {
    Domain int primitiveDomain integer,
    //...domains varchar, date, time
  }
  entities {
    Entity Student {
      attributeSet {
        Attribute studentID domain int,
        Attribute studentYear domain int
      } //...attributes studentName, studentSurname
      keySet { keyStudent (studentID)}
      primaryKey keyStudent
    }, //...entities chair, faculty, subject, teacher
  }
  gerunds {
    Gerund Relationship Takes {
      entitiesInRelationship {
        Student (one,many), Subject (zero,many)
      }
    }, //...gerund TeachesClasses
  }
  relationships {
    Relationship Grades {
      entitiesInRelationship {
        Takes (one, one), TeachesClasses (zero,many)
      }
      attributeSet {
        Attribute grade domain int, Attribute examDate domain Date
      }
    },
    IdentificationDependency IsPartOf {
      weakEntity Chair, regularEntity Faculty (one,many)
    }, //...relationship WorksAt
  }
}

```

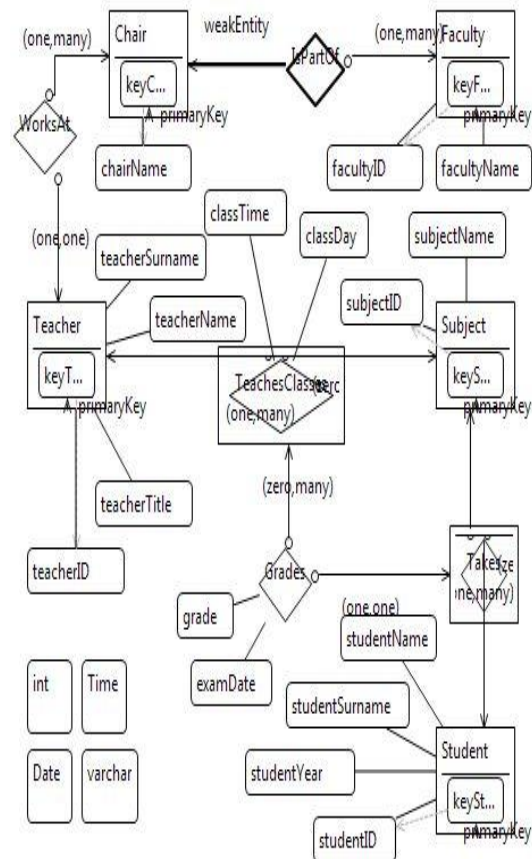


Fig. 3. Example of Faculty IS specification in EERDSL

6. Conclusion

In this paper we presented a DSL for EER data model specification, named EERDSL. Through our previous research we developed the MIST tool. It provides an IS design approach based upon the usage of FTDSL. Our intention was to provide database designers an opportunity to use EER data model, as a commonly used, traditional approach. First of all we needed to create the EER meta-model specified by Ecore that actually represents the abstract syntax of the language. At the level of meta-model, we specified OCL constraints in order to support constraints that cannot be expressed by means of Ecore modeling concepts. Then, we created both textual and graphical notations for EERDSL. In this way we support both group of designers, one preferring graphical modeling languages, and the other preferring textual programming languages. After the database schema specification at the conceptual level, MIST may be used for generation of the relational database model and a class model. As a final product, MIST provides a generation of SQL scripts and procedural code for inverse referential integrity constraints, from a relational model. The tool supports generation of Java classes from a class model.

In our further research, we plan to perform an empirical case study in order to compare FTDSL and EERDSL. To meet this goal, it is necessary to collect practical experience and lessons learned from IS designers. We need information about the amount of generated code, development process speed, and user satisfaction using both of these approaches. We also plan to introduce MIST to our database and MDSO university courses. Our intention is to validate the tool and the approach after gathering enough user feedback data. Another research direction is to extend EERDSL with new concepts allowing more detailed specifications of database models at the conceptual level. The concepts should provide constraint specifications. As we already have provided a conceptual specification of the check constraint at the level of FT models, we plan to create the appropriate formalisms for its specification at the level of EER

model, too. Currently EERDSL provides graphical notation represented by Thalheim in [25]. We also plan to develop and embed into EERDSL some other widely used graphical notations, such as Merise or Elmasri-Navathe's. In that way, we provide IS designers to become familiar with various EER graphical notations, which is particularly important in the education process.

Acknowledgment

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References

1. Aleksić, S., Luković, I., Mogin, P., Govedarica, M.: A generator of SQL schema specifications. *COMSIS*. 4 (2), 81–100 (2007)
2. Aleksić, S.: Methods of Database Schema Transformations in Support of the Information System Reengineering Process. PhD thesis, University of Novi Sad, Novi Sad (2013)
3. Barker, R.: *CASE Method: Entity Relationship Modelling*. Reading, MA: Addison-Wesley Professional (1990)
4. CA Erwin, <http://erwin.com>. Accessed April 26, 2014
5. Cameo Data Modeler, <http://www.nomagic.com/products/magicdraw-addons/comeo-data-modeler.html>. Accessed April 26, 2014
6. Celikovic, M., Lukovic, I., Aleksic, S., Ivancevic, V.: A MOF based meta-model and a concrete DSL syntax of IIS*Case PIM concepts. *COMSIS*. 9 (3), 1075–1103 (2012)
7. Chen P. P.-S.: The entity-relationship model—toward a unified view of data. *ACM Transactions on Database Systems*. *TODS*. 1 (1), 9–36 (1976)
8. Eclipse Modeling Project, <http://projects.eclipse.org/projects/modeling>. Accessed April 26, 2014.
9. Elmasri, R., Navathe, S. B.: *Fundamentals of Database Systems*. Benjamin/Cummings (1994)
10. Eugenia, <http://www.eclipse.org/epsilon/doc/eugenia/>. Accessed April 26, 2014
11. Fidalgo, R. N., Alves, E., España, S., Castro, J., Pastor, O.: Metamodeling the Enhanced Entity-Relationship Model. *Journal of Information and Data Management*. 4 (3), 406–420 (2013)
12. Luković, I.: From the synthesis algorithm to the model driven transformations in database design. In: *Proceedings of 10th International Scientific Conference on Informatics (Informatics 2009)*, pp. 9–18. Slovak Society for Applied Cybernetics and Informatics and Technical University of Košice - Faculty of Electrical Engineering and Informatics, Košice, Slovakia (2009)
13. Luković, I., Mogin, P., Pavičević, J., Ristić, S.: An approach to developing complex database schemas using form types. *Software: Practice and Experience*. 37 (15), 1621–1656 (2007)
14. Luković, I., Popović, A., Mostić, J., Ristić, S.: A tool for modeling form type check constraints and complex functionalities of business applications. *COMSIS*. 7 (2), 359–385 (2010)
15. Luković, I., Ristić, S., Mogin, P., Pavičević, J.: Database Schema Integration Process—A Methodology and Aspects of Its Applying. *Journal of Mathematics*. 36 (1), 115–140 (2006)
16. Luković, I., Varanda Pereira, M. J., Oliveira, N., Cruz, D., Henriques, P. R.: A DSL for PIM Specifications: Design and Attribute Grammar based Implementation, *COMSIS*. 8 (2), (2011)
17. Mernik, M., Heering, J., Sloane, M. A.: When and how to develop domain-specific languages. *ACM Computing Surveys*. 37 (4), 316–344 (2005)
18. Meta-Object Facility, <http://www.omg.org/mof>. Accessed April 26, 2014
19. Mogin, P., Luković, I., Govedarica, M.: *Principi projektovanja baza podataka*. Novi Sad (2004)
20. Object Constraint Language, <http://www.omg.org/spec/OCL>. Accessed April 26, 2014
21. Oracle Designer, <http://www.oracle.com/technetwork/developer-tools/designer/overview/index-082236.html>. Accessed April 26, 2014
22. SmartDraw, <http://www.smartdraw.com>. Accessed April 26, 2014
23. Sybase PowerDesigner, <http://www.sybase.com/>. Accessed April 26, 2014
24. Tardieu H.: *La methode MERISE: Principes et outils*. (1983)
25. Thalheim, B.: *Entity-relationship modeling: foundations of database technology*. Springer (2000)
26. XText, <https://www.eclipse.org/Xtext>. Accessed April 26, 2014

CERVANTES: A Model-Based Approach for Service-Oriented Systems Development

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Abstract

Context: The benefits of the Model-Driven Software Engineering application for Service-Oriented Computing.

Objective: This paper proposes a Model-Based approach for Service-Oriented Systems Development.

Method: Following the Model-Driven Reverse Engineering process, from the models discovery, to the generation of the current Model-Based Approach for Service-Oriented Systems Development.

Results: The CERVANTES metamodel is presented and compared to other initiatives.

Conclusions: This study shows how Model-Driven Engineering can be used to develop Service-Oriented Systems in practice.

Keywords: Service-Oriented System Engineering, Model-Driven Engineering, Service-Oriented Computing.

1. Introduction

Computer systems have had a great evolution in the latest years, and software researchers and developers have been creating abstractions that help them. From the first monolithic programs, which had been developed with defined functions and autonomous behavior, to current systems with greater functionalities which operate in heterogeneous and distributed environments by interacting with other systems, many approaches have been proposed to manage the system and software development complexity.

In the area of distributed systems, Service-Oriented Computing (SOC) is the computing

paradigm that utilizes services as the basic constructs to support the development of rapid, low-cost and easy composition of distributed applications even in heterogeneous environments [15]. SOC proposes to develop technology neutral and loosely coupled systems[14].

Moreover, Model-Driven Software Engineering (MDE) is a software development paradigm which focuses on creating and exploiting domain models (that is to say, abstract representations of knowledge and activities that govern a domain specific application) as a means of alliviating the systems complexity and express domain concepts effectively [16]. Models, metamodels and transformations are the key elements in MDE [5].

In 2001 we set out to create a methodological approach, named CERVANTES, that could be reused in the design and development of distributed systems. This approach was based on these assumptions: i) to follow an architecture-driven development: current and future functionalities should be considered in the architectural design; ii) the design of the subsystems should be independent of technology, platforms, programming languages or messaging protocols; iii) the internal behavior of each subsystem must be semi-formally described giving rise to subsequent validation, and; iv) runtime logs will have valuable information about usage of the system in order to reconfigure a deployment or redesign to improve performance, even dynamically.

Since its definition, CERVANTES has been widely used for the systems design and development within the group, being present in many solutions, which are currently deployed in different domains and real environments.

With the appearance of MDE, we proposed to use this paradigm to facilitate the CERVANTES use. First of all, we needed to change to a model-based perspective, a higher-level representation of our legacy system, as has been recently proposed in Model-Driven Reverse Engineering (MDRE) [4]. MDRE aims to create a set of models that represent the system, and includes three main phases: model discovery, model understanding and model (re)generation.

In this paper, we present the MDRE process for CERVANTES, from the models discovery, to the generation of the current model-based approach for service-oriented systems development. To this end, at the beginning we present the original runtime framework that manages the message interchange and the internal business process, and then, as a result of the MDRE process, the metamodel for distributed systems design and a tool that generates the source code will be shown.

As we said above, this paper is structured following the three main phases of a MDRE process: First, in Section 2, we talked about the Model Discovery phase where the previous components of CERVANTES are presented . Section 3 shows the result of the Model Understanding phase by introducing the CERVANTES metamodel and, in Section 4, the IDE followed by an example of application in practice is presented as the result of the Model Generation phase. A review of related work and a comparison with other alternatives is provided in Section 5. Finally Section 6 concludes and outlines future work.

2. CERVANTES Framework: The origins

In MDRE, the idea is to switch as soon as possible from the heterogeneous real world to the homogeneous world of models. To achieve this goal, it will be detailed the CERVANTES framework, a basic infrastructure that supports the system of systems execution.

This runtime allows the deployment of distributed systems designed as exchanging information through asynchronous *Messages* that are processed by *State Machines*. The framework is based on the following components, as described in the Figure 1a): i) *Core Framework*: contains the common elements to all infrastructure like activation and shutdown mechanisms, metrics, exceptions and distributed logger; ii) *Control Framework*: it encapsulates the logic when a *Message* is received; iii) *Boundary Framework*: responsible for establishing communication with other subsystems by asynchronous messages using various protocols such as Java RMI, .NET Remoting, XML-RPC or SOAP, and; iv) *Entity Framework*: stores the information of the var-

ious *State Machines* in execution on a separate shared memory space for each subsystem and maintains a mirror of the same in a persistent medium.

Based on the previously exposed architecture, the dynamic behavior of the framework follows a sequence of steps, as seen in Figure 1b): 1. A Request is received by the *Server* following a concrete protocol; 2. The *Server* translates to the internal Messaging format and sends to the *Manager*; 3. The *Message* is stored in a priority sorted queue; 4. The Producer-Consumer pattern is used to process the *Message* by the *Manager*; 5. If it was a Request, a *State Machine* to process it is created. If it was a Response, it's automatically sent to the *State Machine* which was waiting for it; 6. The *State Machine* waits for the Token to restart its execution (to avoid race conditions all inter-dependent *State Machines* are managed by a single Thread); 7. When it is the turn of execution, the logic of the workflow starts; 8. Usually every request is associated with a response, so that the end result of the execution of the *State Machine*, the invoked subsystem transmits a final answer. To send the results the same Messaging system is used, so the result is transferred to the *Manager* as a proxy to the *Boundary Framework*, and; 9. The Response is sent by the *Sender* and confirms to finalize the *State Machine*.

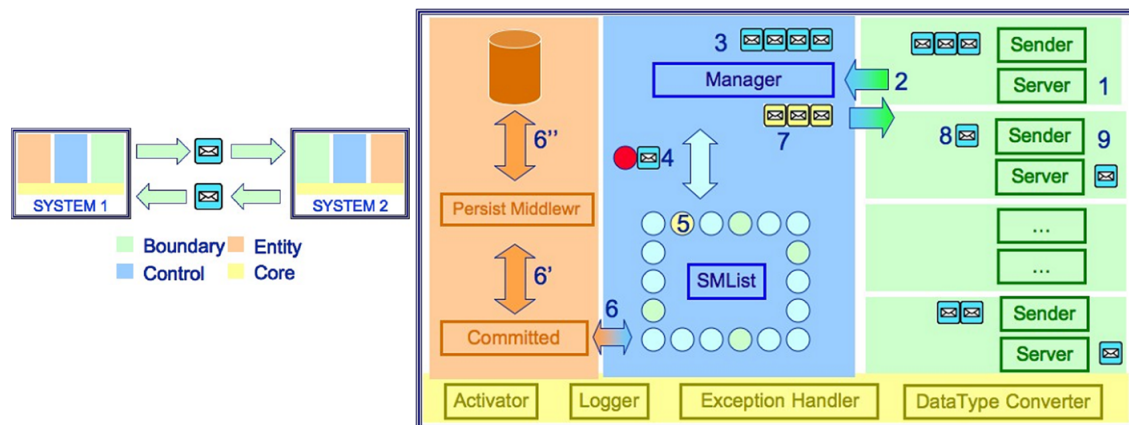


Figure 1. a) CERVANTES Framework Components; b) Runtime steps

This Framework has been the starting point for the Model Discovery Phase according to MDRE process.

3. CERVANTES Metamodel

The following phase is Model Understanding. The goal of this phase is to obtain a kind of manageable representation in MDE. The way we have worked this phase is by inferencing of the support CERVANTES metamodel. This metamodel will be described below.

A CERVANTES system is composed by a set of *CervantesSubsystems* which can be deployed in a distributed and heterogeneous environment. The behaviour of every *CervantesSubsystem* is modelled by a set of *StateMachines* which are composed by a set of *States* and their *Transitions*. A *StateMachine* has at least a *initial* and *finalOK States* mandatory, and it maybe a *finalError State* also. A *Transition* is triggered by a *Message* sending. *Messages* are divided into *Requests*, *Responses* and *Events*. A *Response* can be successful (*OK response*) or *error*. The CERVANTES metamodel can be shown in Figure2.

4. Model Generation

The following phase is Model Generation where the models obtained at the Model Understanding Phase are finally used to generate the expected outcome. In this Section the Integrated Development Environment (IDE) tool known as CERVANTES Studio is presented and a practical

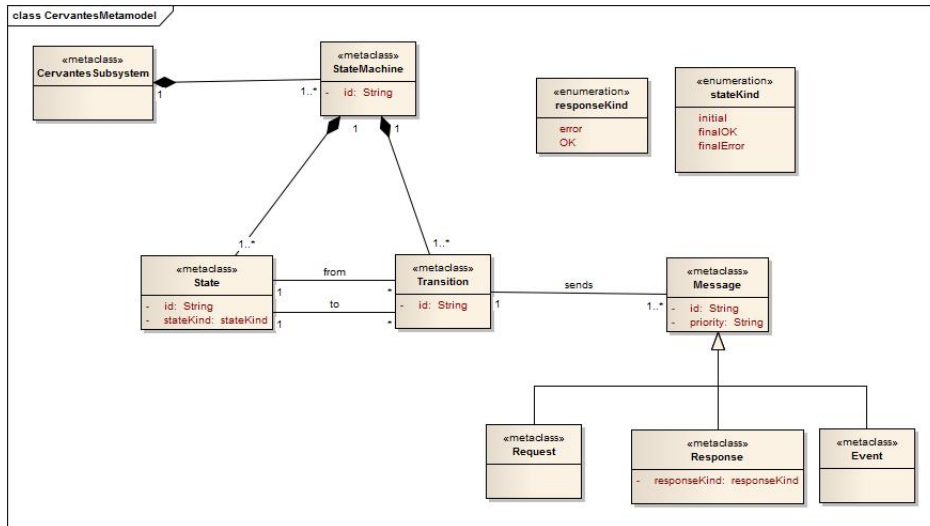


Figure 2. CERVANTES metamodel

case study is exposed.

In order to make use of the metamodel CERVANTES Studio was developed. Based on a Eclipse Modeling Framework (EMF)[6] and Graphical Modeling Framework (GEF)[7], this tool allows the software engineer to model the system of systems, by creating the *State Machines* and the *Messages* and generates the source code for specific platforms, in particular, for Java and C#.net. A screenshot of the *State Machine* Editor is shown in Figure 3.

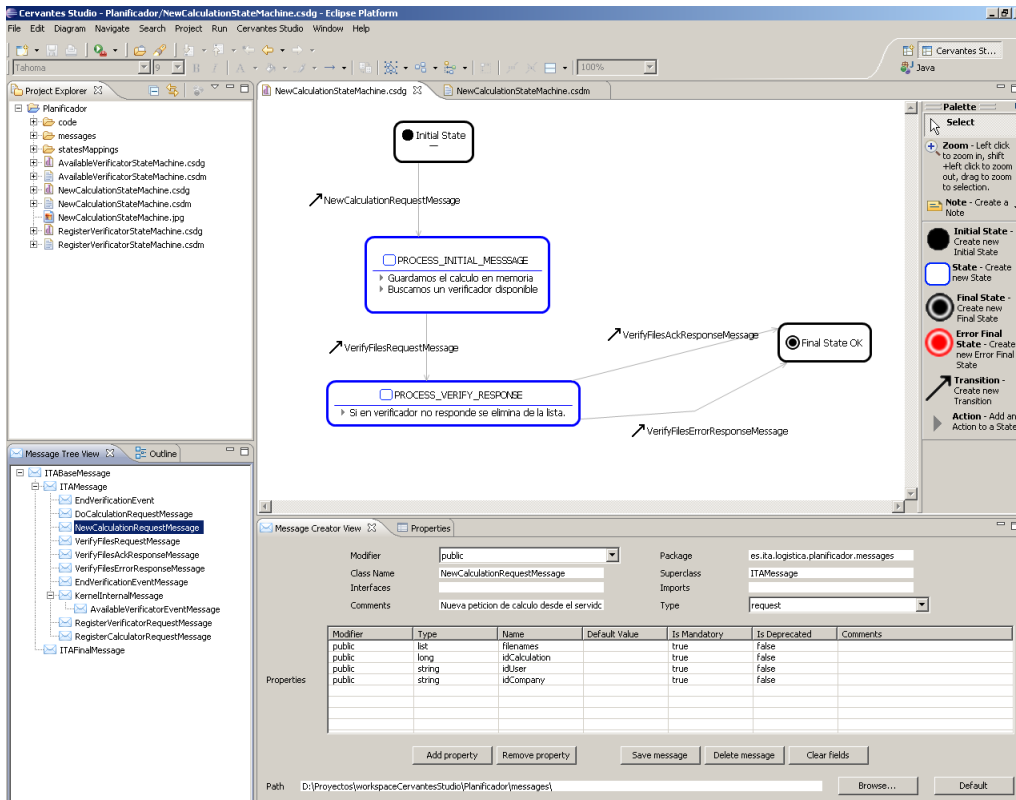


Figure 3. CERVANTES Studio Screenshot

The IDE also includes a metrics monitor. Once selected the metrics server of a CERVANTES Framework instance (namely, server and port), the user can navigate through the

model and for every *State Machine* monitor: i) execution Time (latest, on average, maximum); number of class instances (current, maximum); average execution time per state. This tool is very useful in order to improve the performance of the system by taken usage information.

Since its creation, the CERVANTES framework has been widely used for the design and development of systems within the group, being present in many solutions currently deployed in real environment in different domains and technologies, like telecommunications, healthcare, tourism or logistics, by usign C++, Java and C#.NET programming languages.

As an example of its application in practice, we will describe how CERVANTES was used for the design and development of an Intelligent Taxi Fleet Management System, which was composed of a set of *Cervantes Subsystems* as it is shown in Figure 4: i) *Comm*: the module to bridge connections to the fleet by using different protocols; ii) *Kernel*: the core of the system which maintains the main connection between the rest of the modules; iii) *PBX*: the module to integrate a telephone server; iv) *GIS*: the module which maintains the geographical information system and calculates the best route; v) *Database*: the core of the persistence data of the system; vi) *Operator*: the module to achieve the human interaction.

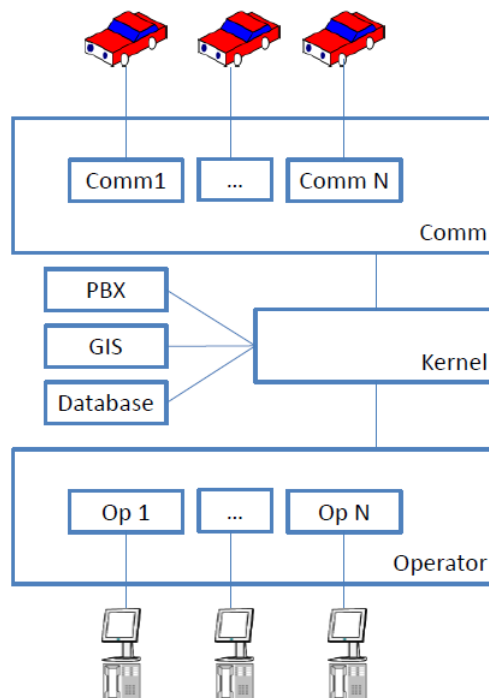


Figure 4. Intelligent Transportation System Architecture

Every subsystem can be deployed in a distributed system and, according to the metamodel, their interfaces are described by using *Messages* and their internal behavior by *State Machines*. An example of the State Machine which processes the Request of an Incoming Call is shown in Figure 5.

5. Related Work and Comparison

Once the MDRE process was finalized, we have a model-based approach for Service-Oriented Systems Development. In this section we have included a general review of similar proposals in the literature, with the aim of knowing them and comparing the main characteristics with our approach.

The Model-Based approach for development of Service-Oriented systems have been tackled by plenty of authors in the last few years. Some of most relevant proposals are:

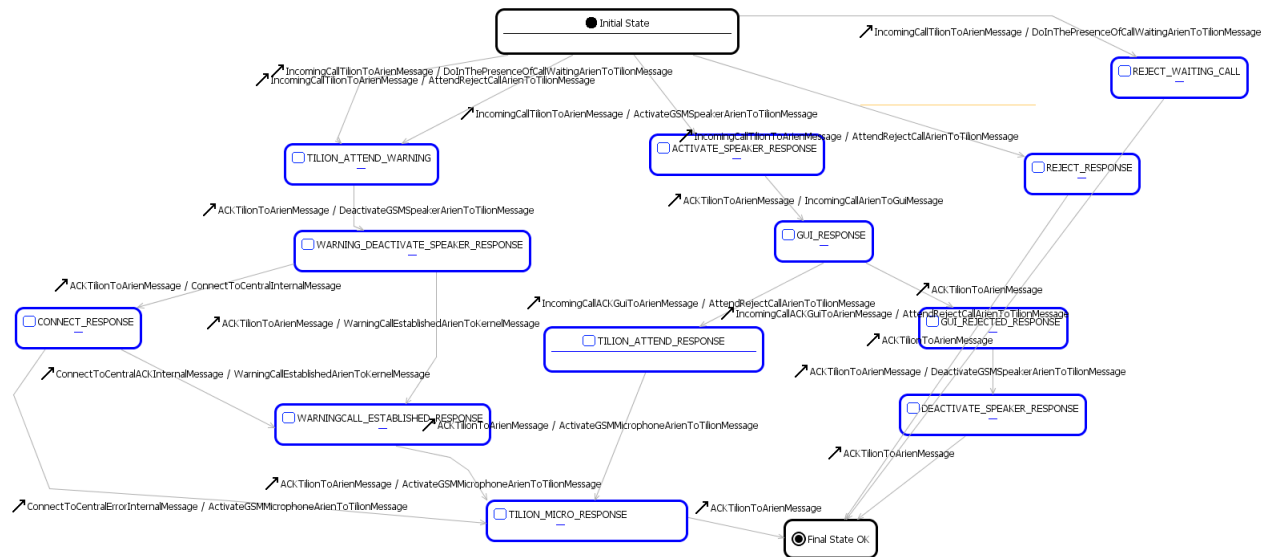


Figure 5. New Incoming Call StateMachine

- a proposal for modelling Service-Oriented Architectures with UML[10];
- a service-oriented modeling framework that employs an agile and universal business and technology language to facilitate analysis, design, and architecture initiatives[3];
- a service-oriented modeling framework that employs an agile and universal business and technology language to facilitate analysis, design, and architecture initiatives[3];
- a service-oriented modeling framework that employs an agile and universal business and technology language to facilitate analysis, design, and architecture initiatives[3];
- an architectural-model based approach for web applications[2];
- a UML profile to graphically design the non-functional aspects in SOA[18];
- a UML profile to graphically design the non-functional aspects in SOA[18];
- a UML profile for software services which allows for the modeling of services, service-oriented architecture (SOA), and service-oriented solutions, by IBM[9];
- a Service-Oriented Modeling Framework (SOMF) as a Model Driven Engineering Methodology that Offers Used-to-Be, As-Is, and To-Be Business and Technological Perspectives of Service-Oriented Modeling[17];
- a UML model to represent SOA static concepts and graph transformations for the behavior[1], and;
- a UML profile for SOA modelling following MDA principles[8];

The main distinguishing factor of our approach regarding other proposals is that CERVANTES has been validated widely by industry, because it has been included in multiple projects in real environments. These real environments are source information for the feature of metrics in execution time allows us to learn and improve the approach.

Regarding related standards, in 2012 the OMG[11] published the Service oriented architecture Modeling Language(SoaML)[13] specification which provides a metamodel and a UML

profile for the specification and design of services within a service-oriented architecture. Its profile provides the flexibility for tool vendors having existing UML2 tools to be able to effectively develop, transform, and exchange services metamodels in a standard way. Its metamodel can be extended for specific purposes. It seems that this proposal has become a standard for SOC modeling. The relationship between SOC and business process seems to be fully addressed by using the OMG Business Process Model and Notation (BPMN)[12] specification. Both are standards and, as such, they try to address the higher quantity of concepts as possible. This fact produces that the learning curve for using in the industry will be increased significantly. Our proposal is focused on being easy-to-learn, simple and common to the service-oriented systems. Again, the practice application in the industry supports our proposal.

6. Conclusions and Future work

This paper presents a model-based approach for Service-Oriented Systems development. This approach is the result of a Model-Driven Reverse Engineering, and the three main phases of the MDRE process have been exposed. The process starts with the CERVANTES framework, which has been widely used for systems development since 2001. According to the process, the paper introduces a metamodel to supports CERVANTES and an integrated development environment (IDE) for using in a MDE way.

From this work and due to CERVANTES has been used in several real projects, some relevant conclusions can be deduced from this experience.

Firstly, a model-based mechanism can be very useful in a Service-Oriented development environment but it should be easy-to-learn for its application in the industry. A simple abstract syntax but tool-supported is a better option than a more sophisticated syntax that incorporates a lot of concepts. However, the usability of the tool by non-experts software developers is very important too, so we are working in a better solution for the MDE tool, as could be Enterprise Architect, widely used in the IWT2 group, where this paper has been developed.

Secondly, the MDRE process is a very useful proposal for including a model-based approach in legacy systems, with the benefits of complexity management that MDE incorporates. We are working in defining a method to automate the three phases and systematize the use in legacy systems.

Finally, we are trying to improve the CERVANTES framework and incorporate new features, as the definition a methodology that covers the entire development lifecycle of a service-oriented systems, or the use of the metrics of usage to support automatic reconfiguration at runtime, as a first implementation of Self-configuration services which configures themselves automatically to adapt to different environments in which they can be installed and can operate to optimize for particular kinds of their use[15].

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References

1. Baresi, L., Heckel, R., Thöne, S., Varró, D.: Modeling and validation of service-oriented architectures: application vs. style. In: ACM SIGSOFT Software Engineering Notes, vol. 28, pp. 68–77. ACM (2003)
2. Beigbeder, S.: Websa: un método de desarrollo dirigido por modelos de arquitectura

- para aplicaciones web (2007)
3. Bell, M.: Service-oriented modeling. John Willey & Sons, Inc (2008)
 4. Brambilla, M., Cabot, J., Wimmer, M.: Model-driven software engineering in practice. *Synthesis Lectures on Software Engineering* **1**(1), 1–182 (2012)
 5. Cetinkaya, D., Verbraeck, A.: Metamodeling and model transformations in modeling and simulation (2011)
 6. EMF: Eclipse modeling framework project. Eclipse Foundation (2014). [Http://www.eclipse.org/modeling/emf/?project=emf](http://www.eclipse.org/modeling/emf/?project=emf), last accessed 04/2014
 7. GMF: Graphical modeling project. Eclipse Foundation (2014). [Http://eclipse.org/gmf-tooling/](http://eclipse.org/gmf-tooling/), last accessed 04/2014
 8. Heckel, R., Lohmann, M., Thöne, S.: Towards a uml profile for service-oriented architectures. In: *Model Driven Architecture: Foundations and Applications*, p. 115. Citeseer (2003)
 9. Johnston, S.: Uml 2.0 profile for software services. IBM developerWorks http://www.ibm.com/developerworks/rational/library/05/419_soa/ Accessed 2014-04-10 (2005)
 10. López-Sanz, M., Acuña, C.J., Cuesta, C.E., Marcos, E.: Modelling of service-oriented architectures with uml. *Electronic Notes in Theoretical Computer Science* **194**(4), 23–37 (2008)
 11. OMG: Object management group, <http://www.omg.org>, accessed 2014-04-10
 12. OMG: Omg’s business process model and notation (bpmn), <http://www.bpmn.org>, accessed 2014-04-10
 13. OMG: Omg’s service oriented architecture modeling language (soaml), <http://www.omg.org/spec/soaml>, accessed 2014-04-11
 14. Papazoglou, M.P.: Service-oriented computing: Concepts, characteristics and directions. In: *Web Information Systems Engineering, 2003. WISE 2003. Proceedings of the Fourth International Conference on*, pp. 3–12. IEEE (2003)
 15. Papazoglou, M.P., Traverso, P., Dustdar, S., Leymann, F.: Service-oriented computing: a research roadmap. *International Journal of Cooperative Information Systems* **17**(02), 223–255 (2008)
 16. Schmidt, D.C.: Model-driven engineering. *COMPUTER-IEEE COMPUTER SOCIETY-* **39**(2), 25 (2006)
 17. SPARX: Service-oriented modeling framework (somf) , <http://www.sparxsystems.com.au/somf>, accessed 2014-04-11
 18. Wada, H., Suzuki, J., Oba, K.: Modeling non-functional aspects in service oriented architecture. In: *Services Computing, 2006. SCC’06. IEEE International Conference on*, pp. 222–229. IEEE (2006)

Complex Propagation of Events: Design Patterns Comparison

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Abstract

Today's applications require high level of interactivity and the applications are expected to update their state, and provide users with immediate correct results. In high complex applications this usually means updating states of a number of objects that are part of complex dependency network. To decouple these dependencies such systems usually employ implicit invocation mechanisms such as well-known Observer pattern. However, building efficient propagation system that will keep object states up-to-date is a challenging task, since a number of issues arise. In this paper we identified 18 qualitative criteria and compared 5 design patterns that can be used to build propagation system on top of applications' business objects. The exhaustive comparison results are given along with discussion and remarks that should be taken in consideration when dealing with this challenging task.

Keywords: Design Patterns, Observer, Mediator, Events, Propagation, Publish-subscribe, Change Manager, Implicit Invocation, Reactive Systems.

1. Introduction

Object oriented paradigm has been acknowledged as a dominant paradigm for developing complex applications for a quite some time. These applications can have large number of objects that are greatly interdependent. That means that object's state and computations are dependent on one or more other objects. Such dependencies can form a large and complex dependency network and such application usually requires high level of interactivity which also adds to its overall complexity. Moreover, users expect to receive immediate results whenever they change any of input parameters. In such system, the main issue around implementing interactivity is in handling dependencies between related objects and keeping the states of these objects synchronized and continuously up-to-date. Building propagation system that will efficiently traverse dependency network, and update required objects is a challenging task, since a number of issues arise. Maier et al. [13] claim that contrary to traditional batch mode programs, "interactive applications require a considerable amount of engineering to deal with continuous user input and output".

There are several design patterns (first of them introduced by Gamma et al. [9]) that are designed for building interactive systems with propagation. They all share the common idea of *implicit invocation* and *asynchronous communication* between dependent objects. Implicit invocation, according to Avgeriou and Zdun [1] and Eugster et al. [7], offers several advantages (such as loose coupling, dynamic adding and removing of dependent entities and components during runtime etc.) over a point-to-point and synchronous communication which

leads to rigid and static applications. In their paper, Maier et al. [13] state Observer pattern to be predominant approach for managing state changes, while Szallies [18] discusses that the Observer pattern introduces an additional level of indirection and blurs state dependencies between objects, which increases flexibility but decreases the understandability and performance of the code.

In this paper we examined and compared design patterns suitable in solving the issues of event propagation and management of dependencies between objects in complex systems. Second section describes the methodology that was used in our research, in the third and fourth section we present and discuss the results respectively, while in final section we drew conclusions.

2. Methodology

In order to address the issues of event propagation and management of dependencies between objects, our intent was to compare existing, explicitly documented design patterns. The first step was to identify design patterns which are intended to deal with *propagation*, *events*, *reactive* and *interactive behavior*, and *implicit invocation*. We performed exhaustive search in several iterations on the following scientific databases: IEEE Xplore, Google Scholar, ACM Digital Library, SCOPUS. Initially, for defining search keywords well-known patterns such as Observer and Publish/Subscribe have been taken as a reference point, so an initial set of search keywords was as follows: *design pattern*, *subject*, *observer*, *event*, *publish*, *subscribe*. Since conducted search did not result in a desired number of patterns, other search iterations were performed. The set of keywords expanded in each iteration, so in the final iteration in addition to already mentioned keywords, it contained a significant number of other keywords (*propagation*, *event notification*, *reactive*, *interactive*, *dependency network*, *implicit invocation*, *inversion of control*, *state changes*), which we combined when constructing search queries.

Despite quite broad and thorough search, we managed to identify only 5 explicitly described design patterns/variants of design patterns: Observer Pattern (simple) [9], Observer Pattern (advanced) [9], Observer Pattern revisited [6], Event-notification pattern [16] and Propagator pattern [8].

Since our research is focused on design patterns in imperative object-oriented paradigm, we did limit our results to design patterns in this paradigm. That said we excluded the results from functional, declarative, aspect-oriented and reactive paradigms. Also the patterns focused on distributed environments (e.g. Publish/Subscribe [7], [1], Event Notifier [11], CORBA notification/event service) were excluded.

Table 1. Qualitative comparison criteria

Criteria		
General attributes	Intent	
	Also known as	
	Related patterns	
	Structure	
Event propagation related characteristics	Object roles: event emitter/receiver	Event granulation
	Dependency network location	Order of propagation
	Dependency network structure	Direction of propagation
	Response to event	Cut-off propagation
	Event data	Acyclic graph handling
	Coupling	Cyclic graph handling
	Subject and Observer relationship	Events composition and filtering

In order to qualitatively compare identified design patterns, we formed a set of 18 qualitative criteria as presented in Table 1. Among considered criteria the first four are proposed by Gamma et al. [9], and are traditionally used to describe design patterns. These will allow us to compare general ideas behind design patterns, to highlight structural differences between them, and to show if and how they relate to other design patterns. Other 14 criteria were chosen in order to differentiate design patterns according to characteristics closely related to the issues of event propagation. They aim to enhance overall understanding of the event propagation problem, and to differentiate design patterns according to their capabilities in this matter. The 14 criteria were carefully extracted from papers which described identified design patterns. Also, papers from aforementioned other paradigms (functional, declarative, reactive programming...) were taken into consideration when forming and justifying this set of criteria.

3. Results

Following the stated methodology, after obtaining the literature review results, the five design patterns and the papers in which they were initially presented were analyzed in detail. The data about these patterns has been extracted according to the set of previously identified comparison criteria and the results are presented in Table 2. Columns contain data regarding characteristics of particular design pattern, while rows present particular comparison characteristics across different design patterns.

Table 2. Results of qualitative comparison

	Observer pattern (Simple) [9]	Observer pattern (Advanced) [9]	Observer pattern revisited [6]	Event-notification pattern [16]	Propagator pattern [8]
Intent	Define a one-to-many dependency between objects so that when one object changes state, all its dependents are notified and updated automatically.			Manage update dependencies between objects by introducing an event notification mechanism.	Define a network of dependent objects so that when one object changes state, all direct and indirect dependents are updated.
Also known as	Dependents, Publish-subscribe	Dependents, Publish-subscribe	-	Implicit Invocation Mechanism	Cascaded Update
Related patterns	-	Mediator, Singleton	Mediator	Observer, Mediator	Composite, Observer, Mediator, Strategy
Structure	Subject and Observer	Subject, ChangeManager and Observer	Observable, ObserverManager, Observer	Observer, Subject, EventStub, StateChange.	Propagator object
Object roles: event emitter / receiver	Depends on implementation (Abstract class or interfaces)	Depends on implementation (Abstract class or interfaces)	Claimed. Both Subject and Observer are expressed as Java Type object.	Depends on implementation (Abstract class or interfaces)	Yes (Propagator)
Dependency network location	Distributed. Subscriptions contained in each Subject.	Centralized. Stored and managed by ChangeManager object.	Centralized. Stored and managed by ObserverManager.	Distributed. Stored in Subject's StateChange objects.	Distributed. Propagator object can contain lists of both predecessors and dependents.
Dependency network structure	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Response to event	Observer's update method.	Observer's update method.	-	One or more arbitrary methods in Observer, as EventStub objects.	Propagator's update method.
Event data	No additional data (Update method has no parameters)	Update method can contain parameters for defining Subject and aspects.	Parameters. Combines push and pull model.	Possible parameters that indicate Subject, event identification, changed data...	Update method can contain parameter indicating predecessor object.
Coupling	Subject and Observer are loosely coupled (to interfaces or abstract classes)	Subject and Observer are loosely coupled (to interfaces or abstract classes)	Decoupled. Observable and Observer are stored in ObserverManager	Subject and Observer decoupled by using EventStub and StateChange objects.	Propagators are loosely coupled (to abstract class).

			as instances of base Java Object.		
Subject and Observer relationship	One-to-many	One-to-many (SimpleChangeManager), Many-to-many (DAGChangeManager)	Many-to-many	Many-to-many	Many-to-many
Event granulation	One event per Subject, one update method per Observer.	Suggested use of aspects to achieve higher granulation.	One event per Observable, one update method per Observer.	Multiple events per Subject, multiple update methods per Observer.	One event per Propagator, one update method per Propagator.
Order of propagation	Depth-first	Depth-first	Depth-first	Depth-first	Depth-first
Direction of propagation	Forward	Forward	Forward	Forward	Forward/Backward
Cut-off propagation	Possible	Possible	Possible	Possible	Yes
Acyclic graph handling	No	Yes, topological sorting or breadth first order of propagation.	Claimed, by maintaining the list of visited objects.	No	Yes, topological sorting, smart propagation.
Cyclic graph handling	No	No	Claimed, by maintaining the list of visited objects.	No	Yes, topological sorting, smart propagation, graph marking.
Events composition and filtering	No	No	No	No	No

4. Discussion

4.1. Pattern Description and General Attributes

All examined patterns explicitly state their purpose as managing dependencies between objects, and therefore share the same intent and idea. They do however differ in various implementation and design aspects. The first three patterns can be considered variants of Observer pattern, while Event-notification and Propagator pattern evolved more or less independently and can be considered as separate patterns. However, Riehle mentions three variants of Observer pattern which include Propagator and Event-notification Pattern as well [15].

Mixture of names used to denote these patterns shows a mess in the nomenclature. A lot of design pattern names are used interchangeably to describe different design patterns or different terms. For example Riehle [16] states Event-notification pattern to be also known as Implicit invocation mechanism, which should rather be considered an architectural style than design pattern. Also, some design patterns had synonyms that are now deprecated.

Our focused patterns are implementing inversion of control mechanisms, which are according to Gasiunas et al. “essential for improving stability and reusability of software systems” [10]. They also state implicit invocation to be a major technique for inversion of control, which is again usually implemented by the Observer pattern. If we take a look at the structure of compared design patterns (see Fig. 1 to Fig. 5), we can see that they follow a general idea of Observer pattern. We can identify two basic roles: entities that emit events and entities that receive these events, and react to them. For a purpose of clarity in the following table we show terms denoting these roles in different patterns:

Table 3. Roles in design patterns

Pattern	Event emitter role	Event receiver role
Observer (Simple)	Subject	Observer
Observer (Advanced)	Subject	Observer
Observer revisited	Observable	Observer

Event-notifier	Subject	Observer
Propagator	Propagator	Propagator
<i>Other terms:</i>	<i>Publisher, Notifier, Broadcaster, Producer,</i>	<i>Subscriber, Reactor, Dependent, Listener, Consumer</i>

By looking at the structure of Simple Observer pattern (see Fig. 1) described by Gamma et al. [9], we can see that two above mentioned roles dominate. Subject represents an object which emits events (notifications) about its state changes, knows whom to notify about these changes, and provides an interface to attach and detach Observers. Observers are objects which are interested in state changes that occur in Subject. They have a responsibility to subscribe to Subject's events and react on them. To achieve higher level of decoupling the roles of Subject and Observer are in this pattern implemented as base classes, which are then inherited by ConcreteSubject and ConcreteObserver. Base class implementation is very common, but implementation with interfaces, composition or combination of these concepts is also possible.

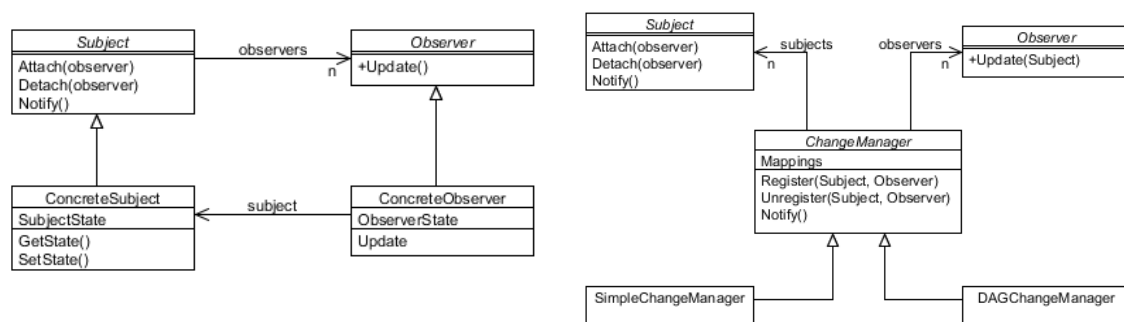


Fig. 1 Simple Observer Pattern [9]

Fig. 2 Advanced Observer Pattern [9]

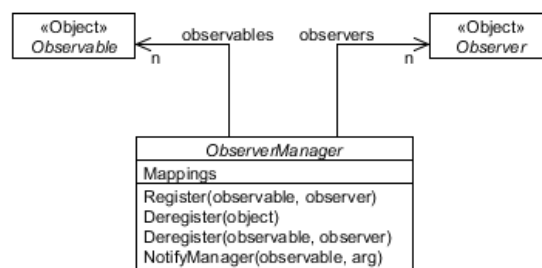


Fig. 3 Observer pattern revisited [6]

Gamma et al. were aware of the limitations of simple version of Observer pattern, so for complex use of this pattern they proposed some improvements and modifications (see Fig. 2). They introduced a third role in Observer pattern – change manager – a central object for managing dependencies between Subjects and Observers. Subject and Observer role are still existent, but this time dependencies between them are not kept in each Subject, but in one central place – hash table inside ChangeManager object. This allows a global management of dependencies and possibility to deliver optimizations and overall improvements by implementing propagation strategies.

In order to improve the Observer implementation, Eales [6] proposed ObserverManager – a central object for controlling a whole lifecycle of Observer-Observable relationships, ensuring no dangling references occur. Also, it manages update process, avoiding multiple redundant updates and cycles. Observer and Observable objects are expressed as Java base type Object.

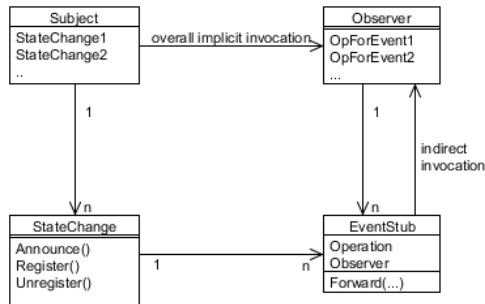


Fig. 4 Event notification pattern [16]

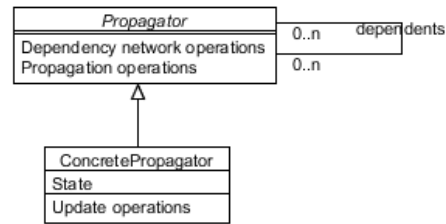


Fig. 5 Propagator pattern [8]

Explicit modeling of abstract state and dependencies, increased decoupling of Subject and Observer and selective registration possibility are some novel concepts that are presented in Event-notification pattern (see Fig. 4) [16]. Subject continues to have responsibility to manage its state, and to publicly expose state changes as StateChange objects. It is now the responsibility of these StateChange objects to register, unregister and notify interested Observers through EventStub objects about state changes. EventStubs are Observer's first class objects who know which operation of Observer should be called in case of StateChange invocation. This structure has some important consequences in addressing the issue of event granulation.

Propagator pattern described by Feiler and Tichy [8] actually represents a family of patterns, consisting of: Strict propagator, Strict propagator with failure, Lazy propagator, and Adaptive propagator. Different variants share common structure, but differ in propagation strategy. Feiler and Tichy [8] see interconnected objects in application as nodes in dependency network. To be a part of dependency network, an object must inherit Propagator class (see Fig. 5), which handles all dependency network related operations and propagation operations as well. Propagator class encompasses at the same time roles of Subject, Observer, and change manager, making the structure of Propagator pattern much simpler than the structure of Observer pattern. However, authors still leave the possibility to implement global change manager as a separate entity using Mediator pattern.

Other design patterns usually participate only in more complex implementations of here considered design patterns. Such is the case with implementations containing change manager role. According to Gamma et al. [9] by encapsulating complex semantics change manager acts as mediator between Subject and Observer, so here we can utilize Mediator pattern. Some authors also propose use of Singleton pattern in change manager implementation, to make it globally accessible and ensure existence of only one manager instance. Such claims are also supported by Eales [6], Riehle [16], Feiler and Tichy [8]. In addition to Mediator and Singleton pattern, according to [8], with Propagator pattern also Composite pattern and Strategy pattern can be associated.

4.2. Event Propagation Related Characteristics

The structure of dependency network consists of a number of objects that are interdependent, so it is a common situation for an object to depend on other objects, but also to influence other objects. Therefore, an object can at the same time encompass both: the **roles of event emitter and event receiver**. This is easily realized in Propagator pattern, since its Propagator role naturally encompasses roles of both event emitter and receiver. In other design patterns, these two roles are clearly separated as Subject (Observable) role and Observer role. However, by applying different implementation approaches, one can accomplish to merge these roles into one object. For example, in Observer revisited pattern as claimed, Observable and Observer objects are implemented as base Java objects, so they can play both roles at the same time. In other design patterns this could be accomplished by implementing at least one of the roles as class interfaces, since multiple-inheritance is rarely supported in modern OO

programming languages. We believe that in complex systems, where dependency networks are formed, it is not convenient to treat event emitter and receiver as separate roles, so a solution like in a Propagator pattern would be more appropriate.

The **location of dependency network** states where the subscriptions to events are located. Regarding to this we identified two types of dependency network: *distributed* and *centralized*. Distributed dependency network implies that subscriptions to events of particular event emitter are contained within that very emitter. On the other hand, centralized dependency network assumes that subscriptions to all events are held in central change manager object in some kind of hash table. This characteristic has some important implications regarding propagation performance and optimization. For example, centralized option with Change manager implementation is more advisable when dealing with complex and large dependency networks, because it keeps all dependencies between objects at one place, which makes it easier to create propagation strategies and apply optimizations. However, compared with distributed option, it additionally blurs dependencies between objects. Advanced variant of Observer pattern and Observer pattern revisited natively implement centralized dependency network, while other design patterns implement distributed option. However, the authors of Propagator pattern and Event-notification pattern also claim change manager implementation as possible.

In dependency network, dependencies between objects are created or destroyed dynamically (at runtime), so it is imperative for design pattern to support **dynamic structure of dependency network**. In patterns implementing the role of change manager this is usually done centrally in change manager itself, while in others it is responsibility of event emitter (e.g. Subject) to maintain a list of its receivers (e.g. Observer). However in both cases event receivers have the role to initiate the process of subscribing and unsubscribing from event.

Responding to event is the responsibility of event receiver, which appoints one of its methods to react to event. In all patterns except Event-notification pattern this is method is hardcoded in design (Update method), while in Event-notification pattern arbitrary method can be assigned to one or more of Subject's events. Hardcoding a method that will be responsible for reacting to event greatly reduces the flexibility, because we react to possible several different events with the same method. So, although it increases complexity of implementation, Event-notification pattern has the advantage in this case. However, instead of implementation with EventStubs and StateChange objects, one could preferably go with simpler implementations with delegates.

In order to appropriately react to event, receiver often needs to **retrieve additional data** from event emitter. Here we can differentiate two models: push model and pull model [5]. With push model, emitter sends additional data to receiver along with event notification. Receiver receives this data whether it needs it or not, usually as parameters of update method. On the other hand, with pull model receiver only receives event notification, and if additional data is required it is pulled from emitter by receiver. Both models have their own advantages and disadvantages, and the best model to choose depends on particular situation. A question of when to use parameterization of event notification (push model) and when not to (pull model), is also discussed by Riehle [15].

Loose coupling is generally recognized as a factor influencing quality characteristics of software (such as reusability and maintainability). Achieving loose coupling between interconnected objects and components is one of the reasons for utilizing Observer and related patterns. Here, this is done by employing principles of implicit invocation and coupling object on interface or abstract class level. For example, all that Subject needs to know about object it notifies is that it implements Observer interface. On the other hand, the relationship between Observer and Subject can be stronger, especially if Observer needs to pull some specific data from Subject. Although all compared design patterns by default help in achieving loose coupling between dependent objects, Event-notification pattern goes a bit further by introducing EventStub and StateChange objects as an additional level between event emitters and receivers, thus lowering coupling even more.

All focused patterns imply the ability of handling one-to-many **relationship** between event emitter (i.e. Subject) and event receivers (i.e. Observers). More complex scenarios often

require Observer to have the ability to listen more than one Subject, i.e. many-to-many relationship. Although it can be achieved in all considered patterns, this should be approached with caution. Having objects which depend on possibly many other objects, and at the same time influence multiple other objects can result in quite complex network of dependencies. If not properly handled propagation of events in such cases can lead to acyclic behavior, redundant updates and glitches. Gamma et al. [9] also suggest caution here, and suggest the use of their DAGChangeManager instead of SimpleChangeManager.

All considered patterns except of Event notification pattern support one event per Subject (**event granulation**), and one Update method per Observer. Event notification pattern [16] supports explicitly exposing more than one event per Subject through its StateChange objects. Similarly, through EventStub objects allows definition of more Update methods. Gamma et al. [9] also recognize this requirement, and they propose a workaround by using aspects to achieve higher granulation. In this case Subject and Observer still have only one event and one update method, but the user can specify an aspect in which it is interested. Although the original version of Propagator pattern does not support multiple events per object, Boeker [3] in his web article describes implementation of Propagator pattern as an alternative to Observer pattern, and improves it by introducing state change objects, similar to ones in Event notification pattern. Ability to offer several different events per object is a feature which increases flexibility. The examples of such objects with multiple available events can be found in most modern OO frameworks (e.g. Java and .NET frameworks).

An order in which the changes in dependency network are propagated (**order of propagation**) has a significant impact on performance and the correctness of propagation. Feiler and Tichy [8] identify two ways in which changes can propagate through dependency network: Depth-first and Breadth-first propagation. These are analog to well-known search algorithms which are thoroughly analyzed in the literature, for example in [4]. In Depth-first propagation method a changed node always notifies the first direct dependent, which then notifies its first direct dependent, and so on until leaf nodes are reached. Only then initially changed node notifies the second and the other direct dependents. Alternatively, in Breadth-first propagation, a changed node first notifies all direct dependents and only then passes to another level. Depth-first propagation is by default employed by all considered design patterns. However, this method can result in some significant issues such as redundant updates, poor performance, incorrect results, inconsistent data (also called *glitches* [2]). This can happen for example when a node has more than one predecessor, which is quite common situation in dependency networks. Therefore it is essential to appropriately address these issues. Feiler and Tichy [8] and Maier et al. [13] propose topological sorting of dependency network when implementing Depth-first method. Alternatively, implementation of Breadth-first propagation method is going to have the same effect as topological sorting.

Besides order of propagation a **direction of propagation** should also be considered. Feiler and Tichy [8] identify two types of propagation depending on direction: forward (immediate, eager) propagation and backward (on demand) propagation. They also propose different variants of Propagator pattern implementing these approaches: Strict Propagator and Lazy Propagator. Except for the Propagator pattern which supports both approaches, other considered design patterns employ only forward propagation.

In a large and complex dependency network propagation of changes can be quite computationally demanding, so wherever possible optimization steps should be applied. **Cut-off propagation** denotes a simple and obvious optimization step of comparing new value of object's state with current. If both current and the new state are the same, then we can stop (cut-off) the propagation. This optimization step is explicitly supported in Propagator pattern, referred as "smart propagation" [8] and "intelligent adjustment of states" [14]. As a means of implementing cut-off, Feiler and Tichy [8] involve the use of Memento pattern; however, contrary to complex Memento pattern, simple comparison between attribute's current value and the upcoming new value is often good enough. Although not explicitly stated, other considered design patterns can also easily implement this optimization, which we strongly encourage. This is a simple optimization step; however, in complex scenarios more sophisticated optimizations could be required, such as the possibilities to create smart and

adaptable propagation strategies. This poses a great challenge, since the structure of dependency networks is highly dynamic (object can be added or removed from dependency network at any time, the same is with relationships between objects).

Interdependent objects in dependency networks can often form acyclic or even cyclic graphs. Multiple redundant updates, “glices”, inconsistencies, infinite loops are some of the issues that indicate the existence of such circular graphs in one’s application. As already mentioned, it is essential to address these issues in order for dependency network to function properly.

Some of the authors recognized this problem, and included recommendations on how to avoid these issues in particular design patterns. Gamma et al. [9] recommended using DAGChangeManager implementation of Observer pattern (instead of Simple observer pattern and SimpleChangeManager implementation) when dealing with possible acyclic dependency network, aiming at prevention of multiple redundant updates. The order of propagation is crucial in avoiding inconsistent state which arises from acyclic nature of dependency network. Therefore proper measures should be assured, such as aforementioned topological sorting of dependency graph, or employing a Breadth-first method of propagation. Eales [6] claims his Observer pattern implementation avoids multiple updates and cycles by “viewing the update process as graph traversal which maintains a list of visited objects”, although no implementation specifics are provided. Feiler and Tichy [8] in their Propagator pattern propose topological sorting and “smart propagation” as a means of dealing with acyclic graphs. In contrast, Riehle [16] in his Event Notification Pattern doesn’t specify particular strategies to deal with acyclic graphs.

Furthermore, dependency network can contain **cyclic graphs**, which are causing infinite loops during propagation. To prevent this behavior, infinite loop must be manually stopped as soon as dependency network reaches consistent and correct state, and perhaps some additional specific condition is met. Determining a point is safe to be stopped is challenging, since we need to monitor a progress of propagation at all time, and be aware of all objects and dependencies involved in particular propagation instance. Eales [6] states his Observer pattern revisited avoids circular behavior by maintaining a list of visited objects, while Feiler and Tichy [8] propose topological sorting, “smart propagation” and graph marking when dealing with cyclic graphs.

In their original form, none of the examined design patterns supports **composition and filtering of events**. However, in complex environments, the abilities to compose new events from existing ones and to fire or react to events only under certain circumstances (filtering) would be highly desirable. Such features were already pointed out in declarative and reactive approaches ([13], [2], and [10]), and would also be useful in imperative programming.

4.3. Utilizing Design Patterns

Since none of the considered patterns possess all useful features, it is probable that features from different patterns will have to be combined in order to construct satisfactory solution. Therefore, as it can be seen in Table 4, we identified advanced features and we give guidelines for implementing them by using one or combining more design patterns.

Table 4. Guidelines for implementation of advanced features

Feature	Guidelines
Dynamic dependency network	All five patterns apply.
Object can both emit and receive events	See Propagator role in Propagator pattern [8], or consider implementing emitter/receiver as class interfaces.
Objects’ dependencies are held centrally	See implementation of ChangeManager [9] and ObserverManager [6].
Event can be handled by arbitrary method	See implementation of EventStub objects in [16].
Expose multiple events by the same emitter	See implementation of StateChange objects in [16].
Emitter send additional data to receiver	Push additional data to receiver as parameters, or let receiver pull required data from emitter. A combination is also possible.
Loosely coupled dependencies between objects	All five patterns apply. For additional level of decoupling see implementation of EventStub and StateChange objects in [16].

Receiver depends upon multiple emitters	All patterns except for simple Observer pattern apply. However, be sure to address the possible acyclic behavior.
Dependency network forms acyclic graph	Watch for the order of propagation. Be sure to apply breadth-first order of propagation, or a topological sorting of dependency network in case of depth-first order. See DAGChangeManager [9]
Dependency network forms cyclic graph	Apply advanced techniques such as graph marking (maintaining the list of visited objects), topological sorting, and “smart propagation” to break up the loop and avoid redundant updates.
Propagation performance optimization	Apply cut-off propagation step. Keep objects’ dependencies in one central location (hash map) by implementing change manager object. Also, make sure possible acyclic and cyclic behaviors are properly handled, so no redundant updates occur. For most complex scenarios consider developing “smart” and adaptable propagation strategies.
Composition and filtering of events	None of the considered patterns provides such capabilities, however some implementation guidelines and ideas can be taken from declarative and reactive approaches (e.g. [1], [15], and [11]).

The table summarizes the presented and discussed comparison results and gives guidelines on how to implement the features ranging from those supported by all five design patterns to those that require special attention in combination and update of compared patterns.

5. Conclusion

Conducted comparison showed a great similarity between considered design patterns, especially in their overall idea and intent. All design patterns assume the existence of event emitter and event receiver roles, either in separate or in a single object. In a number of considered criteria mentioned design patterns are quite uniform. Such is the case with the ability to dynamically change dependency network, order and direction of propagation, ability to cut-off propagation etc. However, significant differences can be seen in their structure, possibilities and implementations.

Simple Observer pattern is quite modest in its capabilities, and we find it not suited for handling complex propagation cases. Others do satisfy a number of criteria and employ some advanced features, which are common to more design patterns or unique to particular pattern. It appears however, that no design pattern has all desired features.

By comparing these design patterns we managed to recognize several features that should be considered when dealing with complex propagation scenarios: An object should be able to be both Subject and Observer at the same time; It should be possible to choose the appropriate level of event granulation (e.g. one or more events per object, one or more events per component); An object should be able to have zero or more observing objects, while at the same time being able to observe zero or more other objects; It should be possible to selectively register to only some of available events; To additionally decouple Subject and Observer, implementation of events as objects (possibly first-class objects) should be considered; Events should be able to pass certain data (parameters) to the listening object; Adaptable update strategies that allow consistent, non-redundant, fast and scalable update should exist; In a case where one strategy is not sufficient, multiple strategies should be able to coexist; Update strategies should be able to deal with acyclic and cyclic dependency graphs and provide a way to break update loop; Central mediator object (change manager) that manages dependencies between objects and update strategies should be considered; Composition and filtering of events should be considered; Possibility to adjust settings of update process, such as commencing update manually or automatically, updating dependency network partially or entirely; Possibility to perform updates utilizing multithreading options; and Possibility to properly handle update failure should be considered.

A number of individual features can be rather easily implemented and handled. However, building a system which will be characterized by the ability to update complex network of interdependent objects in a fast, flexible, consistent, and scalable manner is a much harder task with different emerging issues that are mentioned in the discussion part of the paper.

Resolving aforementioned issues presents a possibility to expand this topic and conduct further research, which should result in building adequate model and framework for events

propagation. Approaches covered in this paper are based on imperative programming paradigm, so a comparison with approaches developed in other paradigms would be valuable. This is especially the case with solutions presented in the area of reactive programming and reactive systems based on declarative/functional programming (e.g. [10], [17]), aspect-oriented programming (e.g. [12]) and hybrid approaches. Although omitted from this study, propagation of events in distributed environment brings even more challenges and also possibilities for future research.

References

1. Avgeriou, P., Zdun, U.: Architectural Patterns Revisited – A Pattern Language. In: Proceedings of 10th European Conference on Pattern Languages of Programs (EuroPlop 2005). , Irsee, Germany (2005)
2. Bainomugisha, E., Lombide Carreton, A., Van Cutsem, T., Mostinckx, S., De Meuter, W.: A Survey on Reactive Programming. *ACM Comput. Surv.* 45 (4), (2013)
3. Boeker, M.: Propagator in C# - An Alternative to the Observer Design Pattern, *CodeProject*, <http://www.codeproject.com/Articles/38108/Propagator-in-C-An-Alternative-to-the-Observer-Des>, Accessed: July 10, 2013, (2009)
4. Bratko, I.: Prolog Programming for Artificial Intelligence. Addison Wesley (2000)
5. Buschmann, F., Meunier, R., Rohnert, H., Sommerlad, P., Stal, M.: Pattern-oriented software architecture: System of patterns. John Wiley & Sons, Chichester (1996)
6. Eales, A.: The Observer Pattern Revisited. Presented at the Educating, Innovating & Transforming: Educators in IT, (2005)
7. Eugster, P.T., Felber, P.A., Guerraoui, R., Kermarrec, A.-M.: The Many Faces of Publish/Subscribe. *ACM Comput. Surv.* 35 (2), 114–131 (2003)
8. Feiler, P., Tichy, W.: Propagator: A family of patterns. In: Technology of Object-Oriented Languages and Systems. IEEE (1997)
9. Gamma, E., Helm, R., Johnson, R., Vlissides, J.: Design Patterns: Elements of Reusable Object-Oriented Software. Addison-Wesley (1995)
10. Gasiunas, V., Satabin, L., Mezini, M., Nunez, A., Noye, J.: Declarative Events for Object-Oriented Programming. Technische Hochschule, Darmstadt (2010)
11. Gupta, S., Hartkopf, J., Ramaswamy, S.: Event Notifier, a Pattern for Event Notification. *Java Rep.* 3 (7), (1998)
12. Jicheng, L., Hui, Y., Yabo, W.: A novel implementation of observer pattern by aspect based on Java annotation. In: Computer Science and Information Technology (ICCSIT), 2010 3rd IEEE International Conference on. pp. 284–288. IEEE, Chengdu (2010)
13. Maier, I., Rompf, T., Odersky, M.: Deprecating the observer pattern. Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland (2010)
14. Rege, K.: Design patterns for component-oriented software development. In: 25th Proceedings of EUROMICRO conference. pp. 220–228. IEEE Computer Society, Milan (1999)
15. Riehle, D.: Describing and composing patterns using role diagrams. Presented at the WOON, (1996)
16. Riehle, D.: The Event Notification Pattern - Integrating Implicit Invocation with Object-Oriented. Presented at the TAPOS 2.1, (1996)
17. Salvaneschi, G., Mezini, M.: Reactive Behavior in Object-oriented Applications: An Analysis and a Research Roadmap. Presented at the AOSD, Fukuoka, Japan (2013)
18. Szallies, C.: On Using the Observer Design Pattern. (1997)

Predicting the Changeability of Software Product Lines for Business Application

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Abstract

The changeability, a sub-characteristic of maintainability, refers to the level of effort which is required to do modifications to a software product line (SPL) application component. Assuming dependencies between SPL application components and reference architecture implementation (a platform), this paper empirically investigates the relationship between 7 design metrics and changeability of 46 server components of a product line for business applications. In addition, we investigated the usefulness of Platform Responsibility (PR) metric as an indicator of product line component changeability. The results show that most of the design metrics are strongly related to the changeability of server component and also indicate statistically significant correlation between Maintainability Index (MI) and PR metric. The assessment is based on a case study of the implementation of the product line for business applications in a financial institution. The results show that PR metric can be used as good predictor of changeability in the software product line environment.

Keywords: Software Product Lines, Changeability, Maintainability Index, Metrics, Reuse, Reference Architecture, Platform Responsibility.

1. Motivation

Software maintenance is the most expensive activity that consumes about 50 - 70 percent of development cost [22]. There were many attempts to find ways to minimize maintenance cost by introducing better development approaches that can minimize the costly effects of change, simplify understanding of source code, facilitate early detection of faults, etc. One of the most successful approaches is Software Product Lines (SPL) approach, a set of software-intensive systems that share a common, managed set of features satisfying the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way [12]. This approach and its techniques make a system better maintainable as stated in [15]: "The same design techniques that lead to good reuse also lead to extensibility and maintainability over time".

Business applications are traditionally developed as standalone systems, each having specific architecture. As opposed to traditional approaches that focus on one application, the product line approach means a fundamental shift of focus from the individual system to the product line, i.e. a set of applications that rely on a common product line platform. A software platform is a set of software subsystems and interfaces that form a common structure from which a set of derivative products can be efficiently developed and produced [26]. A common rule of thumb found in literature is that a product lines approach will pay off only after the development of the software product platform and an initial set of products in the family. The relevant literature also claims that there is a significant reduction in costs associated with managing the evolution of the products when a product line approach is followed [23]. Due to the fact that any change in the platform can be relatively easily propagated to all of the product line members, the advantages of using a platform-based approach are even more significant.

The level of effort needed to maintain a software product line is related to the technical quality of the source code. Many software metrics have been proposed as indicators for technical quality of source code [17], [39]. Oman *et al.* proposed the Maintainability Index [35], [13] which attempts to objectively determine the maintainability of software system based upon on the characteristics of the source code. In the ISO/IEC 9126 standard (replaced by ISO/IEC 25010:2011), maintainability is seen as one of the 6 main characteristics of software product quality. IEEE (1990) defines maintainability as “The ease with which a software system or component can be modified to correct faults, improve performance or other attributes, or adapt to a changed environment” [18]. The maintainability is further decomposed into the sub characteristics of analyzability, changeability, stability and testability [21]. Changeability characterizes the amount of effort to change a system (ISO/IEC 9126). In the context of software product lines, where many applications rely on a common platform, the technical quality of source code has its specifics comparing it with an ordinary system, since it is an important determinant for software product lines changeability. Changeability, the subject of this paper, is a key success factor in application areas such as business systems, in which applications are evolving at a rapid pace.

In [29] we have proposed Platform Responsibility (PR), a product line reference architecture coupling metric, to address the product component changeability prediction. In this paper, we further discuss the various issues arising when trying to assess the changeability of software product line components.

Object of the study. Object of this research study is the software product line server side application components and their changeability characteristics.

Purpose. The purpose of the study is to investigate the relationship between a number of design metrics and changeability of software product line components. Specifically, we would like to investigate metrics that can be used as good indicator of product line components changeability.

Perspective. This study targets two perspectives, one from the point of view of the researcher and the second of a developer, i.e. the researcher or developer would like to find out if there are any systematic differences in the changeability based on the design metrics of the individual product line component.

Quality focus. The main objective of this research is to determine whether there is a significant correlation between MI and PR metrics. In case there is a significant correlation between them, we will investigate the usefulness of PR metric as a predictor of product line components changeability, instead of using MI metric since it is too generic and yet not adapted to the product line environment specifics.

Context. The context of the experiment is a software product line for business applications in a financial institution. As a case for a survey we took 46 server side software components used by 9 different business applications within the product line.

2. Related Work

Changeability is related concept to maintainability and it is generally considered as its sub characteristic. Due to the fact that there are a number of different dimensions of maintainability, there exists a great deal of inconsistency in terminology. Matinlassi *et al.* proposed three maintainability abstraction levels; system, architecture and component [24]. The focus of our study is on component changeability, a sub characteristic of major importance for maintainability [32][8]. Several empirical studies have been carried out to investigate the maintainability of software product line artifacts [6], [9], [4], [24], [31] but a review of the literature fails to note significant research related to the changeability of SPL components in the context of external and internal dependencies.

There are different approaches used for the assessment of changeability. Most of them are based on change impact analysis and some of them are based on design metrics. We are using the latter approach.

Ingram and Riddle [20] used six metrics: LOC (lines of code), DIT (Depth of Inheritance Tree), WMC (Weighted Methods per Class), CBO (Coupling Between Objects) and

McCabe's Cyclomatic complexity to demonstrate a correlation between software size/complexity and change proneness. In their study change tendency was measured as the number of files changed for each revision. The result of the study suggests that classes with the highest CBO were the most likely to change.

Chaumon *et al.* used experiment which showed a high correlation, across systems and across changes, between changeability and the access to a class by other classes through method invocation or variable access. This relationship refers to the so called afferent coupling (Ca), the number of classes in other packages that depend upon classes within the package. The more a class is used through invocation of its methods and outside references to its variables, the larger the impact of a change to such a class. On the other hand, no result could support the hypothesis that the depth of the inheritance tree has some influence on changeability [3].

Wilkie and Kitchenham [37] tested the usefulness of the CBO (Coupling Between Objects) metric in predicting the classes that are likely to be affected by a change. Their object of study was a multimedia conferencing system which consists of 25.000 lines of code. The metrics used in their study were: CBO, WMC (weighted methods per class) and number of functions per class. The research results show that the CBO metric is useful in identifying the most change prone classes. Also the same metric does not identify the classes likely to experience ripple effect changes.

Aldekoa [17] extended the Maintainability Index where the maintainability index of each features is measured. The metric is based on the average of the McCabe's Cyclomatic Complexity value [25] which directly measures the number of linearly independent paths through a program's source code.

Tizzei *et al.* [31] tested positive and negative change impact of component and aspect based design on Product Line Architecture (PLA) stability. They concluded that the combination of aspects and components supports the design of high cohesive and loosely coupled PLAs and improve modularity.

In our study, we focus on the changeability assessment based on the product line component dependencies. The dependency may exist between product line components and internally owned (e.g. SPL platform) or externally owned (e.g. Spring) components. We presume that changeability of a component is better and more under control of internal development when the number of external dependencies that exist for a component is lower. This assumption is along the lines of the recommendations of good modular design, which seeks to achieve a high degree of internal cohesion, and the less external communication (coupling).

These external and internal dependencies among components and between components and the product line platform can serve to assess the impact of change as changes can propagate from one component to other components through the dependencies.

3. Experimental Design

Here, we provide some background on the product line for business application investigated in this study, describe goals, hypotheses, dependent and independent variables.

3.1. System Investigated

The source of data we have collected for this study was a product line for business applications in a financial institution. The data we have collected include two versions of the 9 applications and its corresponding server components. First version included 43 server components, while the second version included 46 components, having 3 additional components added to the product line. The selection of the product line was influenced by its technical complexity and the fact that the author has been involved in its development. The product line is a Java-based group of 9 applications based on the shared platform. It is a closed-source system built with several external components which include: Apache POI, which is used for reading and writing Microsoft Office files, iText for reading and writing

PDF files, Apache Shiro for user authentication with Active Directory, Apache uploads, for uploading files to a server, Aktiviti for process engine and Jasperreports used for the generation of business reports.

To study the product line component changeability, the maintenance data were limited to the Java source code which was collected from Subversion Edge source code repository [14]. Maintenance tasks carried out on non-java application artifacts were out of the scope of this study.

3.2. Goals, Variables and Hypotheses

The main goal of this study is to determine the design metrics that can be used as good indicators of product lines component changeability. In order to determine that, we collected historical maintenance data from a product line for business applications. The objective of this study is to determine the differences in changeability for software product lines components using the product line platform as a base. Motivation for this study is a need to understand the differences in changeability among components within the product line. One objective of introducing software product line is to provide the environment for better changeability. In order to support the better changeability, it is important to understand what differences can be expected within the product line, and explain them in order to improve the product line changeability.

3.3. Dependent Variables

In this paper, Platform Responsibility (PR) [29] and Maintainability Index (MI) [35] are both used as the dependent variables to quantify product line components changeability. Our goal here is to show that both, PR and MI measure the changeability of components, but from different perspectives. The objective of the research is to verify the hypothesis that PR is more suitable dependent variable for studying the relationship between design metric and component changeability in software product line environment.

Figure 1 shows the elements the PR metric is calculated from. When introduced at [29], PR metric is analyzed within the Distance framework of measurement theory [28] and framework based on desirable properties which serves guidance provided to define proper measures for specific problem [10]. These frameworks ensure that the metrics developed using these guidelines are tested to be valid and that they can be used as measurement instruments [29].

PR is a combination of three coupling metrics: D3 - number of distinct references outside the platform that depend upon classes within the platform, D4 - the number of distinct references inside the component that depend upon classes within environment (e.g. Java RTE), D5 - number of distinct references inside the component that depend upon classes within external components. It measures the “level of responsibility” of a reference architecture implementation (a platform) to communicate to the external components needed by application component in order to provide business logic to an application. The more the component delegates a communication to the external components the more it is protected from frequent changes to the external third party components. The three coupling metrics are combined and used to calculate the PR value, stated by equation 1.

$$PR = \left(1 - \frac{D4 + D5}{D3 + D4 + D5}\right) * 100 \quad (1)$$

The range for this metric is from 0 to 100. The larger the PR, the more maintainable is the product line component. Components with a PR less than 50 are more difficult to maintain than components with PR between 50 and 100 which have reasonable maintainability.

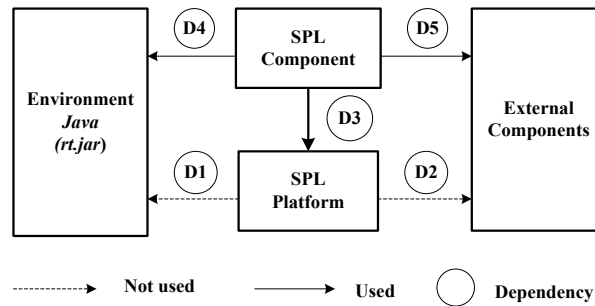


Fig. 1. Platform Responsibility Metrics [29]

MI, our second dependent variable, is a combination of widely-used and commonly-available measures [4, 27, 30, 35, 36, 38]. MI is a complex calculation involving a number of different metrics: Cumulative Halstead Effort of all the parts of a class, Number of methods in class, Total Cyclomatic Complexity of all the methods in the class, Total Number of Java Statements in class [34]. The metrics are combined into parts and then used to calculate the MI value, stated by equation 2.

$$\mathit{EffortPart} = 3.42 * \log(\mathit{HEFF}/\mathit{NOMT})$$

$$\mathit{CyclomaticPart} = 0.23 * \log(\mathit{TCC}/\mathit{NOMT})$$

$$\mathit{LinesPart} = 16.2 * \log(\mathit{NOS}/\mathit{NOMT})$$

$$\mathit{MI} = 171 - \mathit{effortPart} - \mathit{cyclomaticPart} - \mathit{linesPart} \quad (2)$$

The larger the MI, the more maintainable is the product line component. Components with a MI less than 65 are difficult to maintain, components between 65 and 85 have reasonable maintainability and those with MI above 85 have excellent maintainability. Since MI measurement is not a trivial task, we used JHawk 5.1 tool to measure MI for each product line component.

3.4. Independent Variables

The selection of the independent variables includes 7 object oriented design metrics of size, complexity, coupling and inheritance. The definition of those object oriented design metrics is given in Table 1. The metrics selection is based on the previous research results which have indicated that ACC, ADIT, AMC, and AWMC have statistically significant effects on maintainability [38]. The selection is based on the metrics selection criteria, a set of criteria for choosing suitable metric set [1]. Also, the metric selection is based on distinct metrics characteristics which we have identified and used to omit the metrics which measure the same thing. Finally the metrics selection was limited by available tools we could have used for this case study. The goal of our metrics selection criteria was to avoid measuring too much or measuring too little and not gaining sufficient insight into the desired objective. These metrics are commonly used and have been validated [7].

Table 1. Definition of design metrics

Metric	Description
ABD	Average block depth
ACC	Average cyclomatic complexity
ADIT	Average depth of inheritance hierarchy
AMC	Average number of methods per class
ALCM	Average lines of code per method
AWMC	Average weighted methods per class
NMETH	Number of methods

Some metrics such as CC, DIT, MC, LCM, and WMC are originally defined at the class level. However, this study is performed at the product line component level. Therefore, those metrics may not be directly used as independent variables. In order to use them in this study, for each such metric, its mean among classes is calculated and used as an independent variable. Naming of those metrics is prefixed by an “A”, for example, the average CC metric is named ACC, when used at the component rather than at the class level.

3.5. Hypotheses

The hypotheses that relate metrics to product line components maintainability are listed and described in Table 2. The relationship column (+/-) indicates the direction of correlation between each metric and changeability (PR), where “+” means positive and “-“ means negative correlation. Different authors have measured correlation between source code metrics and maintainability [2, 16, 38]. To date various methods have been developed and introduced to measure maintainability, however, there are a software product lines specifics, since they heavily rely on the platform used by its components. It will be addressed by this study. This experiment introduces a new relation measurement, the correlation between PR and MI metrics, since they potentially measure the same thing, but from different perspective, one (MI) from a generic perspective, the other (PR) from the product line specific perspective.

Table 2. The hypotheses

Metric	+/-	Description
MI	+	Measure the same thing as PR
ABD	-	Component become more complex
ACC	-	Component become more complex
ADIT	-	Component coupling increases
AMC	-	Component become more complex
ALCM	-	Component become more complex
AWMC	-	Control flows are more complex
NMETH	-	Number of faults and difficulty increases

4. Execution

The experiment was based on data (Java source code) collected through the two major releases of the product line in a financial institution. To ensure the data validity, the Java source code metrics of collected data are measured twice, once using CodePro Analytix™, tool [19], and again with JHawk tool [33], but just for the metrics which could be measured by both of the tools. These tools measure and report on key quality indicators in a body of Java source code. In cases the results from the tools were different, we used JHawk results as representative, since the JHawk tool was also used to measure the MI metrics which depends on some of the other measured metrics.

4.1. Sample

The product line reference architecture implementation (platform) together with 9 applications has all together 161.376 lines of Java source code without comments (LOC). The rest of the source code has been written by using Transact-SQL, XML, HTML, CSS, Java Script languages. In this study we analyze the Java source code used by server side business application components, consisting of 33.139 LOC, and of 27.252 Java statements (NOS).

Table 3 provides a summary of the maintenance tasks and the impacts on the product line components between the two releases of the product line applications.

Table 3. The component changes and their impact

Maintenance type	Components affected	Classes affected	LOC affected
Add	35	68	7314
Change	33	61	101
Delete	11	0	87

The results from the table show that most of these maintenance tasks were addition of the new functionalities.

5. Analysis

In this study we focus on investigating the capability of Platform Responsibility (PR) metric to serve as indicator of application component changeability. As indicated earlier in Section 2 (**related work**) and in [11], [5], many studies have already investigated the OO and coupling (Ca, Ce) metrics for this purpose, however, the metrics to measure coupling between product line application components and their reference architecture implementation (platform) has not been used as a predictor of product components changeability.

5.1. Descriptive Statistics

Table 4 shows the descriptive statistics for two accumulated versions of the server business components. The selection of these metrics is based on the fact that they measure different structural properties of a component: size, coupling, complexity, and inheritance, and since they refine classical object-oriented (Chidamber and Kemerer metrics) [3], which are well established and based on sound measurement theory.

Column "Skewness" is a measure of the asymmetry that shows whether the data distribution is skewed. Column "Kurtosis" is a measure of the "peakedness" that shows whether the data are peaked or flat relative to a normal distribution.

The low mean for NMETH and AWMC indicate that there are a small number of components which are having very high number of methods. Their distribution and the distribution of AMC metrics show high variations across the product line, which may reflect the lack of development experience of the programmers involved in those components. Figures 2 and 3 show the PR and MI metric frequency distribution. Both of the metrics distributions form a symmetrical, bell-shaped pattern, which approximates a normal distribution of the data. Second, the mean, mod and median for both metrics are equal and are located at the center of the distribution. Third, most of the values are clustered around the center of the distribution.

Table 4. Descriptive statistics of the server components

Metric	Minimum value	Maximum value	Mean value	Standard deviation	Skewness	Kurtosis
PR	46.87	85.71	59.95	6.88	1.17	2.79
MI	88.42	119.01	101.95	5.82	0.58	0.62
ABD	1.11	1.7	1.41	0.12	-0.38	-0.58
ACC	1.19	2.47	1.63	0.27	0.89	0.71
ADIT	3	6.29	4.29	0.78	0.54	-0.16
AMC	2.4	22.8	7.75	4.19	1.70	3.18
ALCM	6	20.44	12.26	3.24	0.06	-0.29
AWMC	3.8	44.2	12.86	7.68	1.99	4.79
NMETH	6	255	45.09	48.26	2.45	7.17

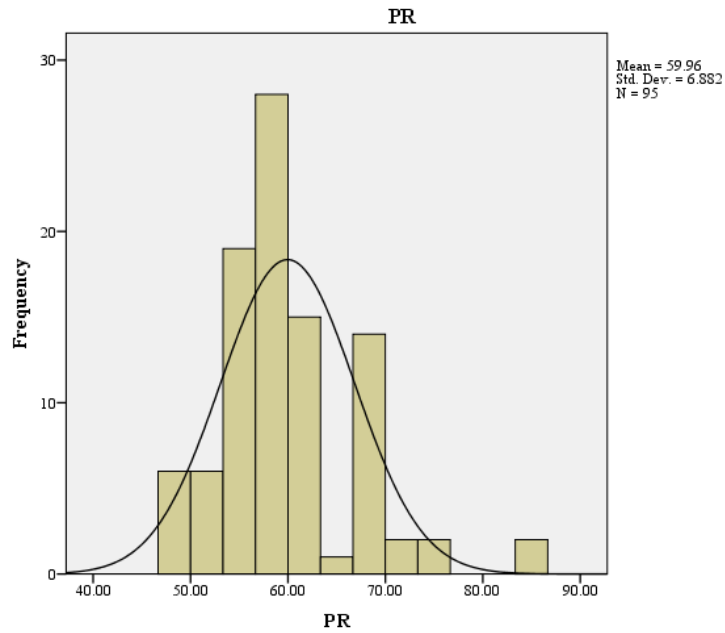


Fig. 2. PR metric histogram

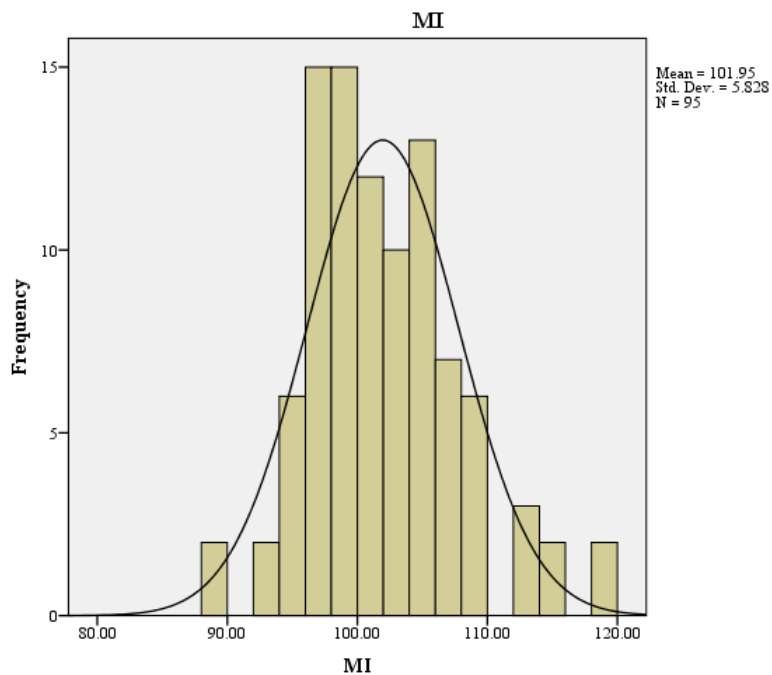


Fig. 3. MI metric histogram

Figure 4, the scatterplot, shows the relationship between PR and MI variables. The scatterplot shows an upward trend, a positive correlation, in which a direct relationship exists between PR and MI variables. That means that an increase in PR is related to an increase in MI, and a decrease in PR is related to decrease in MI. The figure also shows that the homoscedasticity assumption is met, because the variability of the PR variable, pretty much remains relatively constant from one MI value to the next. The two outliers (PR=86, MI=118 and PR=86, MI=119) shown at the upper right corner at figure 4, are due to the rare event of components

which interface is designed but their business logic was never implemented. This components are candidates to be dropped from the product line and could be excluded from the analysis.

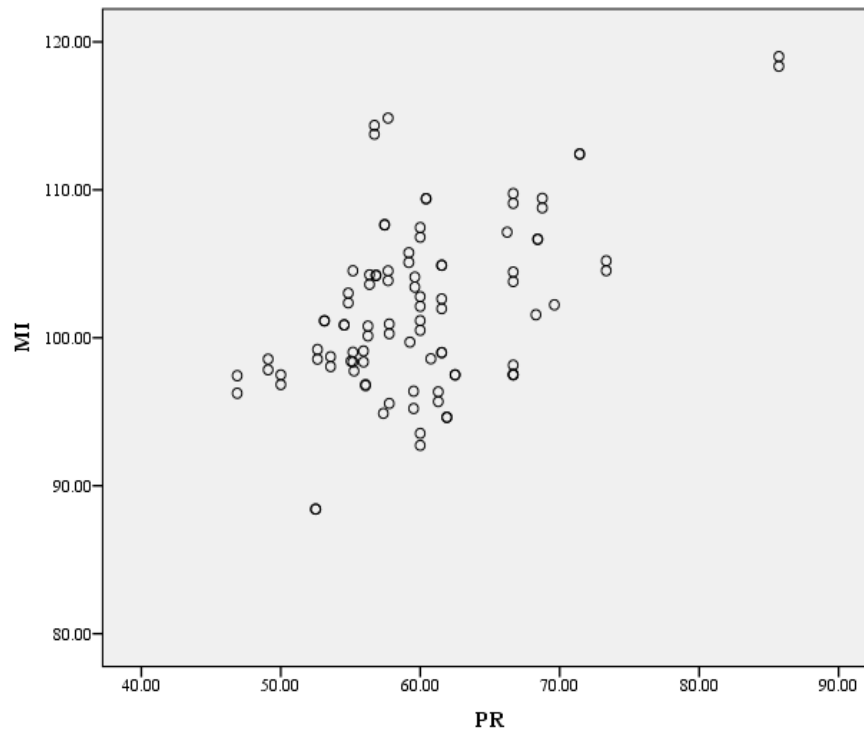


Fig. 4. MI and PR metric data distribution

5.2. Hypotheses Testing

Correlation technique was used to analyze the relationship between design metrics and both PR and MI metrics, and also between MI and PR metrics them self. Since our goal was to prove that PR metric can be used as a changeability predictor, we needed to find out if there is a positive correlation between MI, widely-used measure, and PR, newly proposed measure. The significance of the correlation was tested at 99% confidence level (i.e. $p\text{-level} \leq 0.01$) and at 95% confidence level (i.e. $p\text{-level} \leq 0.05$). The results obtained by applying this analysis are given in table 5 and 6, where ** and * values indicate statistically significant correlations.

Among the 7 design metrics used in this study, all were found to have significantly correlated negative effect on changeability (PR). ALCM (Average Lines of Code per Method) shows the highest negative correlation followed by ACC and AWMC. It is most probably the result of tendency that class methods with more lines of code than average, are using more of the external components than average methods, which makes the component less changeable. Therefore, the hypotheses related to those metrics are supported.

Table 6 shows the correlations between design metrics and MI, where only 3 metrics (ABD, ACC, and ALCM) were found to have statistically significant negative effect on maintainability (MI). ALCM (average lines of code per method) shows the highest negative correlation followed by ABD and ACC.

The correlation between Maintenance Index (MI) and Platform Responsibility (PR) is moderate, $r = 0.526^{**}$ which we consider strong in the context of the software product lines environment. The correlation indicates that PR can be used for the same purpose as MI in

case we are predicting product line component changeability. Therefore, as the values of these metrics increase, the changeability of the components and hence the product line decreases.

Table 5. PR and metrics correlations

Metric	Pearson correlation coefficient (r)
ABD	-.296**
ACC	-.353**
ADIT	-.304**
AMC	-.313**
ALCM	-.477**
AWMC	-.374**
NMETH	-.277**

** . Correlation is significant at the .01 level (2-tailed)

Table 6. MI and metrics correlations

Metric	Pearson correlation coefficient (r)
ABD	-.777**
ACC	-.751**
ADIT	.016
AMC	-.050
ALCM	-.941**
AWMC	-.239*
NMETH	-.072

** . Correlation is significant at the .01 level (2-tailed)

* . Correlation is significant at the .05 level (2-tailed)

6. Interpretation

The data analysis is interpreted with respect to the hypotheses stated in section 3.5. All hypotheses are tested using Pearson correlation. It can be concluded that there are significant differences among the components, depending on their design metrics characteristics. This is true for all the hypotheses. Furthermore, there is significant correlation between MI and PR metrics, and thus the exceptional usage of PR instead of MI in software product line environment can be suggested.

A strong relation between import coupling metrics (efferent) and maintainability characteristics has been reported by Dagginar *et al.* [16]. Import coupling considers interactions of the class or component that is using the functionality of other classes or the component.

The results of this study, where we used the PR dependency metrics, also measure the import coupling for server component which is using the functionality of the platform (D3), environment (D4) and external components (D5). The results are consistent with those of other study and suggest that changeability of product line components depends on source code design characteristics.

There are limits of this study to generalize the results of our experiment to industrial practice. The specific business environment, programming language, developers experience and technical environment are not representative of the population we want to generalize to, but the threats are reduced by making the experimental environment as realistic as possible.

7. Conclusion and Future Work

In this paper we have investigated the relationships between 7 design metrics and software product line component changeability, a sub-characteristic of maintainability, based on a software product line implementation in a financial institution. The metrics used here, measure coupling, size, inheritance and complexity of a product line components used by the 9 applications from the product line. The Maintainability Index (MI) was used as the dependent variable together with recently proposed Platform Responsibility (PR) metric. Our goal was to find out if PR metric can be used instead of the MI metric in case the study is carried over within software product line environment. Pearson correlation analysis results indicate a statistically significant correlation between PR and MI metrics, and also between most of the individual metrics and component changeability represented by those metrics. We have also found the ability of the design metrics to predict components changeability, when design metrics are used together. The results of this research support the idea to use the PR metric as predictor of changeability in the software product line environment. The correlation between MI and PR is interesting because it is much easier to measure PR than MI metric. This indicates that PR metric may be used more often in the future as a predictor for product line component changeability. The major limitation of this study was the sample size and the specific technical environment which was used to develop the product line in a financial institution. This study contributes preliminary and novel empirical knowledge about the relationships between some design metrics and product line components changeability. In the future work we will employ classical linear regression to investigate the relationship between design metrics and changeability of software product line components. Also, the future work will include the analysis of influences of individual design metrics.

References

1. Abreu, F.B., Carapu\cca, R.: Object-oriented software engineering: Measuring and controlling the development process. In: proceedings of the 4th International Conference on Software Quality. (1994)
2. Aggarwal, K.K., Singh, Y., Chhabra, J.K.: An integrated measure of software maintainability. In: Reliability and maintainability symposium, 2002. Proceedings. Annual. pp. 235–241. IEEE (2002)
3. Ajrnal Chaumon, M., Kabaili, H., Keller, R.K., Lustman, F., Saint-Denis, G.: Design properties and object-oriented software changeability. In: Software Maintenance and Reengineering, 2000. Proceedings of the Fourth European. pp. 45–54. IEEE (2000)
4. Aldekoa, G., Trujillo, S., Mendieta, G.S., Diaz, O.: Experience Measuring Maintainability in Software Product Lines. In: JISBD. pp. 173–182. Citeseer (2006)
5. Ayalew, Y., Mguni, K.: An Assessment of Changeability of Open Source Software. *Comput. Inf. Sci.* 6 (3), p68 (2013)
6. Bagheri, E., Gasevic, D.: Assessing the maintainability of software product line feature models using structural metrics. *Softw. Qual. J.* 19 (3), 579–612 (2011)
7. Belsley, D.A., Kuh, E., Welsch, R.E.: Regression diagnostics: Identifying influential data and sources of collinearity. John Wiley & Sons (2005)
8. Bengtsson, P., Bosch, J.: Architecture level prediction of software maintenance. In: Software Maintenance and Reengineering, 1999. Proceedings of the Third European Conference on. pp. 139–147. (1999)
9. Briand, L.C., Bunse, C., Daly, J.W.: A controlled experiment for evaluating quality guidelines on the maintainability of object-oriented designs. *Softw. Eng. IEEE Trans. On.* 27 (6), 513–530 (2001)
10. Briand, L.C., Morasca, S., Basili, V.R.: Property-based software engineering measurement. *Softw. Eng. IEEE Trans. On.* 22 (1), 68–86 (1996)
11. Burrows, R., Garcia, A., Taïani, F.: Coupling metrics for aspect-oriented programming: A systematic review of maintainability studies. In: Evaluation of Novel Approaches to Software Engineering. pp. 277–290. Springer (2010)

12. Clements, P., Northrop, L.: *Software product lines: Practices and Patterns*. Addison-Wesley Boston (2002)
13. Coleman, D., Ash, D., Lowther, B., Oman, P.: Using metrics to evaluate software system maintainability. *Computer*. 27 (8), 44–49 (1994)
14. CollabNet: Subversion Edge, Release: 1.3.0.
15. Coplien, J., Hoffman, D., Weiss, D.: Commonality and variability in software engineering. *Softw. IEEE*. 15 (6), 37–45 (1998)
16. Dagpinar, M., Jahnke, J.H.: Predicting maintainability with object-oriented metrics—an empirical comparison. In: *Proceedings of the 10th Working Conference on Reverse Engineering (WCRE)*. pp. 155–164. (2003)
17. Fenton, N.E., Pfleeger, S.L.: *Software metrics: a rigorous and practical approach*. PWS Publishing Co. (1998)
18. Geraci, A., Katki, F., McMonegal, L., Meyer, B., Lane, J., Wilson, P., Radatz, J., Yee, M., Porteous, H., Springsteel, F.: *IEEE standard computer dictionary: Compilation of IEEE standard computer glossaries*. IEEE Press (1991)
19. Google, Inc: CodePro Analytix. Google, Inc (2011)
20. Ingram, C., Riddle, S.: Linking software design metrics to component change-proneness. In: *Proceedings of the 2nd International Workshop on Emerging Trends in Software Metrics*. pp. 31–37. ACM (2011)
21. International Organization for Standardization: ISO/IEC 9126-1: *Software engineering - product quality - part 1: Quality model*, (2001)
22. Jalote, P.: *A Concise Introduction to Software Engineering*. Springer (2008)
23. Kang, K.C., Sugumaran, V., Park, S.: *Applied software product line engineering*. CRC press (2009)
24. Mari, M., Eila, N.: The impact of maintainability on component-based software systems. In: *Euromicro Conference, 2003. Proceedings. 29th.* pp. 25–32. IEEE (2003)
25. McCabe, T.J.: A complexity measure. *Softw. Eng. IEEE Trans. On*. (4), 308–320 (1976)
26. Meyer, M.H.: *The power of product platforms*. Simon and Schuster (1997)
27. Misra, S.C.: Modeling design/coding factors that drive maintainability of software systems. *Softw. Qual. J.* 13 (3), 297–320 (2005)
28. Poels, G., Dedene, G.: DISTANCE: A framework for software measure construction. *DTEW Res. Rep.* 9937. 1–47 (1999)
29. Rosko, Z.: *Assesing the Responsibility of Software Product Line Platform Framework for Business Applications*. Presented at the CECIIS-2013, (2013)
30. Schach, S.R., Jin, B., Wright, D.R., Heller, G.Z., Offutt, A.J.: Maintainability of the Linux kernel. *IEE Proc.-Softw.* 149 (1), 18–23 (2002)
31. Tizzei, L.P., Dias, M., Rubira, C.M., Garcia, A., Lee, J.: Components meet aspects: Assessing design stability of a software product line. *Inf. Softw. Technol.* 53 (2), 121–136 (2011)
32. Vigder, M.: The evolution, maintenance, and management of component-based systems. *Compon.-Based Softw. Eng. Putt. Pieces Together*. 527–539 (2001)
33. *Virtual Machinery: JHawk*. (2013)
34. *Virtual Machinery: JHawk 5.1 Documentation-Metrics Guide*, (2012)
35. Welker, K.D., Oman, P.W.: Software maintainability metrics models in practice. *Crosstalk J. Def. Softw. Eng.* 8 (11), 19–23 (1995)
36. Welker, K.D., Oman, P.W., Atkinson, G.G.: Development and application of an automated source code maintainability index. *J. Softw. Maint. Res. Pract.* 9 (3), 127–159 (1997)
37. Wilkie, F.G., Kitchenham, B.A.: Coupling measures and change ripples in C++ application software. *J. Syst. Softw.* 52 (2), 157–164 (2000)
38. Zhou, Y., Xu, B.: Predicting the maintainability of open source software using design metrics. *Wuhan Univ. J. Nat. Sci.* 13 (1), 14–20 (2008)
39. Zuse, H.: *A framework of software measurement*. Walter de Gruyter (1998)

A Multimodel Approach for Specifying the Requirements Variability on Software Product Lines

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Abstract

Requirements engineering is a key activity on any software development project. In Software Product Line development, this activity is even more important since requirements may encompass commonality and variability. Furthermore, a requirement specification usually is composed by more than one model. In this context it is necessary to specify the requirements variability in the different models of a Software Product Line requirements specification. In order to solve this issue, this paper proposes a multimodel approach for specifying the requirements for the products of a Software Product Line. This multimodel is used in a model-driven development process in order to obtain the requirements of a single product by applying model transformations. This solution increases the flexibility allowing developers to add more views depending on the domain and to obtain the product requirements by using model-transformations, whereas improves the productivity. The feasibility of the approach is illustrated through a running example.

Keywords: Requirements Engineering, Software Product Line Engineering, Model-Driven Development, Domain Engineering, Application Engineering.

1. Introduction

Software Product Lines (SPL) development is a paradigm to produce a family of software products based on an intensive reuse strategy. The SPL development is usually divided in two main processes: the domain engineering and the application engineering. At the *domain engineering* a set of core assets is built. At the *application engineering* these core assets are used to produce the specific products.

The Requirements Engineering (RE) at SPL development needs to cope with common, variable, and product-specific requirements not only for a single product but for the whole set of products. On these products, many requirements will be common across the product line, and many of them will be optional. Requirements common across the SPL are written with variation points that can be filled in or exercised to create product-specific requirements [4]. In this context, the problem of dealing with these variation points across the requirements specification is a topic of interest in the SPL development.

The Model-Driven Development (MDD) is a paradigm where the models are the first class citizens of the software development process. MDD is based on an intensive reuse

strategy by using model transformation among models at different abstraction levels. The MDD approach helps to establish in the traceability among different models. Furthermore, the transformations among models help to increase productivity. In order to create software product lines by applying MDD, product variability has to be represented on every modelling level and preserved under model refinement [18].

In a previous work we presented Feature-Driven Requirements Engineering approach (FeDRE) [14], which provides support to the requirements specification of SPLs. In this paper, we integrate FeDRE in a multimodel infrastructure in order to establish the relationships among the functional requirements viewpoint with the variability viewpoint, and to obtain the requirements of the product under development by applying model transformations. The contributions of this paper are twofold: i) The extension of FeDRE in order to provide support to the specification of requirements variability in multiple models at the domain engineering stage by applying model-driven engineering principles; ii) the integration the Common Variability Language (CVL) [15] in the multimodel in order to obtain the product requirements from the domain requirements by applying model transformations at the application engineering stage.

This paper is structured as follows: Section 2 discusses several proposals which deal with the specification of requirements variability on SPL. Section 3 presents the multimodel for representing the requirements variability of a family of products. Section 4 presents the proposed process to define and specify the requirements of a SPL which permits the automatic derivation of the product requirements. Section 4 shows an example to illustrate the feasibility of the approach. Finally on Section 5 draws the conclusions and further work.

2. Related Work

Several approaches deal with the requirements specification, and its variability in SPL development. On the one hand, some proposals are focused on how to enrich requirement models to deal with the variability (e.g. [6]). On the other hand, some proposals use technics to compose the requirements with the variability (e.g. [1], [3], [10]) with different purposes.

The approach presented in [6] proposes the creation of relationships between elements in the activity diagrams and the corresponding features by using annotations and presence conditions, which are used to indicate the existence of model elements depending of the feature configuration. In FeDRE we express the variability in a different model in order to avoid polluting the functional requirements specification with variability information.

Another solution is to use a compositional strategy (e.g., Modeling Language for Requirements (VML4RE)). VML4RE [1] presents two main contributions. First, the VML4RE language is a Domain Specific Language (DSL) able to compose requirements with feature models; and second, a requirements process that uses: i) a feature model to perform the variability identification; ii) use cases and activity diagrams to describe the SPL domain requirements; and a iii) a VML4RE model to relate the feature model with the requirement models. FeDRE uses the CVL language for describing the requirements variability and for obtaining the product requirements, instead a specific DSL for each problem as VML4RE does. Another compositional strategy is applied on the Modeling Scenario Variability as Crosscutting Mechanisms (MSVCM) [3] approach, which is focused on obtaining the product requirements by means of the following artifacts: use case model, feature model, product configuration, and configuration knowledge. These artifacts are taken as input in the weaving process which composes the product specific use case model. MSVCM describe the scenarios by means of textual templates, whereas in FeDRE we specify the use cases by means of activity diagrams. Another compositional proposal is applied on Goknil et al. [10] where a multimodel approach is defined for reasoning about requirements and their relations. The process that guides the requirements specification is not covered like in FeDRE. Moreover, this latter approach does not provide automation for obtaining the product requirements.

As conclusion, we analyzed several proposals that cover the specification of requirements. Annotative proposals (e.g. Model Templates [6]) has the disadvantage of polluting the functional specifications with variability information. In FeDRE we consider to

have two models of variability: external and internal; which are related among them in the multimodel. Finally, other proposals that used compositional techniques (e.g. [1], [3], [10]), do not provide guidelines to obtain the requirements from the feature model; oppositely, in FeDRE we bring a solution to guide how to specify the requirements and its variability, taking as input the feature model, and we are able to obtain the product requirements automatically.

3. A Multimodel for Modelling Requirements Variability SPLs

In this Section we provide an overview of the multimodel for representing the requirements of the products that comprise the SPL. A multimodel is a set of interrelated models that represents the different viewpoints of a particular system and the relationships among elements on these viewpoints [2]. In a previous work the multimodel was used to guide the software architect in the derivation and improvement of product architectures in a model driven software product line development process [12]. This multimodel included initially four viewpoints: the variability, functional, quality, and transformation viewpoints. In this paper we adapt this multimodel in order to deal with the traceability among the external variability, represented in the variability viewpoint, and the requirements viewpoint with the aim to obtaining the product requirements through model transformations. The goal of this strategy is to provide a framework to model the requirements variability in a domain-independent way. The multimodel for this purpose is composed of two viewpoints:

- **The variability viewpoint** expresses the commonalities and variability within the product line. This viewpoint expresses the external variability of the SPL. Its main element is the *feature*, which is a user-visible aspect or characteristic of a system [5]. The variability view of the multimodel has been defined using a variant [11] of the cardinality-based feature model [7], defined specifically for its application in a model-driven product line development context.
- **The requirements viewpoint** expresses the variability at the requirements level which realizes the external variability. We express this variability by using the CVL language [9] which allows expressing the variability of a Domain Specific Language (DSL). CVL allows establishing variability points over a base model defined in a DSL. This variability is defined by means of Meta Object Facility (MOF) compliant metamodels. The CVL approach works with two models: the *CVL model*, which defines variation points in the base model; and the *CVL resolution model* which resolves the variability for generating resolved models. The main CVL entity to represent the variability abstractions is the Variability Specification (Vspec).

We define a relationship among the features from the variability viewpoint and the VSpec elements. This solution allows, at the application engineering, obtaining a CVL resolution model that it will be used to obtain the application requirements through model transformations.

4. A Model-driven Approach to Obtain the Product Requirements

In this Section we present a process with different activities in order to specify the requirements of the family of products and their variability in order to obtain the product requirements. The process covers the two main SPL processes: Domain Engineering, and Application Engineering. Fig. 1 shows the main activities of the FeDRE approach.

4.1. Domain Engineering

The Domain Engineering activities take as input three main artifacts from the Scoping activity [14] First, the *Feature Model* [13] represents the SPL external variability by using: features, SPL variations, and constraints among the features in the SPL. Second, the *Feature Specification* is a template that captures the detailed information of the features. Finally, the *Product Map* is an optional document where the set of relationships among features and products are described.

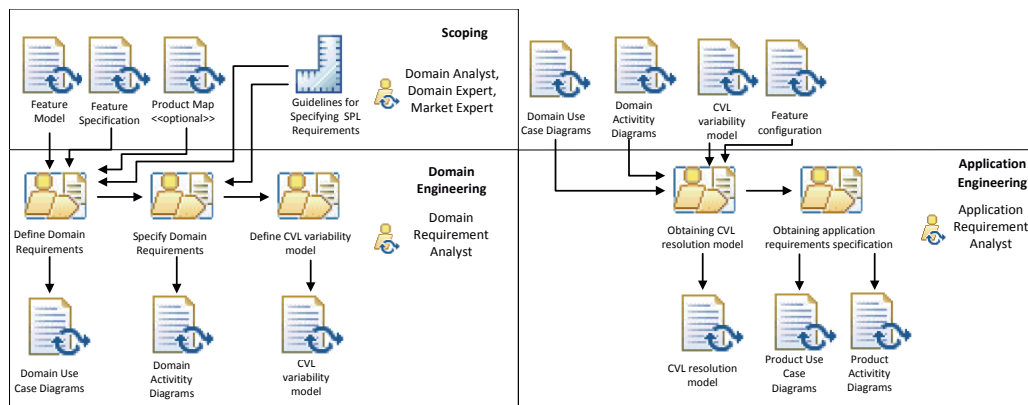


Fig. 1. FeDRE process: a) Domain Engineering; b) Application Engineering

FeDRE was defined using and extending the PLUSS approach [8] considering the feature model as the main artifact for specifying SPL requirements. The aim of the approach is to perform the requirements specification in a systematic way by using the features identified in the scoping activities through the use of a set of guidelines¹. The multimodel is used to keep the traceability among the SPL external variability and the requirements variability (the internal variability), which is presented through a CVL model in the requirements viewpoint. In FeDRE we support two requirements variability mechanisms: at the use case level by using “extends” relations, or within *activity diagrams* by using *Decision Nodes during the use case specification*. Three main activities have been defined for the Domain Engineering: *Define Domain Requirements*, *Specify Domain Requirements*, and *Define CVL variability model*. In this Section we describe each one of these activities. The *Domain Requirements Definition* activity is usually performed in an iterative and incremental manner. Sets of selected features from the Feature Model can therefore be defined as units of increments for the specification. The guidelines assist the Domain Requirements Analyst when identifying the requirements using as input the Feature Model. Firstly, the Domain Requirements Analyst must decide which of these features would be specified by means use cases (*which*). After deciding which features need to be specified as use cases, the *Domain Requirements Analyst* had to identify which use cases should be associated to each feature (*what*). Since some use cases with similar behavior may be identified for different features that have the same parent, the *Domain Requirements Analyst* should decide where to relocate the specification for this use case (so as to avoid the redundant specification of similar behavior). When this happens, the use case is specified only once at the parent feature level. After the identification, use cases are modelled. Finally, the Domain Requirements Analyst specifies the variability at the use case diagrams by using “extends” relationships. The output of this activity is the use case diagram.

Specify Domain Requirements

The next step is to specify these domain requirements by using UML activity diagrams, which represents workflows of activities with choice support, iteration and concurrency. We use activity diagrams extended with *Activity Partitions*. The partitions divide the nodes and edges to constrain and show a view of the contained nodes [17]. Every *Actor* has an *Activity Partition* that represents the action flow. The System will have always an *Activity Partition* since we model the interactions among different actors and the System. Other element is the *Decision Node*, which represent controls nodes that choose between outgoing flows. The Decision Nodes allow expressing multiple alternatives, which should be used to represent variability.

¹ The FeDRE guidelines are available at: <http://bit.ly/fedreguidelines>

Define CVL Variability Model

The CVL Language allows us to represent the requirement's variability independently from the DSL used to model the requirements. The variation points in CVL refer to base objects with the aim to define the base model modifications precisely. In this approach the *base model* is composed of: the use case, and the activity diagrams. This solution allows setting up variation points without modifying the DSL models.

4.2. Application Engineering

On the application engineering we obtain the requirements for a specific product taking as input the multimodel and the feature configuration. Two main activities are considered based on model transformations: *obtaining the CVL resolution model*, and *obtaining the application requirements specification*. The first activity takes as input the multimodel and the feature configuration and produces a CVL resolution model. This CVL resolution model is taken as input in the second activity together with the CVL variability model and the base model (the use case diagrams and the activity diagrams) to obtain the product requirements through CVL transformations.

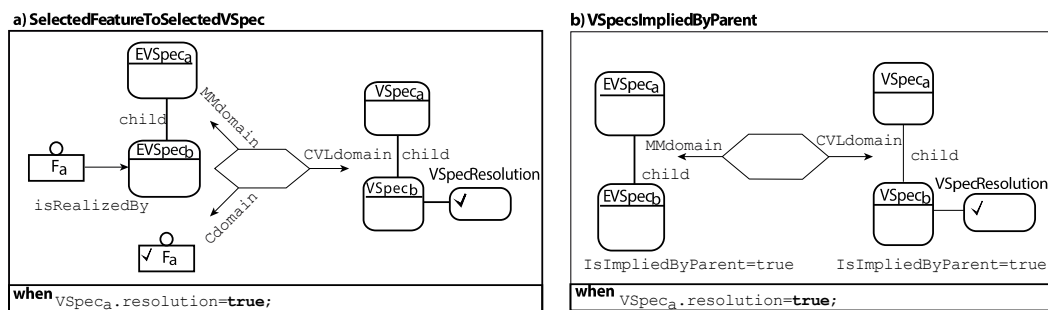


Fig. 2. Transformations defined in QVT-Relations graphical notation [16]

Obtaining the CVL Resolution Model

The input artifacts in this activity are the: the multimodel, and the feature configuration. A *feature configuration* is a set of features, which satisfies the constraints defined on the feature model. The CVL resolution model is generated through a QVT Relations [16] model transformation that take as input: the multimodel (which includes the feature model, the CVL variability model, and their relationships) and the feature configuration. The transformation process comprises a set of QVT relationships between two domains: the *source domain* that is the metamodel which supports the configuration model; and the *target domain*, that is the metamodel which supports the CVL modeling language. Three transformations are defined: *RootFeatureToRootVSpec*, which creates the CVL element container when exists a root feature on the configuration model; *SelectedFeatureToSelectedVSpec* (see Fig. 2.a), which positively resolves the set of VSpecs which realizes the features selected in the configuration model; and *VSpecsImpliedByParent* (see Fig. 2.b), which positively resolves a VSpec if its field *IsImpliedByParent* is defined as true and it is child of another VSpec that has been previously positively resolves. After applying the model transformations we obtain the CVL resolution model which contains the set of VSpecs which had been positively resolved.

Obtaining the Application Requirements Specification

The CVL resolution model resolves the variability in a base model. In this activity we use the traceability between the base model (use case diagram, and activity diagrams) and the CVL specification. The CVL transformation uses the resolution model and the CVL specification for obtaining the requirement specification models for the product.

5. Example: the Savi mobile Emergency Notification Family of Products

In this Section we illustrate the approach with an example. The example is based on a real application in the SAVi² SPL, which is a set of mobile applications that allow sending emergency notifications. Additionally, some products can send notification by using the Twitter and Facebook social networks.

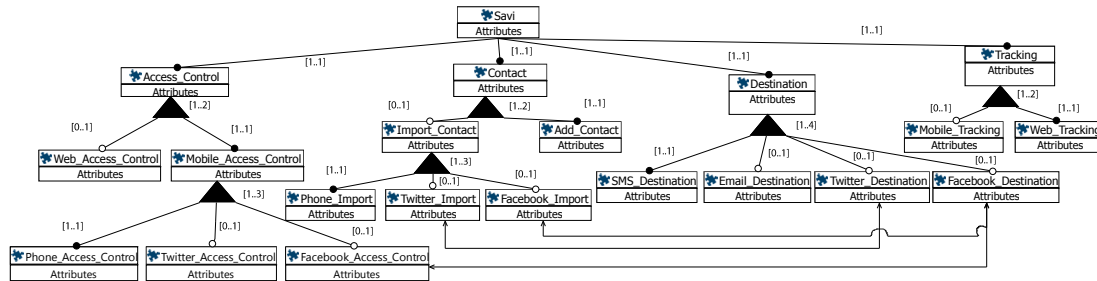


Fig. 3. Savi Feature Model

5.1. Domain Engineering

This activity specifies the SPL requirements for domain engineering by applying the FeDRE guidelines. Fig. 3 shows the Feature Diagram for the Savi product line. In the identification of the requirements we select a group of features in the increment unit for the current interaction. The *Domain Requirements Analyst* has to decide which of these features would be specified by use cases. According to the first task of the guidelines the specification starts with the feature *Access Control* and its children, because they are a group of features that share functionality. The FeDRE guidelines allow us to use two variability mechanisms, in this example we use both mechanisms in order to illustrate the approach. For the *Create User* use case (see Fig. 4.a) two possible extensions are defined by means the “extend” relationships. The extend use case are: *Link Twitter*, and *Link Facebook*. Each of them is associated with an actor that represents the external systems (Twitter, and Facebook).

The second type of variability is at the activity diagram level (Fig. 5.a). The activity diagram has one normal flow of activity, which it is the mobile login. Two alternatives may be included: *Twitter Login* and *Facebook Login* depending on the configuration.

5.2. Application Engineering

In this activity we take the configuration as input with the feature model and CVL variability model from the Domain Engineering. A feature configuration is shown on Fig. 4.b. For this product the customer desires an application with a *Mobile Access Control* and additionally *Twitter Access Control* support. After apply the transformation we have the CVL resolution model. This CVL resolution model contains which VSpecs are going to be resolved positive or negative. Finally, taken as input the CVL resolution model, the CVL transformation is executed in order to generate the product requirements.

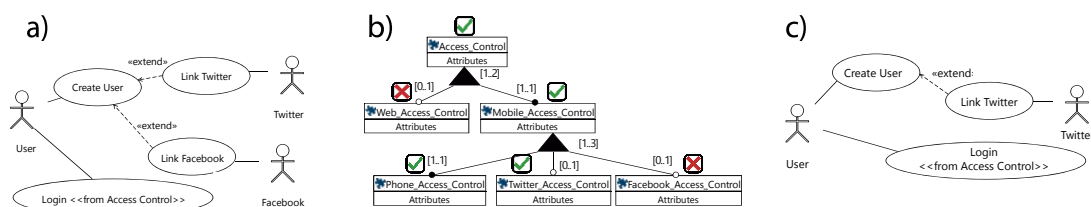


Fig. 4. a) Domain Use Case diagram, b) Configuration, c) Product Use Case Diagram

² Available at: <http://goo.gl/1Q490>

The result produces a use case diagram (see Fig. 4.c) associated to the features *Mobile Access Control*, *Phone Access Control*, and *Facebook Access Control* where the base use case is extended with the use case *Link Twitter*. The use case *Link Facebook* and its relationship “extends” to the base use case is removed since the feature *Facebook Access Control* is not selected. The use case *Login* will be extended by using the activity diagram variability mechanisms. Fig. 5.b shows the generated activity diagram for this product. Two possible alternatives are modeled. In the main action flow, the user sends the data to the System and the System shows a response with a confirmation of an error message. In the alternative flow, the user request to login with the Twitter data. In this case the System sends the data to the *Twitter System* (represented in a different partition). The response of the *Twitter System* is sent to the *System* again and the appropriate message is shown.

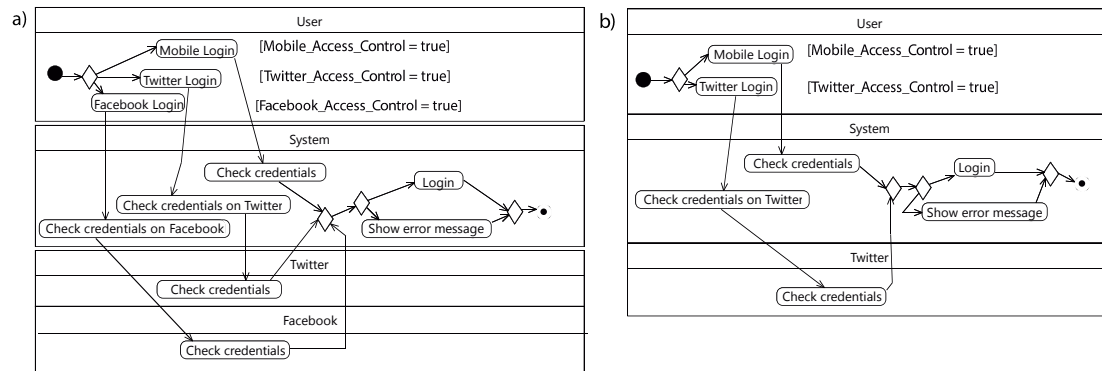


Fig. 5. a) Domain Activity Diagram, b) Product Activity Diagram for the Login Use Case

6. Conclusions and Future Work

This paper presents an approach which extends FeDRE for specifying the requirements of a family of products with a model-driven solution. The approach supports the two main processes of a SPL: i) *Domain Engineering*, where the requirements and its variability are modeled by using a multimodel that allows establishing the relationships among the requirements viewpoint and the variability viewpoint; ii) *Application Engineering*, where a strategy based on model transformations is used to obtain the product requirements. This solution provides support to the explicit representation of the traceability among the external variability (at SPL level) and the internal variability (at use cases and activity diagrams level) without polluting the requirement models with variability information. Moreover, this approach allows obtaining the product requirements by using model transformations improving the flexibility, reusability. An example based on a real software product line which manages an emergency notification system is used to illustrate the feasibility of the approach.

Future work will include experiments for assessing the feasibility of the approach applied in different domains. Concretely, it has been planned a case study based on a Cloud Computing SPL. We also pretend to extend the multimodel by considering the non-functional requirements as a new view. Furthermore, we are investigating how to assure the consistency among the different viewpoints that conform the multimodel.

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References

1. Alférez, M., Santos, J.P., Moreira, A., Garcia, A., Kulesza, U., Araújo, J., Amaral, V.: Multi-view Composition Language for Software Product Line Requirements. In:

- Proceedings of the Second international conference on Software Language Engineering (SLE). pp. 103–122. Springer, Denver, USA (2009)
2. Barkmeyer, E.J., Feeney, A.B., Denno, P., Flater, D.W., Libes, D.E., Steves, M.P., Wallace, E.K.: Concepts for Automating Systems Integration. National Institute of Standards and Technology, Bureau Drive, Gaithersburg, USA (2003)
 3. Bonifácio, R., Borba, P.: Modeling scenario variability as crosscutting mechanisms. In: Proceedings of the 8th ACM international conference on Aspect-oriented software development (AOSD). pp. 125–136. ACM, Charlottesville, Virginia, USA (2009)
 4. Clements, P., Northrop, L.: A Framework for Software Product Line Practice, Version 5.0, <http://www.sei.cmu.edu/productlines/framework.html>, Accessed: April 01, 2014, (2007)
 5. Clements, P., Northrop, L.: Software Product Lines: Practices and Patterns. Addison-Wesley Professional, Boston, MA, USA (2001)
 6. Czarnecki, K., Antkiewicz, M.: Mapping features to models: A template approach based on superimposed variants. In: 4th International Conference on Generative Programming and Component Engineering (GPCE). pp. 423–437. Springer, Tallin, Estonia (2005)
 7. Czarnecki, K., Kim, C.H.P.: Cardinality-based feature modeling and constraints: A progress report. In: International Workshop on Software Factories, held at Conference on Object-Oriented Programming Systems, Languages, and Applications (OOPSLA). pp. 16–20. ACM Press, San Diego, California, USA (2005)
 8. Eriksson, Magnuss, Börstler, Jürgen, Borg, K.: The PLUSS approach - domain modeling with features, use cases and use case realizations. In: Proceedings on 9th International Conference on Software Product Lines (SPLC). pp. 33–44. Lecture Notes in Computer Science, Rennes, France (2005)
 9. Fleurey, F., Haugen, Ø., Møller-Pedersen, B.: A generic language and tool for variability modeling. SINTEF, Oslo, Norway (2009)
 10. Goknil, A., Kurtev, I., Millo, J.-V.: A Metamodeling Approach for Reasoning on Multiple Requirements Models. In: Proceedings of the 17th IEEE International Enterprise Distributed Object Computing Conference (EDOC). pp. 159–166. Vancouver, BC, Canada (2013)
 11. Gómez, A., Ramos, I.: Cardinality-based feature modeling and model-driven engineering: Fitting them together. In: Int. Workshop on Variability Modeling of Software intensive Systems (VAMOS). pp. 61–68. Universität Duisburg-Essen, Linz, Austria (2010)
 12. González-Huerta, J., Insfrán, E., Abrahão, S.: Defining and Validating a Multimodel Approach for Product Architecture Derivation and Improvement. In: 16th International Conference on Model-Driven Engineering Languages and Systems (MODELS). pp. 388–404. (2013)
 13. Kang, K.C., Cohen, S.G., Hess, J.A., Novak, W.E., Peterson, A.S.: Feature-Oriented Domain Analysis (FODA) Feasibility Study. T, Software Engineering Institute, Carnegie Mellon University (1990)
 14. Oliveira, R.P. de, Insfran, E., Abrahão, S., Gonzalez-Huerta, J., Blanes, D., Cohen, S., Almeida, E.S. de: A Feature-Driven Requirements Engineering Approach for Software Product Lines. In: Proceedings of the VII Brazilian Symposium on Software Components, Architectures and Reuse (SBCARS). pp. 1–10. IEEE, Brasília, Brazil (2013)
 15. OMG: Common Variability Language (CVL) Revised Submission, <http://www.omgwiki.org/variability/doku.php>, Accessed: April 01, 2014, (2012)
 16. OMG: Meta Object Facility (MOF) 2.0 Query/View/Transformation Specification, <http://www.omg.org/spec/QVT/1.0/PDF/>, Accessed: April 01, 2014, (2008)
 17. OMG: UML 2.4.1 Superstructure Specification, <http://www.omg.org/spec/UML/2.4.1/Superstructure/PDF>, Accessed: April 01, 2014, (2007)
 18. Schaefer, I.: Variability Modelling for Model-Driven Development of Software Product Lines. In: Int. Workshop on Variability Modeling of Software intensive Systems (VAMOS). pp. 85–92. Linz, Austria (2010)

Integrating Usability Practices into Agile Development: A Case Study

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Abstract

Within agile software development there is a growing concern with how development organizations can integrate usability work into agile practices. The concern occurs as frustration experienced in practice by agile developers and usability designers, and it also occurs as a gap in the research literature. With this paper we report from a case study in a software company that is committed to agile development, to usability work, and to their integration. The theoretical starting point is an initial framework that has been elicited from the research literature; and the paper's contribution is an extension and modification of the initial framework based on our case study results. The resulting framework points to three enablers (attitudes, compromises, skills), three tasks (upfront design, low-fi prototyping, iterative evaluating), and three alternative modes of collaboration/work organization (parallel, embedded, fully integrated) in agile usability practices. In addition, end-user involvement may vary. The paper contributes by extending existing frameworks on integration and thus providing better explanations for practitioners and researchers of integration of usability.

Keywords: Agile Development, Usability, Integration, Case Study.

1. Introduction

Usability work and agile software development both share focus on delivering value, are iterative in nature and engage in continuous testing [15, 17]. There are differences however in how they approach these issues, which leads to difficulties in integrating them in practice. In agile software development, value assessments are based on code quality and there is a single focus on speed of development [3, 2]. Conversely in usability work, value assessments are based on the quality and coherence of design and the approach to development is reflective and deliberate [2]. With evidence suggesting that the integration of usability work into the agile development process leads to improved product quality and better user experience [17], how to ensure this integration has emerged as a major concern of research.

Research has been conducted on this culminating in a framework of practices that have been endorsed by researchers as critical for the integration of agile methods and usability work [27]. These practices cover issues such as what should be done, who should be involved, and how the development process should be coordinated. There have however been few examinations from practice or acknowledgement of the role situational considerations play in

ensuring this integration [27, 11]. A consequence of this is that there is a lack of clarity surrounding how this integration occurs in practice or what is critical for this integration [13]. In this paper we seek to contribute to a better understanding of the integration of usability work into agile development practices. By examining a software company we seek to answer the question: How is usability work integrated with agile practice and what characterizes this integration?

2. Related Research

Agile methods have over the last decade emerged as prominent approaches to software application development [7]. Their advent signaled a new era in software development. Unlike the rigid, engineering approaches that characterized the early years of systems development, these new methods were flexible, light weight and more amenable to changes in business requirements [8]. They prescribed an incremental and iterative approach to software application development which allowed for better management of requirements and also resulted in solutions that were more aligned with customers' needs [16]. The two most popular agile methods used in practice are XP and Scrum and it has been observed that these two methods are often combined in practice [14], see Table 1. This is not to say that they are rigorously adhered to, as most organizations use tailored variants or in house methods whose application may involve one or more agile practices [7].

Table 1. Agile practices [11]

Agile practice	Definition	Agile practice	Definition
Sprints	Release new versions of the software in very short cycle	Simple design	The design should be as simple as possible
Sprint planning	Planning business priorities and technical estimates	Pair programming	Two develops on the same computer
Daily meetings	Short daily status meeting	Testing first	Write test code before writing function code
Retrospectives	Reflect on strengths and weaknesses after each cycle	Continuous integration	Integrate and build the system when a task is completed.
40 hour week	Work time is generally limited to 40 hours per week	Collective ownership	Anyone can change any code anywhere in the system
On-site customer	Include an actual user on the team, available full time	Refactoring	Restructuring the software without removing functionality.

For usability work this increased adoption of agile methods has come at a price. Agile methods present non-trivial constraints to the systematic performance of usability work [11]. Agile development favors just-in-time requirements over in-depth exploration of user requirements [3, 6], emphasizes rapid, iterative releases of software over sophisticated planning and design characterizing usability work [1,9,24], and advocates user involvement as customer involvement over the actual end users [3, 30]. This has led to sustained research interest into how these issues might be resolved with particular emphasis placed on how usability work and agile methods might be better integrated.

A recent literature review has condensed and highlighted the seven prescriptive practices, which researchers have advocated should be adhered to, if usability work is to be successfully integrated into agile software development [27], see Table 2.

Table 2. Integrative practices [27]

Integrative practices	Description	Rationale
Upfront design	Conduct activities such as contextual inquiry to identify usability requirements	Enables insight into use context and users' perspective [3]
Low- fi prototypes	Translate identified user requirements into paper prototypes	Increases understanding of the user interface and usage [24]
Testing in between iterations with the application users	Test prototypes with real users to see if they meet usability and workflow requirements	Enables use focused refinements
Usability designers and developers work in parallel	Usability designers should work in a separate design track from the developers who similarly should have their own developer track	Enables synchronization of work flow

Usability designers should be involved in the project	Usability design team should be present to take on tasks relating to usability	Ensures usability concerns are always at the fore
Usability designers should be fully integrated into the development team	Usability designers should participate in agile activities such as sprint planning, daily meetings	Facilitates easier sharing of findings from user research
End users should be involved in the project	Real users from the target system population should be involved in the project particularly during upfront analysis and testing	Ensures a reliable baseline for requirements predating to usability

The issue with these prescriptive practices is that integration is depicted as consistent and predictable [11]. It is an approach grounded on assumptions regarding how this integration occurs in practice and the context within which it occurs [27]. Further it fails to consider how processes are rarely followed methodically in practice [11].

There have been a few studies examining how development organizations integrate usability work into their agile development processes. Integration may be achieved in practice through articulation work, where usability designers and developers each step outside their boundaries to create opportunities for common action with one another [11] or may implicitly alignment work where they each assume responsibility for coordination and resolving integration tensions [4]. This requires mutual awareness of each other's tasks, that there are expectations about acceptable behavior, that there is a negotiation of progress and that they engage with each other [13]. Organizational culture is also of some significance for integration [10, 12], and usability designers could be reduced to doing reactive work [21, 18]. Usability designers' countermeasures can be to employ workshops to introduce usability work [5], be persuasive [5], and negotiate, communicate and be flexible about their beliefs [20].

These studies show that examining practice allows for a better understanding of the dependencies and mechanisms that make the integration of usability work and agile methods possible [13].

3. Case Study

Company XYZ is a Nordic IT service provider and independent partner of selected software vendors. It operates in four countries and employs 100 systems and software professionals. The organization has a focus on solution consulting, development and optimization. It has a strong foundation in enterprise and business intelligence systems. The company has two divisions of particular interest: the Portal & Solutions (P&S) division and the Business Intelligence (BI) division. The P&S division had considerable experience of more integrated usability work and agile development. The BI division on the other hand had recently completed a large project with a strong focus on usability.

3.1 Data Collection and Analysis

This is an interpretive case study based on qualitative data. Interpretative research allows us to see the agile practices and the integration practices as socially constructed and thus open to several interpretations by organizational actors but also to us as researchers [28,19,29]. With a case study we seek to explore the particulars in its organizational context with the potential of highlighting their practices and the circumstances that the case organization faces.

Data were collected from 7 informants, see Table 3. These informants were recommended by the contact person on the basis that they were well-informed about the issue being investigated and able to communicate about it. The interviews were semi-structured and followed the ideas and techniques laid out in [25] and conducted following an interview guide. The interview guide was designed based on the framework put forward in Section 2 summarized in Tables 1 and 2. These interviews which we conducted in English were audio recorded and later transcribed.

Table 3. Overview of interviews

Interviewee	Division	Role	Interview length	Quotations
Anton & Benny	BI	Domain expert	1 h 18 min	49
Cilla	P&S	Usability designer 1 and front end developer	1 h 2 min	57
Dority	P&S	Usability designer 2 and front end developer	1 h 6 min	34
Eric	P&S	Product Manager	1 h	39
Frank	P&S	Scrum master	1 h 10 min	55
George	P&S	Usability designer 3 and front end developer	1h	27

The interviews were analyzed using qualitative contents analysis [25,22]. The data were analyzed utilizing the framework in Tables 1 and 2. The transcripts were loaded into DeDoose, a cloud-based tool for qualitative data analysis. In the qualitative contents analysis the following procedure was applied:

1. One author coded all the empirical data based on the coding scheme (cf. Tables 1, 2, and 4).
2. The two other authors reviewed the coding.
3. Disagreements on selection of quotations, on particular coding, and on definitions of codes were gradually and iteratively resolved.
4. When agreement of the resulting coding was reached the analyses offered by DeDoose were used to create an overview of the empirical base. E.g., a coding frequency analysis was used to see the relative importance of codes in the empirical base. E.g., a co-occurrence analysis was used to see how the integration practices co-occurred with the agile practices.
5. To reduce the resulting codes into a smaller number of analytic units, the codes were examined for similarities. A pattern was observed and the codes were then clustered together according to their observed similarities. Three categories emerged from this process.

Based on this contents analysis and the systematic application of the coding scheme the case presentation and the findings were elicited.

3.2 Overview of the Analysis

Table 4 provides an overview of the analysis. Based on the frameworks in Section 2 we see that there is much evidence of the integration of usability work into their development practices. The right hand side shows frequency of the occurrences of the seven integration claims, cf. Section 2, with the most prominent being ‘Designers partially involved’ (24) and ‘Testing between sprints’ (19). It also shows that the new code ‘Enablers’ emerged with a total of 44 occurrences - this emerging code will be explained in detail in the following Section. The left hand side of the Table shows frequency of occurrences of agile practices, cf. Section 2, with the most prominent being ‘Sprints’ (17) and ‘Planning game’ (17). A contents analysis shows that these occurrences contain evidence that these practices are actually being used in the case company to a large degree. To control for counter-evidence the code ‘Aberrations’ were applied to all quotations where the interviewees only talked about a practice without any evidence that it was in use. A cross-quotation analysis shows that these aberrations concern the less frequent practices, e.g., ‘Daily scrum’ (2).

The differences between the roles occupied by the interviewees have been analyzed. The main difference is that the usability designers refer more to integrative practices than the others and the software development managers refer more to agile practices. These are, however, not significant - with the only exception being the number of occurrences of

‘Enabler > Attitudes’ referred to by one usability designer in particular. Therefore, the detailed analysis continues without making a strong distinction between the interviewees’ roles.

Table 4. Overview of qualitative codes and frequency of evidence

	Role			Sum
	Domain expert	UX designer	Manager	
Agile practices (across all practices in [11], cf. Table 1)	23	31	41	95
Integration practices				
Upfront design	3	3	4	10
Low-fi prototypes	3	3	5	11
Testing between sprints	4	6	9	19
Work in parallel	1	2	1	4
Designers partially involved	8	9	7	24
Designers fully integrated		8	3	11
End users involved	1	3	5	9
Enablers		1	1	2
- Attitude		20	4	24
- Compromises	2	6		8
- Skill sets		9	1	10

3.3 Findings

Our study aimed to understand how usability work was being integrated in this company. There are three main findings which emerged from the data analysis. These pertained to enablers of integration, what tasks were being done and forms of collaboration.

3.3.1 Enablers

The usability designers refer much to enablers of integration (Table 4). Enablers are found also in the other interviews across the different roles and divisions. Hence, the integration does not only depend on the practices in the framework, it also depends on what can enable projects and their developers, managers, and designers to further possible integration practices. The following quotation shows an example of this:

“I think nowadays customers have realized the importance of usability, nowadays they really want that new systems are not like the previous ones with bad user interface. They want that [...] we work with usability from the start and they are very committed to my point of view to that.” (Eric)

The quotation not only shows that usability is on the agenda in a positive way and that the conditions with the clients enable this. It also shows more specifically that the attitudes of the clients and of the product manager is part of enabling work being done on integrating usability into the development project. Attitudes are central enablers, but sometimes the necessary attitudes are absent as this quotation shows.

“Sometimes the developers’ attitudes is a problem, they don’t want to accept the fact that I do know this better and sometimes they just have to learn, sort of the bad way, hard way to do it.” (Cilla)

The analysis thus shows that it is relevant to include enablers in our understanding of how usability work can be integrated with development. It further shows that there are three aspects of enablers (Table 4). These are: (1) attitudes; (2) compromises; and (3) skill sets. Attitudes occur more often than the two other, and without favorable attitudes many other aspects of integration will face difficulties.

From this analysis we can now define ‘integration enablers’ as something that furthers or assists in achieving integration of usability work into development practices. The claim coming from the analysis of the case is that enablers are or can be important for integration.

We can also in more detail suggest that ‘attitudes’ are the perceptions held by involved actors (e.g., clients, users, designers, developers, and managers) on how necessary usability work is for the quality of the final product. From the literature we know that these actors may have different attitudes, and from this case we see that positive attitudes become important enablers. Along the same line we suggest that ‘compromise’ is an enabler that similarly influences the behavior of actors with the differences being that a compromise is a resolved disagreement on the relevance and usefulness of usability work. A different enabler is ‘skill set’ which we based on the case come to define as answers to which skills are needed to perform usability design and evaluation and in particular how to bridge the gaps between development and usability work.

3.3.2 Integrated Usability Practices

The data analysis shows three types of integrated usability practices were referred to: upfront design (10 occurrences), low-fi prototyping (11 occurrences) and testing between sprints (19 mentions; see Table 4). These practices were found in the case, but they varied greatly between projects and the two divisions.

In the P&S division upfront design covered methods to “*get end-users on the loop*” (Eric). This could involve, e.g., “*wire framing with end users during the conceptualization phase.*” Sometimes, the wireframes were also initiated by other project stakeholders than usability designers. For example, the customer could supply “*wireframes models and sort of visual design*” designed by another subcontractor. Dority mentioned that the graphic designers behind such designs often failed to think about “*the interactive design*” and “*sort of drew beautiful layouts,*” but did not think much about the consequences to functionality. Whenever this occurred, upfront design tasks would be extended to include an evaluation of the design concept, discussions on how the system-user interaction should occur, focusing on the end users’ point of view, and ensuring that both the implementation and the service design match to the user needs. Cilla also talked about how they also sometimes engaged in user research by carrying out user surveys and having “*tight workshop(s)*” where they went through ideas with the customer. This was not a standard practice as sometimes “*the timetable would be so hectic that the customer would say, forget that we already know what we want and [there is] no need for that*”.

As a contrast to upfront design, usability work in the BI project began with low-fi prototypes after the first initial version of the layout was delivered by the technical project team. The usability designers could not design a user interface for business intelligence applications from scratch and no upfront design was thus conducted. The reason for this was hinged on the application type and the expectations of the clients.

In P&S, the prototyping phase follows the upfront design phase. The team uses interactive wireframes as low-fi prototypes. Dority argued that these wireframes were more productive as if they were to “*just describe the screens and then create sort of word documents where you describe all these things ... it is easier to understand the overall whole thing.*”

Testing and usability evaluation iteratively between sprints was mentioned several times in P&S, but it was much less frequently implemented in practice. Usability tests were usually done during the prototyping phase on the interactive prototypes, but little or no testing occurred during the development phase. Users were seldom involved in these tests and the usability designers typically carried out heuristic evaluations by themselves. The observed usability issues were fixed and the designs passed on to the developers. Frank noted that this was because most of the time their clients did not “*have the budget for that (testing) all the time.*” On rare occasions, customers “*would use some other company that has expertise or specialized for usability testing*” (Frank) upon project completion.

In the BI project, the clients were focused on functional tests on the application and preferred no usability testing between iterations. Usability testing was carried out at the end of the project. During these tests, the developers were placed in a separate room where they were able to observe the usability designers performing these tests. Many usability problems were

noted and the magnitude of these problems led one of the domain experts to make the following conclusion:

“So, the lesson here is that usability testing should be done; if there is only like resources to do it once or if it is too expensive, then it should be done in the middle of the project not at the end but the best case would probably be to do it iteratively a couple of times, maybe 5 times with the users to get the best result.”

3.3.3 Collaboration

The analysis shows that there are three forms of collaboration employed in the case company: working in parallel (4 occurrences), designers partially involved (24 occurrences), and designers fully integrated (11 occurrences). These three forms follow the framework at an overall level, cf. Section 2, but the case shows these in more detail that all three forms may be useful in the same company yet under differing circumstances.

In the P&S division, usability designers are partially involved, but often also fully integrated and no project is ever carried out without usability designers. The designers participate in the initial planning of the project where they show clients the return on investment they stand to gain by investing in usability work. The company has come to *“understand the importance [of having] usability guys working all the way from the first meeting to the end of the live of the system”* (Eric).

The usability designers are also front end developers in P&S. George reiterates on whether the relative importance of usability work is a consequence of their development tasks:

“If I just wouldn’t do any coding, but just working as a usability designer, it doesn’t change that I am working with same people and we have freedom to like share the tasks when we form some groups ... and if it is the case that I am only doing the usability design, I am still sure my voice would be heard, we would have meetings and I would say maybe you should consider this and that.”

In several P&S projects the usability designers were fully integrated into the team and participated in the division’s daily scrum meetings and planning meetings. Frank mentioned how during planning meetings that they *“discuss every task and issue open[ly] together and what [they] should do”* and made *“sure that the coders [understood] what they need to do before the usability guy can do his or her stuff.”* This process also applied the other way around as it was important that the developers and usability designers came to agreement on what was feasible in terms of design and of development.

The passing of designs between the usability designers and developers is organized to be executed in parallel. The usability designer ahead of a sprint specifies the functionalities from the wireframes that have been created. This gives specific details for the developers to create the view in the sprint. The aim is *“to keep the design ahead of the development phase but not so that all the design is done before you start the development phase. The design is sort of done”* (Cilla).

Conversely for the BI project, the involvement of the usability designers was not as extensive as in the P&S division. The BI division was involved in the project for about 100 or 150 days. The client on the other hand had hired the usability designers to participate in the project for only 10 days. Also the BI team and the usability designers never met in person. This arrangement meant that the usability designers worked in parallel with the BI team and were thus not partially involved or fully integrated:

“The whole time they were available the whole project was pretty much ten days, so it was maybe three days and couple of calls, they would call me for example and ask if it is possible to do this or some kind of fonts or stuff like that and we just went through it on the phone and that was pretty much it”. (Domain expert)

There was a downside to this arrangement as despite the usability designers' familiarity with the platform, they ended up *"coming up with so much stuff"* and their initial designs were *"over the top"*. The lean forms of communication between the BI team and the usability designers ended up being a critical element of their collaboration. As the usability designers passed on their design guidelines and designs to the BI team, the BI team would on their own part evaluate the feasibility of these recommendations. If issues were noted, they would communicate these to the usability designers by phone and email.

"But when the graphic designer doesn't know if it is possible he can do something like this and if we can implement this then we will but if not then we won't". (Domain expert)

This somewhat parallel collaboration between the BI team and the usability designers turned out to be effective as the domain experts noted that, *"we had good discussions with them and now we are going to use them more and more"*.

4. Discussion

Our findings suggest altogether three contributions to the previous literature on integrated usability practices in agile development which will be discussed below:

1. Identification of the three enablers (attitudes, compromises, and skills) as necessary for practice integration
2. Three concrete usability design tasks varyingly integrated to agile development: upfront design, low-fi prototyping and iterative evaluation
3. Three modes of collaboration between usability designers and developers (parallel, embedded and fully integrated) and end-user involvement varyingly observed in relation to the integrated usability design tasks

The previous literature reviews on integrating usability practices with agile development have been focused on highlighting the process model underlining existing approaches to integration [26] and on the motivations, warrants, theoretical backing and reported challenges (i.e., rebuttals) of integration [27]. The identification of the three enablers for integration provides a new category of phenomena, which warrants future research and managerial attention. Whereas previous case studies have identified challenges for integrated usability work in agile development milieus [18]. Especially, the categories 'attitude' and 'compromise' which we observed in the data seem to highlight importance of working with organizational culture. Recognizing and facilitating necessary changes in organizational culture for integrated usability and agile design are needed in the management of groups involving agile developers and usability designers. As well, more detailed, perhaps even professionally verified and standardized definitions of skill sets for the "agile usability designer" of the future should be developed and verified. More explicitly defined skill sets would enhance education and competence development of the future professionals, both developers and usability experts, to become familiar and to adopt more integrated practices.

Three general-level, previously identified practices of integrated usability development: upfront design, low-fi prototyping and iterative usability evaluation [27], were varyingly present in our target organization. And that's about it: we found no traces of other concrete usability tasks in our case! Low-fi prototyping seemed to be a practice which fitted to all projects in our case, while upfront design was found less suitable in the business intelligence project. Whereas the most projects in our target organization seemed to skip iterative testing and evaluation between sprints and during development, the developers and usability experts seemed still to wish iterative usability testing to be increasingly used in the future. Our results also address that end-users were not always involved in the "agile usability" practice, but the iterative evaluation could take place plainly heuristically with "skilled usability experts". Thus, iterative evaluation actually took sometimes place, but often without end users. In some occasions end users were involved only in the very beginning and in the end, and sometimes even less. Whereas our informants identified the need for and potential benefits of end-user involvement and more iterative testing, and would probably have re-produced the ideal "key

practices” as identified by [23] - feedback days, user workshops and micro-testing - in a general-level interview, our research shows that the actual practice may vary even within one organization and may skip end-user involvement for various reasons. More in-depth, perhaps action-oriented, research will be needed to reveal how end-user involvement and more iterative usability work during actual software development could really work more frequently in action, instead of plainly popping up as rhetorically recognized “ideals” in the professional field studies and practitioner interviews.

The case study enlightened us to re-categorize three of the previously observed “integrative usability practices” [27]: usability designers and developers working separately, usability designers as part of development projects, and usability designers as fully integrated to development - as alternative modes of collaboration between developers and usability designers. In our case we found evidence of all the three modes of organizing collaboration. In our case, the usability designers recognized the role of their tasks when integrated especially in relation to (and sometimes within) the daily scrum and sprint practices. In previous literature and cases [11], the prevailing mode of collaboration seems to be that the usability designers and developers represent separate work roles and work rather separately in parallel to the development, just handing over the usability specifications before and between sprints to the developers. While we saw that such parallel practice had been in use in some projects, the designers and developers had also chosen tighter modes of collaboration. Especially, the P & S division had recognized the benefits from more embedded and even integrated collaboration forms among usability designers and developers. Further research will be needed whether explication of collaboration modes between designers and developers is only needed in relation to daily scrum, sprints or when a developer is simultaneously usability professional in connection to pair programming, or whether usability work should also be more visible in other types of agile practices as well? Such research, however, requires in-depth fieldwork, perhaps even experimentation, for observing which practices would really work in action, how and why.

5. Conclusion

This article represented a case study on how usability work was integrated to agile development practices in a systems development organization, which had explicitly committed itself to these ideals. The data analysis highlighted the importance of three enablers, attitudes, compromises, and skills, as necessary prerequisites for reaching integrated and agile usability practices. However, despite its commitment on both agile development and usability, and while possessing already good experiences from such integrative practices as low-fi prototyping and upfront design, our target organization still poses a great variance in everyday practice with regard to actual implementation of iterative usability testing/evaluation and end-user involvement. As well, the organizing collaboration between developers and usability designers could vary greatly from project to project - while the overall ideal was recognized to be a more embedded, if not fully integrated, mode of collaboration. The study addresses a need further research on the enablers of integrated practice, such as on how to facilitate organizational culture on attitudes and compromising between sometimes deviating preferences of usability designers and developers, as well as on how to develop skill sets among the professionals towards the more “integrated” practitioners. More in-depth research is also needed on how iterative usability testing and evaluation practices together with increased end-user involvement could move from words to deeds.

References

1. Armitage, J., Are Agile Methods Good for Design? *Interactions* 11(1),14-23 (2004)
2. Arnowitz, J.: Taking the Fast Ride: Designing while Being Agile. *Interactions* 20(4),76-79 (2013)

3. Blomkvist, S.: Towards a Model for Bridging Agile Development and User-Centered Design. In: Seffah, A., Gulliksen, J. and Desmarais, M.C. (Eds.) *Human-Centered Software Engineering — Integrating Usability in the Software Development Lifecycle*, pp. 219-244. Springer, Netherlands (2005)
4. Brown, J.M., Lindgaard, G. and Biddle, R.: Joint Implicit Alignment Work of Interaction Designers and Software Developers. In: *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense through Design*, pp. 693-702. ACM, Copenhagen, Denmark (2012)
5. Cajander, Å., Larusdottir, M. and Gulliksen, J.: Existing but not Explicit - The User Perspective in Scrum Projects in Practice. In: Kotzé, P. et al. (Eds.) *Human-Computer Interaction – Interact 2013*, pp. 762-779. Springer Berlin, Heidelberg (2013)
6. Chamberlain, S., Sharp, H. and Maiden, N.: Towards a Framework for Integrating Agile Development and User-Centred Design. In: Abrahamsson, P., Marchesi, M. and Succi G. (Eds.) *Extreme Programming and Agile Processes in Software Engineering*, pp. 143-153. Springer Berlin, Heidelberg (2006)
7. Conboy, K.: Agility from First Principles: Reconstructing the Concept of Agility in Information Systems Development. *Information Systems Research* 20(3), 329-354 (2009)
8. Dybå, T. and Dingsøyr, T.: Empirical Studies of Agile Software Development: A Systematic Review. *Information and Software Technology* 50(9-10), 833-859 (2008)
9. Düchting, M., Zimmermann, D. and Nebe, K.: Incorporating User Centered Requirement Engineering into Agile Software Development. In: Jacko, J. (Ed.) *Human-Computer Interaction*, pp. 58-67. Springer Berlin / Heidelberg (2007)
10. Ferreira, J., Sharp, H. and Robinson, H.: Values and Assumptions Shaping Agile Development and User Experience Design in Practice. In: Sillitti, A. et al., (Eds.) *Agile Processes in Software Engineering And Extreme Programming*, pp. 178-183. Springer Berlin, Heidelberg (2010)
11. Ferreira, J., Sharp, H. and Robinson, H.: User Experience Design and Agile Development: Managing Cooperation through Articulation Work. *Software Practice and Experience* 41(9), 963-974 (2011)
12. Ferreira, J.: Agile Development and UX Design: Towards Understanding Work Cultures to Support Integration. In: Bajec M. and Eder, J. (Eds.) *Advanced Information Systems Engineering Workshops*, pp. 608-615. Springer Berlin, Heidelberg (2012)
13. Ferreira, J., Sharp, H. and Robinson, H.: Agile Development and User Experience Design Integration as an Ongoing Achievement in Practice. In: *Agile Conference (Agile), 2012*, pp. 11-20. IEEE Computer Society (2012)
14. Fitzgerald, B., Hartnett, G. and Conboy, K.: Customising Agile Methods to Software Practices at Intel Shannon. *European Journal of Information Systems: An Official Journal of the Operational Research Society* 15 (2), 200-213 (2006)
15. Fox, D., Sillitto, J. and Maurer, F.: Agile Methods and User-Centered Design: How these Two Methodologies are Being Successfully Integrated in Industry. In: *Proceedings Of The Agile 2008 Conference*, pp. 63-72. IEEE Computer Society (2008)
16. Highsmith, J. and Cockburn, A.: Agile Software Development: The Business of Innovation. *Computer* 34(9), 120-127 (2001)
17. Hussain, Z., Slany, W. and Holzinger, A.: Investigating Agile User-Centered Design in Practice: A Grounded Theory Perspective. In: Holzinger, A., Miesenberger, K. (Eds.) *HCI and Usability for E-inclusion*, pp. 279-289. Springer Berlin, Heidelberg (2009)
18. Isomursu, M., et al.: User Experience Design Goes Agile in Lean Transformation - A Case Study. in: *Agile Conference (Agile), 2012*, pp. 1-10. IEEE Computer Society (2012)
19. Klein, H.K. and Myers, M.D.: A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems. *MIS Q* 23(1), 67-93 (1999)

20. Kollmann, J., Sharp, H. and Blandford, A.: The Importance of Identity and Vision to User Experience Designers on Agile Projects. In: Agile Conference (Agile), 2009, pp.11-18. IEEE Computer Society (2009)
21. Kuusinen, K., Mikkonen, T. and Pakarinen, S.: Agile User Experience Development in a Large Software Organization: Good Expertise but Limited Impact. In: Winckler, M., Forbrig, P. and Bernhaupt, R. (Eds) Human-Centered Software Engineering, pp.94-111. Springer Berlin Heidelberg (2012)
22. Miles, M.B. and Huberman, A.M.: Qualitative Data Analysis: An Expanded Sourcebook. 2nd Ed. United States of America: Sage Publications (1994)
23. Nielsen, L. and Madsen, S.: The Usability Expert's Fear of Agility: An Empirical Study of Global Trends and Emerging Practices. In: Proceedings of The 7th Nordic Conference on Human-Computer Interaction: Making Sense through Design, pp. 261-264. ACM (2012)
24. Obendorf, H. and Finck, M.: Scenario-Based Usability Engineering Techniques in Agile Development Processes. In: CHI '08 Extended Abstracts on Human Factors in Computing Systems, pp. 2159-2166. ACM, Florence, Italy (2008)
25. Patton, M.Q.: Qualitative Research. In: Encyclopedia of Statistics in Behavioral Science: John Wiley & Sons, Ltd (2005)
26. Silva Da Silva, T., et al.: User-Centered Design and Agile Methods: A Systematic Review. In: Agile Conference (Agile) 2011, pp.77-86. IEEE Computer Society (2011)
27. Wale-Kolade, A., Nielsen, P.A., and Päivärinta, T.: Usability Work in Agile Systems Development Practice: A Systematic Review. In: Linger, H. et al., (Eds.) Building Sustainable Information Systems, pp. 569-582. Springer, US (2013)
28. Walsham, G.: Interpretive Case Studies in IS Research: Nature and Method. European Journal of Information Systems 4(2),74-81(1995)
29. Walsham, G.: Doing Interpretive Research. European Journal of Information Systems 15(3), 320-330 (2006)
30. Wolkerstorfer, P., et al.: Probing an Agile Usability Process. In: CHI '08 Extended Abstracts on Human Factors in Computing Systems, pp. 2151-2158. ACM, Florence, Italy (2008)

Mapping Agile Practices to CMMI-DEV Level 3 in Web Development Environments*

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Abstract

Agile approaches formally appeared ten years ago and nowadays are a valid alternative for organizations developing software. Agile methodologies are especially interesting to those developing Web environments applications, as they can fit properly the special characteristics of this type of developments. In addition, maturity models like CMMI-DEV (Capability Maturity Model Integration for Development) focus on assessing the maturity level of organizations developing or acquiring software. These models are well established and can increment quality of development processes to enhance costumers' satisfaction. CMMI-DEV level 3 provides a good compromise on maturity gained and effort needed. The feasibility of getting it through a combination of Agile methods can be very useful to organizations developing systems in Web environments, as they can keep the adaptability of Agile together with a more mature development process. This paper proposes a set of Agile methods so as to reach all CMMI-DEV maturity level 3 generic and specific goals. Based on this analysis, the paper proposes further research lines.

Keywords: Agile, Scrum, Web Engineering, CMMI, Software Engineering.

1. Introduction

CMMI-DEV (Capability Maturity Model Integration for Development) is part of CMMI (Capability Maturity Model) family. This maturity model provides a comparative framework to assess the maturity level that organizations can reach when developing or acquiring software solutions [10]. It is assumed that the fact of achieving the different CMMI maturity levels is related to product quality improvements [21] and more than 5.000 companies are using CMMI all over the world [9]. Besides, Web-based developments have special characteristics that differentiate them from classical development projects, such as a complex navigational structure; critical interface requirements, (such as unknown users or availability, among others); security aspects; increase on maintenance efficiency, avoiding downtimes; delivery as soon as possible; reduction of "time-to-market" and adaptation to quick-changing requirements [5, 15, 37]. Some of these characteristics, for instance, reducing "time-to-market" or quickly adaptation to undefined requirements, are becoming more and more important in Web projects [36]. As it is known, one of the principles of Agile approaches is to embrace changes [5], thus

* The views presented on this paper are those of their authors, and do not necessarily reflect those of their employers

Agile approaches offer a suitable framework for the exposed Web development characteristics [37], such as quick response to changes, adaptability and reduction of development time [8, 9]. In addition, classical approaches regarding up-front requirements gathering demands a stable environment. This is not the case of Web projects, where requirements are constantly changing. The incremental and iterative way of processing requirements provided by Agile [17] may better fit this particular case. In the last years, a growing trend can be observed in the use of Agile, including major companies like Microsoft, Amazon or Yahoo. This trend is also observed in Web environments [1]. However, the more Web applications are becoming popular, the more their quality requirements are increasing. As mentioned, higher levels of CMMI-DEV maturity model are associated with quality improvements. Thereby, the usage of Agile methods to achieve the proposed goals of CMMI-DEV maturity levels could offer organizations developing Web environments the possibility of combining quality and maturity levels with the ability to respond to changes, even when sometimes both approaches, Agile and CMMI, have been regarded as opposite; as both include valid principles for software development that are not necessarily incompatible [20]. In particular, CMMI-DEV level 3 can present a good compromise between CMMI formalism and Agile adaptability [13, 28]. Based on the foregoing, this work identifies the following objectives: map a set of Agile practices with CMMI-DEV level 3 goals; take out the relevant conclusions and identify the future lines of research. For this purpose, this paper is organized into the following sections: after this introduction, Section 2 offers an overview of Agile and CMMI and Section 3 summarizes the related work. Section 4 presents a detailed mapping between the identified Agile practices to CMMI-DEV level 3 specific and generic goals. Finally, Section 5 states the main conclusions and further lines of research.

2. Overview of Agile Methodologies and CMMI-DEV

2.1. Agile Methodologies

Agile is a label which groups a set of different methodologies and techniques that appeared in software development during the last decade of the 20th century, as an evolution of the previously existent iterative and incremental approaches. The main goals of these practices were, firstly, to ensure that valuable results were delivered to customers and users as soon as possible, and lastly, to allow development organizations to adapt easily their products to users' changing requirements. All of these approaches shared the values and principles stated in the "Agile Manifesto" [5]: collaboration between development team and business, quick response to changes even in late phases of development, short feedback cycles, early delivery of value or focus on technical excellence. Some of the most popular Agile approaches are: Scrum [42], eXtreme Programming (XP) [6] or Lean Software Development [35]. However, Scrum is, by far, the most common Agile method, which is used either alone or combined with other Agile techniques [34].

2.2. CMMI-DEV

The Capability Maturity Model Integration is an approach to process improvements for organizations to develop effective processes [10]. CMMI includes CMMI-DEV, the maturity model for organizations building or acquiring software, whose current version is 1.3 [10]. This updated version includes a set of practices in twenty-two process areas, and it is structured into levels in order to help organizations better their development processes. The model recommends two representations, named Continuous and Staged respectively, that depict different improvement paths for organizations. Our work will be based on the Staged representation, which focuses on the global maturity level of an organization considering it a way of characterizing its performance. In the Staged representation the organization improves a subset of processes in each of the maturity levels, preparing them to the next one. Five maturity levels are defined in this type of representation: Initial, Managed, Defined,

Quantitative Managed and Optimized, and Table 1 shows the set of CMMI-DEV level 3 process areas in the Staged representation:

Table 1. CMMI-DEV maturity level 3 process areas.

Process Area	Category	Process Area	Category
Decision Analysis and Resolution (DAR)	Support	Requirements Development (RD)	Engineering
Integrated Project Management (IPM)	Project Mgmt	Risk Management (RSKM)	Project Mgmt
Organizational Process Definition (OPD)	Process Mgmt	Technical Solution (TS)	Engineering
Organizational Process Focus (OPF)	Process Mgmt	Validation (VAL)	Engineering
Organizational Training (OT)	Process Mgmt	Verification (VER)	Engineering
Product Integration (PI)	Engineering		

3. Related Works

This section presents in detail the existing related works on this topic, considering any approach, coming from Agile world trying to incorporate values from CMMI, or vice versa. We have paid special attention to studies focusing on Web environments. As a result, we have found approaches like the ones by Morales *et al.* [32], Jakobsen *et al.* [24, 25], Sutherland *et al.* [20] and Maller *et al.* [29], describing how different organizations with a strong CMMI culture incorporate Agile practices (like Scrum, XP, Lean or TDD) in their development processes. These studies have some common patterns: They have the form of case studies, analyze organizations already being assessed in higher levels of CMMI, present a slightly detailed high-level mapping between Agile practices and CMMI goals and all focus on general development processes, without including Web development particularities. The main gap of such literature is that authors explain in general terms, how an already CMMI-assessed organization incorporates Agile practices. Nevertheless, they neither describe how an organization can progress through CMMI levels using Agile practices nor how to map Agile practices with CMMI goals (even if some of them cope with the latter briefly). We have also found works where the process of Agile organizations starting with formal assessments on different CMMI maturity levels is described, like these by Cohan *et al.* [11], Baker [3, 4], Garzas *et al.* [19] and Bon *et al.* [8]. These papers present some case studies dealing with how companies using Scrum or XP successfully went through a formal CMMI assessment. In Garzas' paper, only CMMI level 2 is assessed against Scrum, without analyzing maturity level 3 goals. The remaining papers are centered on the preparation of the assessment process and not on describing the mapping between the different practices and goals, which either is not presented or it is done at a very high-level. These papers also point to general software development processes, without including Web projects peculiarities. In contrast, Miller *et al.* [31] present a case study regarding how a company started with an Agile software development implementation based on Scrum methodology and a formal assessment process at CMMI maturity level 2 at the same time. This approach analyzes the problem from the general development perspective by presenting the mapping in a non-detailed way, only studying maturity level 2 goals. As the progress on CMMI-DEV level is linked to quality improvements [21], our work extends the analysis to maturity level 3.

In addition, a set of theoretical works has been gathered, like those by Lukasiewicz *et al.* [28], Zang *et al.* [44], Marçal *et al.* [30], Omran *et al.* [33] and Díaz *et al.* [16]. These studies introduce a mapping between a certain set of Agile practices (mainly Scrum or a variation of Scrum) and the goals of a certain CMMI maturity level. Lukasiewicz's work introduces a mapping between Scrum and some process areas of CMMI levels 2 and 3. Then, a variation of Scrum is proposed to fill in the gaps. Nevertheless, it focuses on generic developments, without taking into account Web specificities and without covering all process areas. Marçal's work analyzes the mapping between Scrum and CMMI project management process areas of maturity levels 2, 3 and 4, but there is no proposal on how to fill in the identified gaps. Díaz maps Scrum and CMMI level 2 also from a theoretical point of view, but only covering some process areas, without considering Web specificities, neither. In contrast, we propose a mapping for the full

set of process areas of CMMI-DEV level 3, not only using Scrum, but also some other Agile practices and methods that can cope with Web projects particularities.

As a conclusion, we can state that there is no work proposing a full mapping between a set of Agile practices and methods and all CMMI-DEV maturity levels 2 and 3 process areas that considers Web projects particularities, with the exception of our previous work [43]. It analyzes the mapping between Scrum and the full set of CMMI level 2 process areas for Web development environments, as well as recommends a set of Agile practices to fill the identified gaps, by proposing an Agile framework to reach all level 2 goals. This is the only work focusing on Web projects. Therefore we can consider it to be the starting point for this study. The conclusions of this previous work allows extending our study to all CMMI-DEV level 3 process areas by intending to map a different set of Agile practices (not limited to Scrum practices) to all specific and generic goals of all CMMI maturity level 3 process areas, taking into account Web development projects characteristics.

4. Mapping Proposal

As previously mentioned, our work [43] recommended a set of Agile practices covering all specific and generic goals of CMMI-DEV level 2 process areas. In this section we offer a mapping between a set of Agile practices and CMMI-DEV maturity level 3 specific and generic goals for Web development projects. This mapping proposal has been designed by analyzing the description of each one of the process areas goals and its proposed practices, to later matching them with the description of the Agile practices and techniques provided in the literature.

4.1. Specific Goals

Table 2 summarizes the proposal for CMMI-DEV maturity level 3 specific goals:

Table 2. Results for CMMI-DEV maturity level 3 generic goals.

P. A.	Goal	Proposed Agile techniques
DAR	SG 1 Evaluate Alternatives	DAR supports the analysis of possible decision-making processes using a formal evaluation procedure. At a project level, the process of identifying, evaluating and selecting alternatives can be performed by means of the Highsmith's techniques in the "Envisioning" phase of his Agile Project Management approach [22]. This phase will allow assessing the feasibility of projects systematically, identifying their scope and budget, prioritizing them in terms of value and planning them at a high level in liaison with the project's stakeholders. The set of practices included in this phase would cover the six specific practices of this specific goal.
IPM	SG 1 Use the Project's Defined Process	The goal of IPM is to manage the project involving stakeholders in it. Scrum [42] is suggested as the basis to achieve the goals of this process area, covering at least three SG2 specific practices. Using Schwaber's approach to implement Scrum at enterprise level [39], which would allow institutionalizing Scrum as an organization standard process, is proposed in order to cope with seven SG1 specific practices.
	SG 2 Coordinate and Collaborate with Relevant Stakeholders	
OPD	SG 1 Establish Organizational Process Assets	OPD aims to establish and maintain a usable set of organizational process assets, work environment standards, and rules and guidelines for teams. Using Schwaber's process [39] to implement Scrum at enterprise level can be useful to cover the first three specific practices, although there are no particular Agile practices to establish processes at organization level. Besides, at this level, the establishment of ground rules for the teams and "definitions of done" [42], as prescribed by Scrum, can be useful so as to establish the organization work standards, covering 6 and 7 specific practices. The extension to Scrum proposed by our previous work [43] can be also applied to the organization measurement repository, allowing tackling 4 and 5 specific practices.
O P F	SG 1 Determine Process Improvement Opportunities	

	SG 2 Plan and Implement Process Actions	OPF focuses on planning, implementing and deploying organizational process improvements. The Agile field providing support to the goals of this process area can be Lean Software Development, including: <ul style="list-style-type: none"> - Agile retrospectives at project and enterprise level [14, 35] for SG1 and SG2 specific practices. - Process improvement workshops [26] for SG 2 and SG3 specific practices.
	SG 3 Deploy Organizational Process Assets and Incorporate Experiences	
OT	SG 1 Establish an Organizational Training Capability	OT deals with developing the team's skills and knowledge. An organizational training plan should be implemented with "Amplify learning" practice of Lean Software Development [35] to achieve this goal. Reducing feedback and learning cycles and working on iterations will suit Web development characteristics properly and allow covering the seven specific practices of the two goals
	SG 2 Provide Training	
PI	SG 1 Prepare for Product Integration	PI's goal concerns to ensemble the final product. Web development demands reducing "time-to-market" as much as possible. Agile practices below can be implemented in order to achieve this goal together with that of this process area: <ul style="list-style-type: none"> - Continuous Integration [6], which will cover 1 and 2 specific goals practices. - Continuous Delivery [23], which will also cover 3 specific goal practices.
	SG 2 Ensure Interface Compatibility	
	SG 3 Assemble Product Components and Deliver the Product	
RD	SG 1 Develop Customer Requirements	RD is about eliciting and analyzing requirements. As requirements in Web environments are not often clear at the beginning of the project, the idea is to include user stories [12] combined with other techniques, such as Personas [38] and Storyboards [38], as elements of Scrum Product Backlog [42] that will evolve through the project. This approach will cover specific SG1 and SG2 practices. The use of Scrum framework to elicit, define, build and validate requirements in projects Sprints will guarantee that the rest of the specific practices will be covered.
	SG 2 Develop Product Requirements	
	SG 3 Analyze and Validate Requirements	
RSKM	SG 1 Prepare for Risk Management	RSKM has the goal of identifying potential problems and mitigate their adverse consequences. Even though Risk Management is not a field deeply developed in Agile, the following techniques can be used along with Scrum process to manage Web projects risks: <ul style="list-style-type: none"> - Agile Risk Management [27], to cover SG 1 specific practices. - Risk Burn-down charts [13], for SG2 and SG3 specific practices.
	SG 2 Identify and Analyze Risks	
	SG 3 Mitigate Risks	
TS	SG 1 Select Product Component Solutions	TS copes with selecting, designing and implementing solutions to requirements. As Web developments are characterized by short feedback cycles and fuzzy requirements, the use of the following practices will fit both, the goal of this process area and Web projects needs: <ul style="list-style-type: none"> - Spike Solutions [40] and Exploratory testing [40] for SG 1 practices. - Simple Design [40] and Incremental Design and Architecture [40], for SG2 and SG3 practices.
	SG 2 Develop the Design	
	SG 3 Implement the Product Design	
VAL	SG 1 Prepare for Validation	VAR deals with ensuring that the team builds "the right product". As mentioned, unknown and changing requirements characterize Web developments. Thus, in this case, Agile test practices might be quite useful. The proposed practices to achieve the process area goals are ATDD (Acceptance Test Driven Development) or "Specification by example" [2], which will cover all SG1 and SG2 practices.
	SG 2 Validate Product or Product Components	
VER	SG 1 Prepare for Verification	VER ensures that the team builds "the product the right way". There are several testing techniques that help achieve the goals of this process area, most of them coming from XP: <ul style="list-style-type: none"> - Continuous integration [6] for SG1 practices. - Pair programming [6] for SG2 practices. - Test-Driven Development [7] for SG1 and SG3 practices.
	SG 2 Perform Peer Reviews	
	SG 3 Verify Selected Work Products	

4.2. Generic Goals

Table 3 presents the proposed set of Agile methods in relation to CMMI level 3 generic goals.

Table 3. Results for CMMI-DEV maturity level 3 generic goals.

Generic goal	Comments
GG1 Achieve Specific Goals	The aforementioned set of Agile practices will ensure meeting this goal by achieving the specific goals of each process area.

GG2 Institutionalize a Managed Process	This goal is linked to setting a management process for the defined development process. Establishing practices at organization level by means of the techniques proposed for IPM and OPD process areas will enable completing this goal.
GG3 Institutionalize a Defined Process	This objective is linked to establishing a process at organization level, which can be adapted to each particular project. Agile practices proposed for IPM and OPD process areas will also be used to achieve this generic goal.

5. Conclusions and Future Work

To conclude, it must be stated that a combination of different Agile techniques could be used to achieve all CMMI-DEV maturity level 3 generic and specific goals in a Web development environment. In this case, the approach is based on using Scrum framework in order to manage and guide the project. Scrum process provides an iterative and incremental framework to build products, although it should be implemented at enterprise level, in order to allow institutionalizing the process and build an enterprise-wide assets repository, which is tailored-made for each individual project. This set of practices covers mainly IPM and RD process areas. The process proposed to deploy Scrum at enterprise level can also be useful for OPD process area. A set of technical practices together with Scrum must be implemented to achieve engineering process areas goals. These practices come from XP and early testing worlds, such as continuous integration and delivery, pair programming, incremental design and spikes, specification by example and Test Driven Development, among others. Such practices cover PI, TS, VAL and VER. On the top of Scrum and along with technical practices, some other Agile methods help organizations reach CMMI-DEV maturity level 3: Continuous improvement and organizational learning coming from the Lean Software Development context to cover OPF and OT goals; Agile Risk Management approach and its set of tools to cover RSKM and Agile Project Management envisioning phase, in order to support the decision making process in an Agile way to cover DAR goals.

As it has been highlighted, this proposal is fully compatible with our proposal issued for CMMI-DEV level 2 in Web environments. Thus, the implementation of this set of practices will make an organization progress step by step through CMMI-DEV model, increasing its process maturity, but keeping its Agility.

A future line of work could consist in formalizing and integrating the proposed techniques in a consistent framework, as well as keeping the identification of Agile practices, methodologies and techniques that together can allow organizations producing Web developments to achieve the higher levels of CMMI-DEV model goals (4 and 5). Merging this set of practices with the already identified set for levels 2 and 3 will allow the definition of this consistent framework that will help in the process of institutionalizing Agile practices for Web development in a continuous improvement environment assessed by a widespread model like CMMI-DEV. As NDT [18] is a well-established Web development methodology, compatible with Agile lifecycles, we have realized that proposing one alternative, named Agile-NDT, will enable reaching the aforementioned goals. Finally, evaluating the model in a real-life implementation through a formal assessment or a self-assessment will be required in order to validate the proposals included in our work.

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References

1. Ambler, S.W.: Lessons in Agility from Internet-based Development. IEEE Software 19(2), 66-73 (2002)

2. Adzik, G.: *Specification by Example: How Successful Teams Deliver the Right Software*. Manning Publications, Shelter Island (2011)
3. Baker, S.W.: *Formalizing Agility: An Agile Organization's Journey Toward CMMI Accreditation*. Proceedings of Agile Conference, pp. 185-192. IEEE, Denver (2005)
4. Baker, S.W.: *Formalizing Agility, Part 2: How an Agile Organization Embraced the CMMI*. Jul. 2006. Proceedings of Agile Conference. IEEE, Minneapolis (2006)
5. Beck, K., Beedle, M., Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., Grenning, J., Highsmith, J., Hunt, A., Jeffries, R., Kern, J., Marick, B., Martin, R.C., Mellor, S., Schwaber, K., Sutherland, J., Thomas, D.: *Manifesto for Agile Software Development* (2001), <http://www.agilemanifesto.org>, Accessed February 2014
6. Beck, K., Andres, C.: *Extreme Programming Explained: Embrace Change*, Second Edition. Addison-Wesley, Boston (2004)
7. Beck, K.: *Test Driven Development: By Example*. Addison-Wesley, Boston (2008)
8. Bos, E., Vriens, C.: *An Agile CMM*. In: Zannier, C., Erdogmus, H., Lindstrom, L. (eds) 4th Conference on Extreme Programming and Agile Methods. LNCS, vol. 3134, pp. 129-138. Springer, Heidelberg (2004)
9. CMMI Institute. *Published Appraisal Results*. Frok <https://sas.cmmiinstitute.com/pars/>, Accessed June 2014
10. CMMI Product Team: *CMMI for Development, Version 1.3*. Carnegie Mellon University (2010), <http://www.sei.cmu.edu/reports/10tr033.pdf>, Accessed February 2014.
11. Cohan, S., Glazer, H.: *An Agile Development Team's Quest for CMMI Maturity Level 5*. Proceedings of Agile Conference, pp. 201-206. IEEE, Chicago (2009)
12. Cohn, M.: *User Stories Applied: For Agile Software Development*. Addison-Wesley, Boston (2004)
13. Cohn, M.: *Managing Risk on Agile Projects with the Risk Burndown Chart*, <http://www.mountangoatsoftware.com/blog/managing-risk-on-agile-projects-with-the-risk-burndown-chart>, Accessed February 2014
14. Derby, E., Larsen, D.: *Agile Retrospectives. Making Good Teams Great*. The Pragmatic Bookshelf, Dallas (2006)
15. Deshpande, Y., Murugesan, S., Ginige, A., Hansen, S., Schwabe, D., Gaedke, M., White, B.: *Web Engineering*. Journal of Web Engineering 1(1), 3-17 (2002)
16. Díaz, J., Garbajosa, J., Calvo-Manzano, J.A.: *Mapping CMMI Level 2 to Scrum Practices: An Experience Report*. In: O'Connor, R.V. et al. (eds.) 16th European Conference on Software Process Improvement. Communications in Computer and Information Science, vol. 42, pp. 93-104. Springer, Heidelberg (2009)
17. Dybå, T., Dingsøy, T.: *Empirical Studies of Agile Software Development: A Systematic Review*. Information and Software Technology 50(9-10), 833-859 (2008)
18. Escalona, M.J., Aragón, G.: *NDT: A Model-Driven Approach for Web requirements*, IEEE Transactions on Software Engineering 34(3), 370-390 (2008)
19. Garzás, J., Paulk, M.C.: *A case study of software process improvement with CMMI-DEV and Scrum in Spanish companies*. Journal of Software: Evolution and Process 25(12), 1325-1333 (2013)
20. Glazer, H., Dalton, J., Anderson, D., Konrad, M.D., Shrum, S.: *CMMI or Agile: Why Not Embrace Both!* Carnegie Mellon University, Software Engineering Institute (2008), <http://www.sei.cmu.edu/reports/08tn003.pdf>, Accessed February 2014
21. Goldenson, D., Gibson, D.: *Demonstrating the Impact and Benefits of CMMI: An Update and Preliminary Results*. Carnegie Mellon University, Software Engineering Institute (2003), <http://resources.sei.cmu.edu/library/asset-view.cfm?AssetID=6365>, Accessed February 2014
22. Highsmith, J.: *Agile Project Management: Creating Innovative Products*, Second Edition. Addison-Wesley, New York (2009)
23. Humble, J., Farley, D.: *Continuous Delivery: Reliable Software Releases Through Build, Test, and Deployment Automation*. Addison-Wesley, Boston (2010)

24. Jakobsen, C. R., Johnson, K.A.: Mature Agile With a Twist of CMMI. Proceedings of Agile Conference, pp. 212-217. IEEE, Toronto (2008)
25. Jakobsen, C.R., Sutherland, J.: Scrum and CMMI Going from Good to Great. Proceedings of Agile Conference, pp. 333-337. IEEE, Chicago (2009)
26. Kniberg, H.: Lean from the Trenches: Managing Large-Scale Projects with Kanban. The Pragmatic Bookshelf, Dallas (2012)
27. Lant, M.: Five Simple Steps to Agile Risk Management, <http://michaellant.com/2010/06/04/five-simple-steps-to-agile-risk-management/>. Accessed February 2014
28. Lukaszewicz, K., Miler, J.: Improving Agility and Discipline of Software Development with the Scrum and CMMI. IET Software 6(5), 416-422 (2012)
29. Maller, P., Ochoa, C., Silva, J.: Lightening the Software Production Process in a CMM Level 5 Framework. IEEE Latin America Transactions 3(1), 15-22 (2005)
30. Marçal, A.S.C., De Freitas, B.C.C., Furtado Soares, F.S., Furtado, M.E.S., Maciel, T.M., Belchior, A.D.: Innovations in Systems and Software Engineering 4, 17-29 (2008)
31. Miller, J.R., Haddad, H.M.: Challenges Faced While Simultaneously Implementing CMMI and Scrum: A Case Study in the Tax Preparation Software Industry. Proceedings of the 9th Information Technology: New Generations, pp. 314-318. IEEE, Las Vegas (2012)
32. Morales Trujillo, M., Oktaba, H., Pino, F.J., Orozco, M.J.: Applying Agile and Lean Practices in a Software Development Project into a CMMI Organization. In: Caivano, D. et al. (eds.) 12th International Conference on Product-Focused Software Process Improvement. LNCS, vol, 6759, pp. 17-29. Springer, Heidelberg (2011)
33. Omran, A.: AGILE CMMI from SMEs Perspective. Proceedings of the 3rd Int. Conf. on Information and Communication Technologies: From Theory to Applications, pp. 1-8. IEEE, Damascus (2008)
34. Pikkarainen, M., Haikara, J., Salo, O., Abrahamsson, P., Still, J.: The Impact of Agile Practices on Communication in Software Development. Empirical Software Engineering 13(3), 303-337 (2008)
35. Poppendieck, M., Poppendieck, T.: Lean Software Development. An Agile Toolkit. Addison-Wesley, Boston (2003)
36. Pressman, R.S.: What a Tangled Web We Weave. IEEE Software 17(1), 18-21 (2000)
37. Ran, H., Wang, Z., Hu, J., Xu, J., Xie, J.: Agile Web Development with Web Framework. Proceedings of 4th Int. Conf. on Wireless Communications, Networking and Mobile Computing, pp. 1-4. IEEE, Dalian (2008)
38. Rasmusson, J.: The Agile Samurai. How Agile Masters Deliver Great Software. The Pragmatic Bookshelf, Dallas (2011)
39. Schwaber, K.: The Enterprise and Scrum. Microsoft Press, Redmond (2007)
40. Shore, J., Warden, S.: The Art of Agile Development. O' Reilly (2007)
41. Sutherland, J., Jakobsen, C.R., Johnson, K.: Scrum and CMMI Level 5: The Magic Potion for Code Warriors. Proceedings of Agile Conference, pp. 272-278. IEEE, Washington (2007)
42. Sutherland, J., Schwaber, K.: The Scrum Guide: The Definitive Guide to Scrum (2011), <http://www.scrum.org/Scrum-Guides>, Accessed February 2014
43. Torrecilla-Salinas, C.J., Escalona, M.J., Mejias, M.: A Scrum-based Approach to CMMI Maturity Level 2 in Web Development Environments. Proceedings of the 14th International Conference on Information Integration and Web-based Applications & Services, pp. 282-285. ACM, Bali (2012)
44. Zhang, L., Dan, S.: Research on Combining Scrum with CMMI in Small and Medium Organizations. Proceedings of 2012 Int. Conf. on Computer Science and Electronics Engineering, pp. 554-557. IEEE, Hangzhou (2012)

What's in a User Story: IS Development Methods as Communication

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Abstract

This paper challenges claims made by Scrum proponents when characterising the communicative nature of user stories: including being more 'authentic' because they comprise spoken language and that they are stories. We argue and decisively demonstrate that neither can be upheld. By incorrectly characterising user stories, we miss opportunities to understand what they are and how they work during development. User stories are better understood by applying a functional theory of communication that emphasises how language is used. By selecting systemic functional linguistics, we can analyse user stories, and have developed a method for factoring unwanted epics into usable user stories.

Keywords: User Stories, Epic, Scrum, Systemic Functional Linguistics, Thematic Progression.

1. Introduction

This paper concerns the nature of user stories within Agile Scrum- a commonly used management method for incremental product and service development [13,18]. User stories have a very specific canonical form that is claimed by their proponents to be an excellent form of communication between product own and sprint development team [18]. Scrum utilises a *product backlog* which is a list of features that are rank ordered by the product owner or client on behalf of whom the features will be developed. The product backlog contains a wish list of features called *product backlog items (PBIs)* generally expressed as *user stories* in the form "As a (role), I want (feature) so that (benefit)". PBIs are meant to have a number of features. They should be independent of each other, negotiable and have business value of some kind. They also must be small, estimable and testable. A redaction of the product backlog is referred to as a *release backlog* comprising PBIs that deliver a subset of the required functionality of the system. Parts of the release backlogs are then allocated to sprint backlogs during the *sprint planning meeting*. The PBIs on a sprint backlog will be developed, tested and shipped by a development team (comprising 4 to 9 people) during fixed-duration iterations called *sprints* (generally 30 days in length). A project management tool used during the execution of the sprint is known as a *burn-down or velocity chart* and this represents the work that remains to be done in completing the PBIs on the sprint backlog. Short *daily scrum meetings* allow the sprint team to quickly report on whether the work is on track and to determine whether the required resources are available. At the end of the sprint, a *sprint review meeting* demonstrates the developed prototype, and a subsequent *sprint retrospective meeting* reviews the process of development and how this can be improved [14]. In terms of Scrum's participants, the sprints are facilitated by a *scrum master* who is responsible for the development process and while having a leadership role they do not have management authority over the team. The *scrum development team* is cross functional and has responsibility for developing the product. A *product owner* is responsible for the vision of the product. While anyone can add to the PBIs, only the product owner is permitted to prioritise

them and is the final arbiter of requirements questions. It is the role of the product owner to be focused on the 'what' rather than the 'how' and this is the justification for the use of user stories, as an accessible straight forward way of representing the needs of those who will use the system rather than the technical interests of those who might build them [18,13].

In this paper we seek to understand how user stories function as communication. In order to do so we first need to identify the kind of communication theory we need and to select an appropriate one to apply to this task. We want to explore what applying an appropriate communication approach tell us about user stories, PBIs, Scrum and systems development in general. This paper is also an attempt to map out some of the implications of thinking about IS development methods as communication. In doing so we hope to better understand what we are doing when applying these methods. By using appropriate communication theory and methods, it may be possible to improve these methods or even create new ones. The structure of the paper is as follows. Section 2 describes how IS Development Methods can be viewed as Communication. We select a linguistic theory called Systemic Functional Linguistics (SFL) to provide basic descriptions of what IS development methods look like from this perspective. In section 3, we apply SFL principles to try to answer the question of what exactly is a user story. In section 4, SFL is applied to identifying and pruning overly complex PBIs referred to as *epics*- the bane of all sprints. By doing so we demonstrate how communication approaches can yield insights into current development practices but is also suggestive of improvements to current development practices. Section 5 provides some conclusions, discussions and proposes further research.

2. IS Development Methods as Communication

2.1 Communication Approaches and Domain Viewpoints

Communication approaches vary to the extent that they can provide complete descriptions of work practices or describe organisational discourse in general. A distinction should be made between a *communication resource*, that describes a facet of language use or activity, or a *communication theory* that consists of a comprehensive range of communication resources and one or more grammars that are used to account for discourse in general. Perhaps the best known communication approach in our discipline is *speech act theory* (SAT) developed by Austin and Searle [3,20]. Speech Acts have been applied in IS [16,10,1] in a variety of specialist and mainstream venues, where they have been put to good use providing new kinds of process descriptions. Indeed [19] demonstrated how speech acts have been used to form executable process descriptions. But speech acts are just one kind of communication resource. Parenthetically, SFL has a system of *speech functions* that removes several known difficulties in applying speech acts; for example the latter's inability to provide grammatical evidence to help in differentiating between competing speech act interpretations.

In exploring the kinds of IS relevant descriptions that could be formed using communication approaches, [5] identified three possible *domain viewpoints* where they could be applied. These can be thought of as a stack. The first viewpoint at the base of the stack is that of *work practices*- the communicative description of either business processes or services. Much of the work of communication-based approaches in IS centres on demonstrating the possibilities of these kinds of representations and in some cases developing systems directly from them. The second viewpoint involves studying the work practices of developers- the *practitioner* viewpoint. The concern of this paper, it is something that is rarely considered in IS communities that utilise communication approaches. The third and final viewpoint at the top of the stack is the *disciplinary* viewpoint concerned with the discursive construction of the discipline; the process orientation in IS and management innovation studies is an example of this viewpoint. We will not consider this viewpoint further here. Communication approaches in the IS discipline differ in the extent to which they can account for generalised organisational discourse, and their ability to do so determines if they can be applied to the practitioner and disciplinary viewpoints at all. Comprehensive communication

theories are likely to handle practitioner and disciplinary viewpoints, while approaches that rely on communication resources are more likely to be limited to the work practice viewpoint.

There are a large variety of comprehensive communication approaches that are potentially applicable to IS. *Formal theories of communication* focus on the structure of individual sentences have proved to be very popular in areas like machine translation of language and computational linguistics in general. But functional communication theories view language as a resource for making-meaning and focus on the uses to which it is applied. From our perspective, the only real choice is to select a *functional communication theory*. Their applied focus is commensurate with the pragmatic and utilitarian goals of systems development discipline itself. The single most significant functional grammar in recent years [8] has been Systemic Functional Linguistics or SFL developed by Halliday and colleagues [12,17,15]. It is the only complete functional communication theory based on semiotics [11]. It has also had a degree of representation within the IS discipline itself [2,4]. We will use SFL in the remainder of this paper.

2.2 Methods as Communication: Basic Descriptions

The communication theory used to theorise ISD methods will determine how methods can be construed. From an SFL perspective, an IS method involves one or more contextually circumscribed completed acts of communication in conventional places or spaces. Completed acts of communication (texts) are situated in an immediate situational context (referred to as *register*) that tells those involved in the communication what is going on (*field*), the social relationships that are taking part in the communication (*tenor*), and how language is being used (*mode*). When we read or listen to a completed act of communication we are able to reconstruct the situational context because there is a systematic relationship between contexts and text. Each of Scrum's stages and their development practices are organised in terms of material settings in which communication occurs and the texts and their associated contexts that are likely to be specific to and characteristic of the specific method and/or methodology. An example of a text that precedes a sprint is the *product backlog*. It is a list in which PBIs are arranged in rank order. After resorting and refinement these PBIs will eventually be implemented as features. The product backlog is a text in which all the sprint team members and the sprint master can add *product backlog items* (PBIs) in user story form for example, but only the product owner gets to prioritise this list. The user stories are also completed acts of communication. In section 3 we turn our attention to describing what kind of texts they are.

The physical space and place in which texts are likely to occur both shape the generic and register characteristics of the text and in turn this textual activity also has an effect on how the space or place is used. The spaces or places are referred to as the *material setting* of the text. Of course most development work is undertaken during meetings, but even here the requirements of some of the development tasks necessitate novel ways of using the space which might appear to be cultural to some extent. Some well-meaning but none-the-less unusual practices have arisen in these materials spaces. One of these practices effectively demonstrates the cultural specificity of developer practices and the need to better understand communication resources. As someone is about to report their activities during a daily scrum meeting, the scrum master throws a ball to a team member who is about to make their report. The ball is used to show the team 'who has the floor'. Only that person is allowed to speak until they are finished or are asked to do so by the scrum master, in which case they throw the ball back to the scrum master. The folk linguistic explanation for this practice is that it puts everyone on the same level politically which is to imply that this practice somehow flattens the unequal social relations of power between members of the team. No amount of ball throwing will reduce social distances or diminish unequal social relations of power within the team. What the ball might show (when and if it works) is the *turn taking* that is occurring in the daily sprint meeting. But anyone could determine the turns taken in a meeting by either being there or reading a transcript of it. We mentioned this kind of practice was cultural; while it probably might work in North America, in Australia tossing a ball at someone might result in it being tossed right back at you- hard! Daily sprint meetings are also often

conducted standing- this helps keep the meetings short, unless you work in Scandinavia where many knowledge workers have desks that enable them to conduct their work while standing- for well documented health reasons.

We have not yet defined the cultural contexts associated with any IS method from a communication perspective- all texts exhibit high level patterning. For example, when we read and write emails we expect to see stages that identify the expected receiver of the text, the author of the text, the subject and the date. We also expect a message that forms the body of the text. Each of these stages is referred to as the *genre elements* of the text and the order in which they occur, and that characterizes memos from some of the text pattern- is referred to as a *genre*. Collections of the same kind of texts exhibit the same genre. So important is genre to texts (as a kind of text type) that IS artefacts effectively codify them for applications, for example, data entry screens, user interfaces and printed reports are all examples of generic organisation. This has important implications for when considering IS development methods as communication. Not only do methods consist of texts, but these texts can be generalized according to their generic structure. Scrum as a IS development method that has a sprint planning meeting that consists of pre-defined text types like agendas, a release backlog based on a product backlog (all written texts), the meeting itself consists of an extended spoken language text. Eventually this spoken language is transformed into a much simplified written transcript and eventually the minutes of the sprint meeting. Also this stage results in another written text the sprint backlog- a list of written language PBIs. In the next section we apply SFL to unpack some of the myths surrounding the nature of user stories.

3. User Stories considered using SFL

3.1 Better because they are spoken...

One of the often held advantages of user stories is that they shift the focus from writing about requirements to talking about them; [6] claims that “[u]ser stories emphasize verbal communication. Written language is often very imprecise, and there’s no guarantee that a customer and developer will interpret a statement in the same way”. Here supporters of user stories seem to be privileging speech over writing. The first thing to consider is that speech is not any more or less precise than writing. Rather than considering communication in terms of ‘precision’ it is more useful to consider it from the semiotic idea of *polysemy*. Both these forms of language support many different interpretations and therefore many different possible meanings.

There is certainly a difference between written and spoken language. In the evolution of language, speech came first, only later with the development of the large scale social organisation and the need to effectively record administrative details, amounts and quantities, did writing develop [11]. Why do functional linguists make a distinction then between written and spoken language? They do so because when we look at the language resources used in both, we see that they are not necessarily the same. Think of the tone resource. We raise our tone at the end of a sentence to indicate a question. But if a speaker is in a very insecure or stressful situation and feeling out of their depth, especially if they are young and/or relatively inexperienced then they may unwittingly indicate their insecurity by raising tones at the end of every utterance. In writing we have to use the question mark “?” to indicate a question but obviously not directly a tone. Parenthetically, if resources are used in speech and writing then they are often deployed differently, see subsection 3.3 below.

In order to negotiate the provision of information and knowledge or the exchange of goods and services, we use language resources that are available only in spoken language (unless of course we transcribe the speech but that is another matter). Following [8], when we talk to each other we use choices that make us initiators of, or responders to, language (the so-called *speech role*). These choices together with the type of *commodity* we are dealing with, whether we are dealing with negotiating goods and services or supplying information, enable us to select an appropriate *speech function*. An initiator will use one of the following speech

functions: an offer, a command, a statement or a question. A responder can accept or reject an offer, comply with or refuse a command, agree with or contradict a statement or answer or disclaim a question. As mentioned earlier, texts can be analysed for speech functions using grammatical rules. Each speech function has an associated grammatical realisation that enables it to be identified in a text with a relatively high degree of reliability. Speech functions co-occur; a question is often followed by an answer, an offer by an acceptance. This is how interlocutors accomplish work with language, by sequencing speech functions between themselves to make meanings. These sequences of speech functions are called *exchange structures*. Finally, patterns of exchange structures are used in routine or conventional spoken language situations. Buying a loaf of bread at a bakery will employ a conventional pattern of exchange structures as well. This pattern is referred to as a *genre*. In this situation, the set of exchange structures involve selecting the items to buy and determining the price, and then paying for those items. Each *genre element* consists of packets of exchange structures. Of course many commercial transactions like buying bread are so thoroughly conventional and so the speech roles, commodities and moves are well known to interactants- in fact they are their own genre called a *service encounter*. Through the experience of a great many similar (and indeed identical) transactions, interactants have experience of every useful and many not so useful approaches to these kinds of situations.

3.2 ... but unfortunately they are written.

The folk linguistic account of user stories can be challenged; user stories are not examples of spoken language! But as we have argued previously, these two modes are different. Writing is not speech written down. If you have ever transcribed authentic spoken language situations as we might find it during development sessions, then there is little doubt that user stories are not authentic examples of spoken language. When we speak in social situations we must collaboratively engage with each other. One interactant might start some idea, and the other might complete it- a phenomena known as *latching*. That sort of phenomena can be used to indicate social relations of power. An interactant might simply cut off the discussion by imposing their belief that it is acceptable based on their perception of having a higher social status. Of course, just because one interactant may have a higher social status does not mean they will necessarily interrupt. Culture plays a part in how these behaviours play out in social settings. Importantly, these kinds of phenomena are not found in written language unless we are transcribing spoken language.

Another line of evidence that confirms that user stories could not possibly be instances of spoken language, or even transcribed spoken language, comes from linguistics, see Table 1 Row 1. Written language is *lexically dense*. By this we mean that it is rich in *nominal groups*- a group of words that consist of a noun and information related to it [9]. Nominal groups provide information on experience. In contrast, when an interactant speaks they may correct what they just said, a phenomena called crossing out. They may use lots of ‘ohs’, ‘arrhs’ and so on to include spaces in their talking that enable them to organise their thoughts about what to say next. Spoken language leaves its mark on the resulting grammar; it is *grammatically complex* as a result. But user stories are lexically complex, especially in the classification of roles (certainly complex for real organisations), in the labelling and description of features and the anticipated or expected benefits they produce. The roles, features and benefits are provided by nominal groups and reveals this simple structure is more lexically dense than grammatically complex. Therefore user stories are examples of written language not spoken language; fortunately user stories are no less authentic because of this.

3.3 User stories are clauses not stories

This still leaves the question of what kind of entity are user stories. From an SFL perspective, user stories are a kind of clause. Clauses are the fundamental unit of the lexico-grammatical organisation of texts. The amazing thing about language is that they weave three different kinds of meaning together simultaneously. The first kind of meaning- *interpersonal*

metafunction, describes how a clause is organized to express interpersonal meanings- we have actually described many of these resources in subsection 3.1 when we dealt with interactants negotiating the provision of information and knowledge or the exchange of goods and services. We will not consider these kinds of meaning further. The second kind of meaning in language relates to the how meanings are packaged into language- referred to as the *textual metafunction* considered in more detail in section 4. The third kind of meaning- *ideational metafunction*- describes how reality is packaged into language both in terms of discrete experiences (*experiential meaning*) and as a flow of experience (*logical meaning*).

First we look at how the flow of experience is represented in a user story- this is primarily a structural view that reveals how meanings are refined by expanding upon the meanings of successive clauses. The user story is such a so-called *complex clause*, see Table 1 Row 1. Clauses enable meanings to be packaged into grammar [7] and the process of identifying constituent clauses is called *clause boundary analysis*. Clauses can be *major clauses* that can stand alone or *minor clauses* that require a major clause to make sense but importantly provide additional details. To identify the number of messages that are being represented in a clause complex, we look for *predictors*- the verb (doing, happening, or being) part of a clause. In Table 1, Row 1 the predictors have been underline. There are two distinct messages (clauses) in this user story. The part of the clause complex 'I want to send out an e-brochure to our former clients' is called an *independent clause* (it stands by itself). It is also a *declarative clause*- a statement responsible for providing information. As a clause 'to advertise our new services' is clearly not capable of making sense by itself. It is referred to as a *non-embedded dependent clause* because it is added as an afterthought to the rest of the clause. Importantly, the non-embedded nature of this dependent clause may be suggestive of alternative things 'to advertise' that may form the basis of additional new PBIs. Of course if these existed, they may be of importance to other roles in the organisation. Looking into the logical meaning of a clause is to take a structural perspective on how these clauses are linked together.

Now we can consider the user story in Table 1 Row 1 from the perspective of experiential meaning by identifying what the clause is doing functionally using what is referred to as a *process*. In this case, the user story is a *material process* something is being done (sent out). User stories are typically about doing things but other processes types are possible in clauses, including thinking things (mental), talking about things verbal), behaving in certain ways (behavioural), existing (existential), identifying or describing attributes (relational processes). We assert that user stories must consist of material processes otherwise they are ill-formed.

We can see that the role part of the user story has no predictor and is therefore a *minor clause*. But the wonderful thing about this minor clause is that it contains a *homophoric reference*- a reference to a role in the organisation being adopted by the product owner. The purpose of this reference is to make sure we don't forget which role the 'I' (read product owner) is playing. Recall that clauses construct three different kinds of meaning. From a textual metafunctional perspective, the minor clause also functions as a so-called *marked topical theme*. The term 'marked' simply means atypical or unusual. In most cases *unmarked themes* are typically used, but user stories employ marked ones. While we could have rewritten this user story to remove this marked topical theme, see Table 1, Row 2, the original version does have the advantage of continually reminding us to describe features directed at supporting the human activity system rather than specifying functions in a computer application.

Table 1. [1] An example of a user story- nominal groups italicized and predictors underlined; and [2] a rewritten user story removing the marked topic theme.

1	As a <i>laboratory manager</i> , I want to <u>send out</u> an e-brochure to our <i>former clients</i> to <u>advertise</u> our new services.
2	The <i>laboratory manager</i> wants to <u>send out</u> an e-brochure to our <i>former clients</i> to <u>advertise</u> our new services.

User stories are not stories either. We encountered genre resources in relation to spoken service encounters in section 3.1 but they also apply to written texts like memos, bulletins, and press releases. Martin and colleagues [17] have surveyed so-called *canonical genres* that are found in many different areas in society. The basic idea is that each activity or discipline can be characterized by those genres that are most applicable to it. A set of so-called *canonical narrative genres* are described in [17] include specific structures for genres that include recounts, anecdotes, exempla and narratives. The narrative structure has three compulsory genre elements called ‘complication’, ‘evaluation’, and ‘resolution’. We recognise this kind of classic structure in film, television and novels- but it is completely absent from user stories; so from an SFL perspective user stories aren’t!

4. Cutting Epics Down to Size: Applying Thematic Progression

A critical aspect of the success of Scrum development projects is having items in the product backlog that are small enough to be implementable within the timeframe of the sprint and yet still provide business value at least from the perspective of the product owner. Each PBI must be examined in order to identify so-called *epics* [6]. Epics are items that are considered to be too complex to handle within a single PBI and that add time and complexity to a Sprint. Identifying epics and successfully decomposing them is entirely dependent on the expertise and experience of the sprint team members and the scrum master. To the best of these authors’ knowledge, no theorized practice has been put forward to account for epic identification and decomposition. However, SFL’s *theme resources* are capable of identifying epics.

A *theme* is defined as the starting point of a message- what a clause is about. A theme contains what is familiar or known and takes the first position in the clause [12,8,17]. In the case of Table 1, Row 1, the theme is identified by ‘I’ in the major clause. There is an interesting feature associated with user stories and theme. The ‘laboratory manager’ of the minor clause is equivalent to the ‘I’ of the major clause. This repetition is called a *reiterated subject* [7] and is a characteristic of user stories. Interestingly, this feature is associated with rapid speech. This is probably where the myth about user stories as spoken language originates. The remainder of the clause is referred to as the *rheme*. It contains the rest of what the clause is about, in particular the new information being represented about the theme.

Once information is presented in a text it can then be further developed [9]. Information can be picked up as a theme at the beginning of the clause or it can be accumulated as new information in the rheme at the end of the clause. User stories are created out of relevant documents in the organisation or discussions with stakeholders that are eventually represented by the product owner as user stories during sprints. When applied to these kinds of extended texts, an analysis of theme describes how the meanings in a text are thematically developed as the talking or reading continues, while an analysis of rheme shows how new information is distributed and accumulated through the text.

An expectation of the development team is that the user stories lead to PBIs that represent coherent and cohesive system functionality. Written language documents from the workplace, or spoken language interview transcripts with organisational stakeholders, can be analysed for theme to identify unambiguously the actual organisational stakeholders around which user stories should be subsequently created. These texts typically have patterns of *theme reiteration* [7] that when represented as users stories will provide descriptions of related and perhaps even duplicate functionality. Analysing the associated rhemes can be useful in signalling confused information in user stories, typically in the form of duplicate or overlapping information across multiple user stories. All of the user stories associated with a particular stakeholder can be clustered together and rewritten into a single large text to provide effectively a list of all their required system features. This ‘constructed epic’ can then be split into its constituent clauses using the clause boundary analysis. Each clause can be analysed for its thematic resources. Irrelevant themes can be excluded from the list of potential user story to develop. We contend that a rheme analysis will help to clarify and identify the actual new features and their characteristics- these will be added to the list of user

stories to generate. Rhemes that are duplicates can be merged into one user story; complex rhemes can be factored into simpler ones and each would be tested for distinctiveness.

5. Conclusions, Discussion and Further Research

Almost every communicative characteristic Scrum practitioners attribute to user stories can be challenged. User stories are commonly referred to as instances of spoken language. However, they are manifestly examples of written language and contain almost none of the tell-tale language resources we expect to see in speech- even if it were transcribed. The only exception to this is a single feature (the reiterated subject) that while associated with rapid speech really serves as a reminder to a product owner as to which role they are playing during a sprint. User stories are also not actually stories.

In this paper we have argued that user stories can be better understood if they are viewed from the perspective of an actual theory of communication. Appropriate characteristics of a communication theory to apply to user stories include that they must be comprehensive, complete and functional so that we can better understand what user stories are, how they function and, as a consequence, why they actually work as they do. We selected SFL and identified user stories as complex clauses. Amongst other things, clauses can be interpreted from multiple perspectives simultaneously; as experiences (experiential) and also how themes and information can be woven together to form extended messages (textual). User stories must not consist of too many constituent clauses, and must reduce circumstantial or dependent clauses to assist in making the resulting user stories smaller, estimable and testable. Well-formed user cases will utilise material processes, that is, they must package experience as 'doing'. The structure of user stories includes language features like marked themes that continually reorient the 'story' back to the organisation and the task and therefore preventing a mind-set that views a feature for a human activity system as a function for a computer application. We also suggest that SFL resources be used to identify anomalous distributions of theme that can signal epics- overly complex PBIs that can then be decomposed or factored into usable user stories. This appears to be the first theorised method for dealing with epics in the Scrum literature.

Despite the 'folk-linguistics' that surrounds user stories as communication, they nonetheless work well because of some of their characteristics. These include the use of a homophoric reference back to the human activity system that is of interest during the sprint; the need for relative simplicity in the organisation of clause complexes, and the exclusive use of material processes. Communication theory can therefore describe why user stories actually function to promote communication between product owners and the development team. We have also demonstrated how communication theory, specifically SFL, can theorise and provide methods for tackling important problems in practical Scrum deployment. For example, we demonstrate how theme resources can deal with epics. In so doing, we have demonstrated that appropriate communication theory and methods have the potential to improve mainstream IS development practices.

Future research will be directed at conducting large scale studies that will no doubt uncover other, as yet unexpected, communicative phenomena during IS development. One aspect of development that is not considered in Scrum is how the user stories represent the actual needs of the roles that are being represented in the user stories- in effect the link between the product owner and their representation of the organisational stakeholders wants and needs in user stories. It is also possible to study how PBIs are reinterpreted and how the meanings change (and in some cases slip). While identifying linguistic resources is one thing, creating useful methods to be applied in the field is another direction this research must take before it can have an impact on actual development practices. This paper is just one small step in considering system development methods as a form of communication between stakeholders.

References

1. Ågerfalk, P. J.: Information Systems Actability. Understanding Information Technology as a Tool for Business Action and Communication Linköping Studies in Information Science, Dissertation No 7, Linköping University Press, Sweden, Linköping (2003)
2. Anderson, P. B.: A Theory of Computer Semiotics: Semiotic approaches to the construction and assessment of computer systems Cambridge Series on Human-Computer Interaction. Cambridge University Press, New York (1990)
3. Austin, J. L.: How to Do Things with Words. Oxford Press, Oxford University (1955/1962)
4. Clarke, R. J.: An Information Systems in its Organisational Contexts: A Diachronic Systemic Semiotic Case Study. Unpublished PhD Dissertation, Australia: University of Wollongong (2000)
5. Clarke, R. J.: Communication and Coordination- Fundamental Issues in Business Processes? International Workshop on Communication and Coordination in Business Processes. Sweden, Kiruna. June 22 (2005)
6. Cohn, M. (2009), http://www.mountaingoatsoftware.com/agil/user-stories_ Accessed April 30, 2014
7. Eggins, S.: An Introduction to Systemic Functional Linguistics 2nd Edition. Continuum: New York (2004)
8. Eggins, S., Slade, D.: Analysing Casual Conversation. Cassell: London and Washington (1997)
9. Gerot, L., Wignell, P.: *Making Sense of Functional Grammar: An Introductory Workbook* Cammeray, Australia: Antipodean Educational Enterprises (1994)
10. Goldkuhl, G: Information as Action and Communication. In Dahlbom B (ed.) The Infological Equation- Essays in Honor of Borge Langefors, pp. 63-79. Goteborg University, Goteborg, Sweden (1995)
11. Halliday, M. A. K.: Language as Social Semiotic: The social interpretation of language and meaning. Edward Arnold, London (1978)
12. Halliday, M. A. K.: An Introduction to Functional Grammar. Edward Arnold, London (1985)
13. Highsmith, J.: Agile Software Development Ecosystems. Addison Wesley, Boston: (2002)
14. James, M. (2014), Scrum Reference Card <http://scrumreferencecard.com/>. Accessed April 30, 2014
15. Kress, G.: Linguistic processes in sociocultural practice. ECS806 Sociocultural aspects of language and education. Deakin University, Victoria Australia (1985)
16. Lyytinen, K.: Implications of Theories of Language for Information Systems. MIS Quarterly. March 61-72 (1985)
17. Martin, J. R.: English Text: System and Structure. John Benjamins, Amsterdam (1992)
18. Pham, A., Pham, P.-V: Scrum in Action: Agile Software Project Management and Development. Course Technology, Australia (2012)
19. Schoop, M.: The Worlds of Negotiation. In: Arkhus, M., Lind, M. (eds.) Proceedings of the 9th International Working Conference on the Language-Action Perspective on Communication Modelling (LAP 2004), Rutgers University, The State University of New Jersey. NJ, New Brunswick, June 2-3, (2004) www.scils.rutgers.edu/lap04/lap04 Accessed April 30, 2014
20. Searle, J. R.: Speech Acts- An Essay in the Philosophy of Language. Cambridge University Press, Cambridge (1969)

Technical Tool Surveys and Comparative Studies: A Systematical Approach

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Abstract

Comparative studies and surveys on different technologies are common practices in research environments, not only when planning a new research line, but also in enterprise environment, for example, when a new project is going to be developed and the suitable technology must be selected. In the research context, an ordinary and formal method frequently followed to analyse the situation is the Systematic Literature Review (SLR). However, SLR is not enough, if the study is oriented towards comparing technologies or tools solutions. This paper presents a mechanism to be applied systematically in surveys and comparative studies of tools and technological solutions. It is based on general concepts defined in SLR, but it extends them in order to cover other necessities. The paper illustrates how this mechanism is applied to a real project named THOT and it offers conclusions and learned lessons from the last trends.

Keywords: Surveys, Comparative Studies, Systematic Literature Reviews, Enterprise Content Management.

1. Introduction

A Systematic Literature Review (SLR) is mainly carried out in order to find and develop innovative ideas for further research. In [21] authors consider SLRs as a means of completing processes based on identifying, evaluating and interpreting all available documents focused on particular research questions or theses in a specific investigation area. However, this process is not only associated with scientific environments. In fact, it can be applied to any domain or environment (such as research, enterprise or engineering, among others) as it is not only related to research work. In addition, it is normally used as a method for carrying out comparative studies on software tools or technology proposals.

Therefore, SLR aims to provide an exhaustive summary of literature relevant to a research, technological or technical question.

The use of SLRs is relatively recent in the Software Engineering (SE) context, but it has gained significant importance in this area as a means to identify, evaluate and interpret all available data to answer research questions on a particular topic in SE. It has been growing in importance as a systematic and structured approach regarding literature reviews since 2004,

when Barbara Kitchenham [9] proposed special guidelines that were adapted to cope with specific problems in the SE area. These guidelines have been used and evaluated [3] [10] [11] [18] in many contexts. Later, in 2007, Kitchenham's guidelines were updated [10]. Last year, Kitchenham's proposal was updated again [13] in order to be implemented, taking into account recent results published by software engineering researchers concerning their experiences when performing SLRs, as well as their advices for improving the SLR process.

Moreover, there are other ideas or views to conduct systematic reviews. For instance, in [20] [21], authors introduce different perspectives of SLRs. They issue their proposal after systematically selecting and analytically studying a large number of papers (SLRs) in order to understand the state-of-the-practice of search strategies in evidence-based SE.

In consequence, these SLRs proposals are highly directed towards answering research questions on some scientific knowledge. Nevertheless, SLR is not enough for a study led to compare technologies or tools solutions.

We have reached this conclusion during the execution of the THOT project. Such project is born because document processes management is becoming essential and critical within Andalusian Public Administration, due to e-Government is performing a key role in setting strategic plans.

At present, the THOT project is being executed by the University of Seville in liaison with the AOPJA (Agencia de Obras Públicas de la Junta de Andalucía). This is an innovative project on document management applied to service agreement records and transport infrastructure projects. It aims to analyze in detail strategies and document management systems (also known as ECM¹ or Enterprise Content Management), in order to investigate and define an innovative solution to improve records management.

There are many reasons for undertaking a SLR dealing with ECM solutions and its application to the THOT project. The most common ones are: (i) to identify what ECM systems currently exist in the market and what they offer for records management and documental processes; (ii) to identify how ECM systems can be adapted to the general guidelines of the Andalusian Public Administration in order to improve the records management; and (iii) to provide a framework to appropriately and objectively compare and facilitate decision-making regarding the most suitable ECM solution for the THOT project.

We have adapted the method proposed by Kitchenham to carry out the comparative study among ECM solutions. However, we have faced some trouble to successfully apply SLR due to our study's characteristics. We have also taken into account other authors such as Zhang [20] [21], Da Silva *et al.* [4] and Wohlin and Prikladnicki [19]. These works are summarized in Section 2.

In this paper we suggest a mechanism that can be used systematically in surveys and comparative studies of tools and technological solutions. It is based on general concepts defined in SLR, but it is extended to cover other necessities.

The paper is structured as follows: Section 2 shows the background of our proposal, which is described in Section 3. Finally, Section 4 and Section 5 present a successful case in which we have applied our proposal and some conclusions as well as future work, respectively.

2. Background

We have studied the most recent works on SLR guidelines to lay the foundations of our proposal, before describing the mechanism we recommend to be applied systematically in surveys and comparative studies of tools and technological solutions.

Zhang and Babar consider that SLRs are normally carried out in order to find out and develop innovative ideas for further research. A SLR is a means of completing processes based on identifying, evaluating and interpreting all available documents related to a particular thesis

¹ According to AIIM, Association for Information and Image Management, [1] ECM consists of strategies, methods and systems used to capture, manage, store, preserve and deliver content, and documents related to organizational processes. ECM systems and strategies facilitate the management of an organization's unstructured information, wherever that information exists.

in a specific investigation area. This process has its own terminology and is applied in different ways. In this line, Zhang and Babar introduce new vocabulary concepts and different perspectives on SLRs [21].

As the SLR process concerns, Zhang *et al* assume that designing and executing an appropriate and effective search strategy is a key step. [20]. Authors argue that these are time-consuming and error-prone activities and consequently, they need to be planned and implemented carefully. Authors also explain that there is an apparent need for a systematic approach to designing, executing, and evaluating a suitable search strategy for optimally retrieving the target literature. In light of this, they suggest an approach, which consists of a collection of known studies, and corresponding ‘quasi-sensitivity’ into the search process for evaluating search performance.. This idea was proposed as a result of selecting and studying a wide range of SLRs in order to understand the state-of-the-practice of search strategies in evidence-based software engineering.

Moreover, some authors put forward that the software engineering research community is starting to adopt SLRs consistently as a research method [4]. However, the majority of SLRs do not evaluate primary studies quality and fail to provide guidelines for practitioners, thus decreasing their potential impact on software engineering practice.

In [19], authors confirm that the search strategy is key to ensure a good starting point for the identification of studies and ultimately for the actual outcome of a particular study.

Finally, we have also considered the guidelines for the systematic review proposed in this paper according to the protocol defined by Kitchenmham *et al*. [13]. These authors establish that a SLR essentially involves three phases: (i) **planning the review**, which aims to decide which method will be used to carry out the review as well as identify and formulate the thesis that the systematic review must validate; (ii) **conducting the review**, which consists in finding and evaluating whether many primary studies associated with the research questions are adequate and relevant enough to be possible sources for further analysis; and (iii) **reporting the review**, which deals with writing up the results of the review and reporting them to potentially interested parties.

Figure 1 shows this process through a timeline that indicates when each SLR phase was applied within the THOT project.

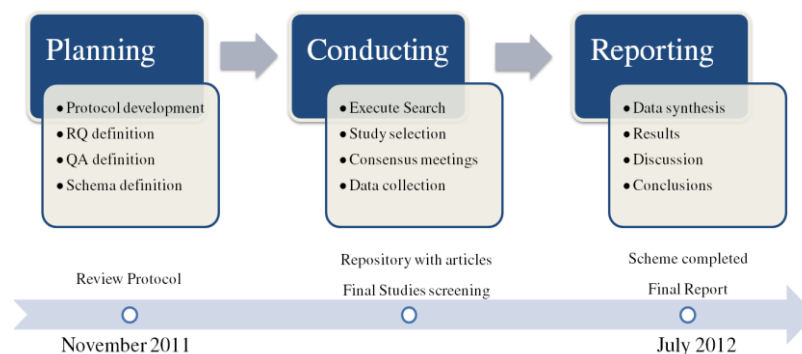


Fig. 1. SLR phases

SLR is seen as a valid formal method to carry out comparative studies and surveys of different tools or technological solutions, despite all these formal proposals. However, it is not enough since other necessities must also be considered. All these reasons make us recommend a mechanism (which is based on the well-known proposals concerning SLR) to be applied systematically in surveys and comparative studies of tools and technological solutions. Section 3 will further describe our proposal.

3. Our Approach

As it was previously mentioned, carrying out a comparative study of technical solutions can be very similar to conducting a SLR. However, the characteristics of technical comparative studies require special attention to some aspects.

This section describes the set of phases focused on the SLR approach presented in Figure 1. Then, we propose a characterization scheme to evaluate different alternatives of ECM systems, with the aim of selecting the most suitable one for the scope and context of this paper. This guarantees quality in the quality continual improvement process of these systems.

PHASE I. Defining the review protocol

In this first phase, the team has to plan the Review protocol of the study in order to delimit the specific context of the work. For this aim, we propose the use of classical elicitation techniques such as interviews, context analysis or checklists.

Three important elements have to be inferred from this phase:

1. Technical and Research Questions (TRQ). They represent which specific questions should the study answer.
2. Quality Assessment (QA). It defines each characteristic that has to be valued for each technical solution. They have to be traced with TRQ in order to answer them.
3. Characterization schema. It is the global result of this first phase. We propose to define a schema where each QA is represented. This schema has to be instanced and completed for each technical solution under study.

At the end of this phase, the team has to get a characterization schema similar to a check list, where each QA is represented in order to answer each TRQ.

PHASE II. Conducting the review

In this phase three different activities must be executed:

Activity 1. Preparing the search. At this point, the team has to define two different tasks:

1. To establish which search criteria will be used.
2. To establish which search sources will be applied.

According to the search criteria definition, we propose to follow the instructions referred in [17]. Search criteria have to be oriented to answer TRQ defined in Phase I.

With regard to search sources, it must be stated that the research search engines used in a SLR, such as ACM Digital Library, IEEE Xplore, ISI Web of Knowledge and so on, are obviously valid in a technical context. However, if we analyze the current situation of technical solutions, we assume that the use of other sources, such as Google or community blogs, among others, is completely necessary.

Activity 2. Executing the search. The search will take place, once the most suitable criteria and sources are defined.

Including other search sources, like Google or blogs, can increase the number of results to a greater extent than only focusing on research search engines. In any case, this activity has to be executed so many times as required in order to delimit which technical solution has to be considered.

Sometimes, it can be very useful to re-analyze the QA defined in Phase I, because they are too ambiguous or concrete, which is likely to provoke two dissimilar consequences; that a large number of technical solutions or none of them can be found.

Another technique that can be useful to delimit the set of technical solutions under study is the analysis of the functional context. We have to keep in mind that our approach is oriented towards comparing technical solutions for a specific problem. Thus, the team could discuss with functional users the set of QA and technical solutions found in order to analyse their suitability for the concrete functional context.

Activity 3. Comparative evaluation of ECM systems. The characterization scheme obtained from Phase I has to be instanced in each approach, after the technical solutions under study (TUS) have been defined.

However, we propose that the team execute another activity before instantiating the schema in order to evaluate the technical solutions.

It is usual to find characteristics that depend on the person who carries it out in the technical evaluation. For instance, usability depends on final users expertise. For this reason, this activity should be divided into three tasks:

1. To define evaluation teams. Studying the set of characteristics, we propose to define the group of people who has to assess each of them. Thus, evaluation subset can be defined in order to obtain different point of views. As it is presented in our example, for instance, we have three different evaluation groups, depending on their expertise on ECM solutions.
2. To instance the schema for each approach in every evaluation group. They, independently, have to value each characteristic in the schema for each TUS.
3. To consolidate the results. After the independent valuation, evaluation teams must arrange a meeting to analyze the individual results and agree a common and unique consolidated result for all evaluation groups.

PHASE III. Reporting

The last phase requires the active participation of the functional team. In this phase, the results obtained from phase II are compared and studied, and each TUS is analyzed in detail in comparison with the rest of TUS.

Using a characterization schema is essential for this phase because it offers a concrete and similar assessment for each approach. The evaluation team can compare every TUS using the same criteria and vocabulary for each of them, which helps setting the final conclusions.

Final reports of the comparative study must be issued at this phase.

4. An Example

The review has been conducted for an effective characterization of ECM systems. We have multiple criteria to calculate the preferences the characterization scheme elements demand. Thus, it is a multi-objective optimization problem, for it is not only important to implement the most valuable ECM system, but also to reduce cost, risk and incertitude.

We will explain how the ECM systems have been analyzed and evaluated and how the comparative evaluation has been carried out.

The guidelines for the systematic review have been explained in previous section. Nevertheless, this proposal initially centers on the systematic review of research studies. For this aim, we have adapted this proposal to focus on studies of ECM systems and all those related fields. A SLR essentially involves three phases: (i) planning the review, (ii) conducting the review and (iii) reporting the review.

- The stages associated with planning the review are: identification of the reviewer's needs, specification of the research question(s), development and evaluation of a review protocol.
- The stages related to conducting the review are: identification of the research, selection of primary studies, study of quality assessment, data extraction and monitoring, and data synthesis.
- The stages concerning reporting the review are: specification of dissemination mechanisms, formatting the main report and evaluation of that report.

The planning phase has two main goals; on the one hand, deciding on which method will be used to conduct the review and on the other hand, identifying and formulating the thesis that the systematic review will prove. Regarding the first goal, as stated above, the method proposed by Kitchenham et al. [13] will be followed, but taking in consideration other authors like Zhang et al. [20] [21], Da Silva et al. [4] and Wohlin and Prikladnicki [19]. Nevertheless, with this systematic literature review, this work aims to answer the next questions in relation to the second goal.

- *Question 1.*- What ECM systems currently exist in the market and what do they offer?
- *Question 2.*- How ECM systems can be adapted to the general guidelines of the Andalusian Public Administration?

- *Question 3.*- What is the most appropriate ECM system the Andalusian Public Administration, and more specifically, the Contracting Services for Transport and Infrastructure Constructions must use?
- *Question 4.* - What areas of improvement are needed for the selected ECM system?

A large number of identified search keywords picked up from these questions have been used in the review process. Some of them are: “Solutions for Managing Enterprise Contents”, “ECM in Real Environment”, “Software for Managing Document Processes”. In addition, the following databases have been considered in the systematic literature review: ACM Digital Library, Ei Compendex, IEEE Xplore, ISI Web of Knowledge, Science Direct, SCOPUS, Springer Link and Wiley InterScience Journal Finder.

Once all planning phase goals have been achieved, the revision process enters in the review phase, which consists in finding and evaluating the adequacy and relevance of many primary studies associated with the research questions as possible sources for further analysis. The primary studies will be searched through the aforementioned databases by means of our keywords. Then, a strategic plan for evaluating the adequacy and relevance of the studies is needed after the search is executed.

Firstly, keywords are looked for each logical criterion in the search field included within the aforementioned databases. Secondly, the set with the previous primary studies is reduced according to the following inclusion criteria:

- (a) The primary study must have been published in the last four years, that is, from 2010 to 2013 (both included). This exclusion criterion is considered realistic and acceptable in the context of this work, because the number of ECM systems and versions has increased in the last years. Therefore, the selected primary study must be recent in order to infer useful conclusions.
- (b) The paper must focus on Computing Science.
- (c) The paper must have been published in any influential magazine (for instance, JCR or Journal Citation Reports).

Thirdly, a new discrimination has been conducted by means of a fast reading of each primary study. That means, the title theme of the primary study must be linked to the topic of this work. For example: «ECM», «Enterprise Contents Management» or «Document Process». Once this condition was satisfied and this primary study cataloged as promising, the introduction and abstract must mention the goals of the research questions posed in this section.

Finally, after carrying out this review, we have neither found concrete solutions for ECM systems nor studies on them. In contrast, we have discovered some work associated with theoretical proposals in the context of ECM systems. Therefore, classic search engines and the Internet have been selected in order to carry out a specific survey of this type of systems. In addition, we have also considered the last Gartner’s analysis concerning Enterprise Content Management. Gartner [7] is an international research and consulting company dealing with Information Technology. This study is popularly known as Magic Quadrant and was presented in October 2012. It consists in evaluating 15 weighted criteria that are based on their relative strengths in the market. They depict markets by using a two-dimensional matrix that evaluates vendors according to their completeness of vision and ability to execute. Moreover, in this second search, we have considered several pre-selection criteria.

After this second search and in accordance with Gartner’s Magic Quadrant for ECM, we will evaluate the following systems (in alphabetical order): Alfresco [2], Documentum [5], Nuexo/Athento [14], IBM FileNet [8] and OpenText [15].

According to all these analyzed systems and the strategy that we will follow, we propose a set of preferences for each element of the characterization scheme that has been defined (we will cope with this definition in the next section). For instance, the weighting established by Gartner for basic functionalities listed above is: Document Management: 0.15, Document Imaging / Image-processing applications: 0.18, Workflow / BPM: 0.22, Records Management: 0.13, Web Content Management (WCM): 0.7, Social Content / Collaboration: 0.15 and Interoperability / extended components: 0.10.

Thus, following Gartner’s criteria, this set of preferences will be defined to adapt the characterization scheme to our project scope. Taking into consideration that we are looking for

the most complete system, the rest of preferences will be thought as important as each set of elements.

The characterization scheme is understood to encompass all the relevant characteristics to analyze ECM systems. We have defined basic characteristics following the recommendations of SEG research group defined in [17] to establish an objective comparative framework. The goal of this paper is to introduce the methodology for performing rigorous reviews of existing empirical evidences into the software engineering community. The advantages of defining these characteristics are to present and evaluate schematically and homogeneously each of the solutions under study. Moreover, this characterization scheme allows setting each evaluation criteria in a clear, concise and unified way.

Our characterization scheme is composed of ten prioritized features, which answer the questions defined in the previous section. This priority is contextualized within the needs of our project: to define an innovative solution for document management applied to procurement of services and transport infrastructure projects within the Regional Government of Andalusia (Spain). Below, we illustrate this characterization scheme: Features (FT) and their Sub-Features (SF).

FT01: Functional modules. The results obtained in the characterization schema Strategy phase point out that a valid ECM system must include natively and minimally the following functionalities. Next, we describe the Sub-Features of this Feature: *SF01*: Document Management, *SF02*: Records Management, *SF03*: BPM (Workflow/ Business Process Management), *SF04*: Document Imaging/ Image-processing applications, *SF05*: Interoperability functions/ extended components, *SF06*: WCM (Web Content Management) and *SF07*: Social content/ collaboration.

FT02: User Orientation. Although ECM systems offer standard solutions on its orientation towards the end user, many companies need using easy and versatile systems because not all their employees have the same user profile to handle computer tools. Next, the Sub-Features of this Feature are described below: *SF01*: Usability compliance, *SF02*: Accessibility, *SF03*: Document preview, *SF04*: Drag & Drop, *SF05*: Bulk uploads, *SF06*: Undo, *SF07*: WYSIWYG Editor (What You See Is What You Get), *SF08*: Customization, *SF09*: Groups and Social networks and *SF10*: Multilanguage.

FT03: Functionality to capture, access, retrieve and view documents. The ability to capture, access, retrieve and display, within the group, includes those features that let anyone customize the system according to the preferences of users or the organization being implemented. Next, we describe the Sub-Features of this Feature: *SF01*: Degree of Cataloguing, *SF02*: Agrupation, *SF03*: Thesaurus Support, *SF04*: Digitalization, *SF05*: Bulk Upload, *SF06*: Content Generation, *SF07*: Office Integration, *SF08*: Forms and Templates, *SF09*: Integration Forms Managers, *SF10*: Advanced Search Methods, *SF11*: Search Algorithms and *SF12*: Display Formats.

FT04: Documental Life Cycle. This Feature enables us to assess the level or degree of support the system offers to the document cycle. Next, we describe the Sub-Features of this Feature: *SF01*: Check-in Check-out, *SF02*: Life cycle, *SF03*: Versioning Support, *SF04*: Actions traceability, *SF05*: Inconsistencies management, *SF06*: Dissemination management, *SF07*: Conservation, *SF08*: Destruction and *SF09*: Physical actions.

FT05: Workflows. This Feature can assess whether the tool supports management with business processes. Next, we describe the Sub-Features of this Feature: *SF01*: Supported standards, *SF02*: Management support, *SF03*: Available options, *SF04*: Motorization, *SF05*: Simulation and modeling, *SF06*: Graphical utilities and *SF07*: Task management.

FT06: eGovernment. Measuring the support and features involving eGovernment is essential, given the context in which this project is developed. This group of features measures the degree of support offered in this context. Therefore, we can evaluate whether the system allows accessing and using valid electronic documents according to the Spanish National Interoperability Scheme guidelines. The Sub-Features of this Feature are described below: *SF01*: Electronic documents, *SF02*: Digital signature, *SF03*: Accreditation and representation, *SF04*: Indexes support, *SF05*: Unique identification, *SF06*: Minimum metadata, *SF07*: Classification plan support and *SF08*: Official time synchronization.

FT07: Interoperability Compliance. A specific section dealing with interoperability has been included: Integration with tools. This Sub-Feature evaluates whether the ECM system provides mechanisms (e.g. APIs) to integrate with third-party tools. Next, we describe the Sub-Features of this Feature: *SF01*: Connection, *SF02*: ERPs, *SF03*: Capture tools, *SF04*: Email, *SF05*: CMIS repository, *SF06*: Web services, *SF07*: Single window, *SF08*: Electronic record, *SF09*: Records manager, *SF10*: Electronic files, *SF11*: Digital signature, *SF12*: EAI and *SF13*: Streaming.

FT08: Security and Control. One of the major objectives of document management solutions is to ensure information security, by controlling access to the system from inside and outside the organization and manage the documents including such information either to archive or destruct them. Consequently, these solutions must provide services that ensure that the information stored is secure. It evaluates whether the system is functional enough to analyze data, or otherwise, whether the system allows using third-party tools. Next, we describe the Sub-Features of this Feature: *SF01*: Exportation, *SF02*: Data Analysis, *SF03*: Activity indicators, *SF04*: Granularity, *SF05*: LOPD, *SF06*: Logs. *SF07*: SSO and *SF08*: Notifications.

FT09: Architecture. Open architecture. It evaluates whether the system has an open architecture (i.e., the system allows adding, upgrading and changing its components) or a closed architecture (i.e., the software manufacturer chooses the components, and the end user does not intend to upgrade them). Next, we describe the Sub-Features of this Feature: *SF01*: Open architecture, *SF02*: Browsers, *SF03*: Mobility, *SF04*: Development kit, *SF05*: Cloud solution, *SF06*: Administrative capabilities, *SF07*: Programming language, *SF09*: Multiplatform, *SF10*: Extensibility, *SF11*: Volumes, *SF12*: High availability and *SF13*: Scalability.

FT10: Cost. Cost (both initial and long-term by maintenance) is one of the most important factors any organization must take into account when choosing an ECM solution. Next, we describe the Sub-Features of this Feature: *SF01* Licenses, *SF02* Infrastructure, *SF03* Open source, and *SF04* Maintenance and support.

FT11: Assistance and RM (Roadmap) Support. This last Feature listed in the latter group includes aspects for the evaluation of the Characteristics support, assistance and roadmap provided by the ECM solution. Next, we describe the Sub-Features of this Feature: *SF01* Certification program, *SF02* User Manuals, *SF03* Service support, *SF04* Formation service, *SF05* Roadmap and *SF06* Manufacturer online assistance.

Along this first iteration, lots of new trends were sensitive of being included in the characterization. In fact, we started the project just considering Alfresco [2], Documentum [5], IBM FileNet [8] and OpenText [15]. Then, in a second iteration we included Nuxeo/Athento [14] and KM [16]. Nevertheless, KM was discarded in the characterization phase because this system did not comply with our project scope purposes, thus Nuxeo/Athento was finally considered.

In the THOT project, we needed to decide what ECM system was the most suitable for our project scope (Andalusian Public Administration, in Spain). As a result, we defined our characterization scheme and each set of preferences for our characterization scheme elements. Therefore, we used a Quality Evaluation Framework (named QuEF) [6] for analyzing and evaluating ECM systems. Moreover, QuEF provides a flexible and efficient solution based on a Web environment, so that organizations can choose the most suitable ECM system for their purposes as well as enforce the quality continual improvement of these systems in the organization.

In the QuEF framework, we used this weighted characterization scheme as a quality model in order to analyze and evaluate the different systems. Thus, in this framework, the quality model was used to manage the comparative evaluation of ECM systems, which were analyzed by means of checklists. These checklists were artifacts generated automatically by the tool support of QuEF, which contained all Features and Sub-Features that we defined to analyze an entity. Consequently, we used all these checklists in order to know the current state of an ECM system and select the most suitable one.

5. Conclusions and Future Work

This paper presents the results of a research project that has been carried out in a real environment. The THOT project is an e-Government project that aims to implement an ECM system in the Andalusian Public Administration, in Spain.

This paper focuses on the first stage of the project and explains how the technological and functional status of ECM systems has been studied. Strategically, it is very important to evaluate all existing alternatives in the market in order to align the scope and purpose of the organization. Besides, a static evaluation is not enough because new improvements to existing systems are continuously appearing and it is necessary to be able to compare alternatives dynamically and objectively. In addition, we have to consider different preferences of the elements that contain an ECM system in terms of our specific context.

The THOT project challenges to innovate research. Although our research group (the Web Engineering and Testing Early, IWT2) has already worked and has mature experience in many aspects of the project, the integration of all the elements into a project of this size and the ability to validate research results and transfers arouse interest to the user and provide elements that will enhance the future work of this research group.

Finally, the project tends to solve the environmental problem by applying principles of e-Government in the public procurement activity, promoting the conversion from paper to electronic media in written communications between managers as well as an efficient and effective strategy with the consequent socioeconomic impact.

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References

1. AIIM: The Global Community of Information Professionals (2014), <http://www.aiim.org/>, Accessed February 2014.
2. Alfresco, <http://www.alfresco.com>. Accessed December 14, 2013
3. Brereton, P., Kitchenham, B.A., Budgen, D., Turner, M., Khalil, M.: Lessons from Applying the Systematic Literature Review Process Within the Software Engineering Domain. *The Journal of Systems and Software* 80(4), 571-583 (2007)
4. Da Silva F.Q.B., Santos A.L.M., Soares S., França A.C.C., Monteiro C.V.F., Maciel F.F.: Six years of systematic literature reviews in software engineering: An updated tertiary study, *Information and Software Technology* 53 (9), 899-913 (2011)
5. Documentum, <http://www.emc.com/domains/documentum/index.htm>, Accessed December 14, 2013
6. Domínguez-Mayo, F.J., Escalona, M. J., Mejías, M., Ross, M., Staples, G.: A Quality Management Based on the Quality Model Life Cycle. *Computer Standards & Interfaces* 34(4), 396-412 (2012)
7. Gartner: Company is based in Stamford, Connecticut, USA, <http://www.gartner.com>, Accessed July 5, 2013
8. IBM FileNet, <http://www-03.ibm.com/software/products/us/en/filecontmana/>, Accessed December 14, 2013
9. Kitchenham, B.A.: Procedures for Performing Systematic Reviews. Technical Report TR/SE-0401 and NICTA Technical Report 0400011T.1, Keele University (2004)

10. Kitchenham, B.A., Charters, S.: Guidelines for Performing Systematic Literature Reviews in Software Engineering, Version 2.3, EBSE-2007-01. Department of Computer Science, University of Durham, Durham, UK (2007a)
11. Kitchenham B.A., Mendes, E., Travassos, G.H.: Cross Versus Within-Company Cost Estimation Studies: A Systematic Review. *IEEE Transactions on Software Engineering* 33(5), 316-329 (2007b)
12. Kitchenham B.A., Brereton O. P., Budgen D., Turner M., Bailey J., Linkman S.: Systematic literature reviews in software engineering – A systematic literature review, *Information and Software Technology* 51(1), 7-15 (2009)
13. Kitchenham B.A., Brereton P.: A systematic review of systematic review process research in software engineering, *Information and Software Technology* 55(12), 2049-2075 (2013)
14. Nuxeo/Athento, <http://www.athento.com/nuxeo/>, Accessed July 19, 2013
15. OpenText, <http://www.opentext.es/>, Accessed December 14, 2013
16. SAP KM, <http://www.architectsap.com/blog/sap/sap-enterprise-portal-sap-netweaver-knowledge-management-sap-km/> Accessed December 14, 2013
17. Software Engineering Group (SEG): Guidelines for Performing Systematic Literature Reviews in Software Engineering, Version 2.3. EBSE Technical Report, EBSE-2007-01. School of Computer Science and Mathematics, Keel University and Department of Computer Science, University of Durham (2007)
18. Staples, M., Niazi, M.: Experiences Using Systematic Review Guidelines. *The Journal of Systems and Software* 80(9), 1425-1437 (2007)
19. Wohlin C., Prikładnicki R.: Systematic literature reviews in software engineering, *Information and Software Technology* 55(6), 919-920 (2013)
20. Zhang H., Babar M.A., Tell, P.: Identifying relevant studies in software engineering, *Information and Software Technology* 53(6), 625-637 (2011)
21. Zhang H., Babar M.A.: Systematic reviews in software engineering: An empirical investigation, *Information and Software Technology* 55(7), 1341-1354 (2013)

Extending Swarm Communication to Unify Choreography and Long-lived Processes

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Abstract

The usual way of doing message passing is to have relatively intelligent processes, objects or actors sending and receiving dumb messages. Swarm communication presents the inverted approach of thinking to messages as relatively smart beings, visiting relatively non intelligent places, to produce better code and a new path for integrating complex applications. Swarm communication can be used as software architecture for an Enterprise Service Bus. This paper extends the swarm communication to support long-lived processes, providing an alternative approach to the standard techniques for executable Business Process Management. The ubiquity of connected devices is a fertile ground for new approaches to application development and systems integration based on complex business processes.

Keywords: Long-lived Processes, Communication Pattern, Message Passing, Asynchronous Communication.

1. Introduction

Combining services to create higher level, cross-organizational business processes, requires pragmatic approaches to model the interactions. Existing standards for service oriented architecture [5] and formalized workflows [19], are used by big companies on big projects but are quite complex and expensive for smaller companies because of the number of required skills. Therefore, many applications are still created with a monolithic architecture and by hard coding business processes in imperative code. Specific languages to describe long-lived processes, orchestration technologies are not in the toolbox of the typical programmers. The growing popularity of micro-services [10], a style of software architecture that involves systems based on a set of very granular and independent collaborating services, require new approaches and pragmatic languages for integration, coordination and orchestration. Ideally, one new language that could solve all the aspects of integration, coordination and orchestration without involving a big learning curve for existing programmers could have huge economic benefits and a large adoption. We already proposed swarm communication as a new type of distributed programming technique in [1]. Swarm communication is an asynchronous message programming pattern. Also, our proposal includes an architecture created for software integration, especially an architecture for doing choreography in an ESB (Enterprise Service Bus) [4]. In our swarm model, our vision over orchestration and choreography match with those presented in [18] "Orchestration differs from choreography in that it describes a process flow between services, controlled by a single party. More collaborative, choreography tracks the sequence of messages involving multiple parties,

where no one party truly "owns" the conversation." Commonly, BPM (Business Process Management) technologies [6] are deployed in ESBs as a service connected to the BUS and they perform orchestration. In this article we show how we can extend the swarm communication to model also long-lived business processes [18], the kind of process that are usually implemented using BPM technologies like BPEL. We use long-lived processed term as expressing the most important aspect of workflow concept used in software systems. By providing a usable high level abstraction and possibility to express long-lived processes in a choreography language, we can replace the use of other orchestration components, significantly simplifying the programming efforts for SOA implementations.

In the next section we will make an overview of swarm concepts and constructs. Also, we will describe our Domain Specific Language [7] for swarms and we provide an implementation sample. In Section 2, we provide the most relevant technical details regarding swarms that help us to argue in Section 3 a new method for modeling long and short-lived processes using swarm communication. This paper finalizes with a section of conclusions and a list of references

2. Swarm Concepts and Constructs

2.1 Overview and the Context

Swarm communication brings a new perspective in the same area where we find well known models such as: actor model [10, 11], Message-Oriented Middleware (MOM) [3] or communications patterns found in systems like ZeroMQ [12] and Enterprise Integration Patterns [13]. According to [21] MOM is a middleware infrastructure that provides messaging capabilities. Our approach, as MOM, reduces the application developers' effort, but is different in terms of communication mechanism.

Programming with asynchronous messages is performed intuitively by using "send" and "receive" primitives or by setting the behavior of the actor on the next message received in the actor model and derivatives. Almost all practical approaches as programming with call-backs, OOP, Scala [16], Erlang [14], observer patterns [9] can be seen as derivatives of the formal actor model. We have shown in [3] that programming with asynchronous messaging can be made by describing chains of message transmissions with behaviors associated for each message transmission, instead of associating behavior within the receiving actor. In our approach an entity that receives messages (actors in usual terminology) still exists but an actor behaves like an idempotent service and not as an active communication participant that changes its state after receiving a message. The simple act of describing the behavior within message and not within actor description can have beneficial practical implications in code maintenance. The behavior is not scattered along multiple actors but in a single place. This way is easier to describe a program that can run in many distributed nodes. While theoretical research on mobile code [2] and on systems for asynchronous calculus exists by many years, our proposal is a practical approach that can be appealing for programmers used to program in mainstream languages Java, C#, Java Script, et al. and that will not easily switch to research programming languages (actor inspired languages, pi calculus et al.).

With swarms, the messages themselves have a long time identity during multiple communication events and an existence during complex communication processes. Messages are changing their state after each communication step.

In all other approaches a message does not have identity or associated behavior. Furthermore identity, state changes or behaviors are associated only with the message receivers (actors). This is the main conceptual difference of our proposal compared with the actor model.

In our vision, a swarm is a set of related messages with some basic intelligence and is based on an intuitive point of view: computer processes communicating by asynchronous messages are more like "dumb trees/flowers" visited by "smart swarms of bees" than "smart nodes" communicating with "dumb messages". In our approach, as we can see in the next

section, we make a rigorous identification of communication phases, and this communication became a choreography which ensures an overall effect on system and not just a simple communication through messages.

2.2 Concepts and Constructs

Swarm communication intends to keep the benefits of asynchronicity such as scalability, high availability, highly parallel computing and loose coupling, while decreasing the complexity and associated costs. A communication use-case can be viewed as a set of complementary messages which are sent in the distributed system to accomplish a “goal”. This set of complementary messages, represented by a swarm, represents the flow of communication between some nodes in a distributed system when a use case happens.

Below we describe the main concepts and constructs that are involved in swarm communication. Any software entity that can be seen as receiving or sending swarm messages represents a *node*. A node is talking to another node by sending a swarm. When we talk by a node sending a swarm we mean that it sends a message that is part of the set of swarm messages. Nodes are materialized by client applications, adapters for existing server-side applications or swarm service providers. In our system we distinguish two types of nodes:

- *Adapters* are server side nodes that provide some services or APIs for an existing application or systems (e.g. ERP, CRM, etc.). Swarm service providers are considered also adapters because usually they use some other low level services (such as NoSql databases, message queues, et al.)
- *Clients*: all applications that communicate by sending swarm messages, excepting adapters, will be called *swarm clients* and are logically connected to an adapter by communication protocols created over TCP sockets or other protocols. In our current experiments we have three possible platforms available: Action Script (Flex) clients, node.js clients and web sockets clients from browser and REST clients. [20]

In order to describe swarms in our implementation we proposed Swarm DSL as a Domain Specific Language. For syntax description we used Backus-Naur Form notation. Swarm DSL is an internal DSL [10] so all Java Script syntactic and semantic rules should be considered. By using an internal DSL we can benefit from existing tools for debugging, IDEs (Integrated Development Environment) and programming expertise, therefore we reduce adoption risks for this new technology.

SwarmDSL language is presented below:

```
swarmDescription ::= "{" meta", "list" } " ", "list" }"
list              ::= declaration { ", " declaration }
declaration      ::= vars | function | phase | ctor
meta ::= "meta" ":" "{" property { ", " property } }"
vars ::= "vars" ":" "{" property { ", " property } }"
function ::= identifier ":" " "
           function(" varArgs ") "{" code }"
phase ::= identifier ":" "{" node", "phaseCode }"
ctor  ::= function
varArgs ::= "" | identifier { ", " identifier }
phaseCode ::= "function()" "{" code }"
property ::= identifier ":" string | identifier ":" identifier
node      ::= "node" ":" nodeName
nodeName ::= "" "#" innerNodeName "" | "" wellKnownNode ""
           | "" "@" groupName ""
```

Therefore, a swarm description can contain four construction types:

-*vars* section in swarm description is a way to document and initialize the variables used by the swarm messages

-*swarm phases* represents the swarm progress towards accomplishing a goal. Such phases contain applications code that change the internal variables of the swarm or the state of the adapters in which the swarm got executed. It is important to notice that the phase’s code is

not part of the adapter, but code of the swarm itself, even if it is executed in the context of the adapter. Except that having a name (*phase name*) and a node hint (an indication of the node where the swarm should be executed), a phase is the behaviour (code) that should happen (execute) when a message is received by a node (adapter). A single swarm can execute code concurrently in multiple nodes and therefore multiple phases can be concurrently “alive”. Swarm variables are not automatically shared between those concurrent executions, remaining to programmers exercise to implement communication between swarms.

-*meta variables* are special variables that are reflecting the current execution of the swarm and can be handled by programmers to influence or control the execution of the swarm in various ways.

- *functions and Ctors*: *Ctor functions* or *ctors* are functions that are called when a swarm is started (similar to constructors in OOP languages). A *ctor function* will initialize the swarm variables and will start swarming in one or multiple phases. Normal functions are utility functions made available to swarms’ code for a greater modularity and code reuse between phases: *swarm()*, *startSwarm()*, *startRemoteSwarm()*, *home()*, *broadcast()* *et al.* In the context of this article we will do an overview only of *swarm()* primitive. We can view the swarm call as same as with Unix fork [17] for the current swarm abstract process because variables are duplicated. Therefore when a new child swarm is born in the context in which a swarm is a collective entity and not an individual entity, we can consider this new child swarm as part of the current swarm. The state of current execution of the swarm, at the moment of the call, is serialized and a message is sent to another node requesting execution of a specific phase to take place there. The node, where this new child swarm will continue, is decided by looking at the phase declaration. The parent swarm can continue to call the swarm primitive as many times as necessary or eventually it will end the execution.

In our DSL each node has a unique identifier in the system that we usually refer as *node name*. As described in BNF grammar, *nodeName* can have three possible values. *Inner* nodes are using resources from a normal node but they do not have any visibility outside of that node. Sending a swarm to an *inner* node does not produce network traffic. Sending a swarm to an inner node is exactly like sending the swarm to the current node, this feature can be used during development for comparing execution times between remote and local communication or when one plans what services (adapters) are required.

wellKnownNode can take as value a well-known node name. Such nodes represent the infrastructure nodes for our application (e.g. *Core* - the node that is the source authority for all swarm descriptions, *Logger* - the node where are stored logging information from all nodes, *SessionManager* that is responsible for managing nodes that keep information about sessions).

Well known nodes can be problematic for scalability (on high load could cause bottlenecks) and can be used for a while till the load increases and should be replaced by groups of nodes. Therefore to enable load balancing, replication and high availability we have introduced the concept of *groups*. Each adapter can join a number of groups by using a *join()* primitive. By joining a group a node becomes accessible to nodes that know the group name but are not aware of its name.

In our grammar we assume that *identifier* and *code* are valid JavaScript identifiers and respectively valid JavaScript source code that can appear in valid Java Script functions.

2.3 Swarm Example

In this section we present a “swarmified” Hello World example using Swarm DSL:

```
helloWorldSwarm={
  vars : { message : "Hello World" },
  meta:{ debug : false },
```



```

start : function(){ this.swarm("concat");}
concat : { //begin phase
  node : "Core",
  code : function (){
    this.message = this.message + "The swarming has begun!";
    this.swarm("print"); }},
print : { //print phase
  node : "Logger",
  code : function (){
    console.log(this.message);}, }
}

```

In this example the swarm execution contains two phases: *concat* and *print*. The phase's execution is performed in two different nodes *Core* and *Logger*. These nodes are different processes, possibly located on different machines, depending on system configuration. A swarm starts through a *ctor* execution and this can be done on any node of the system. For our example, the constructor is called *start* and his role is to lead the swarm in *concat* phase using the *swarm()* primitive. According to our discussion from section 2.2, as we can notice in our example, each phase declaration has two components: *node* and *code*. In *node* we specify the location where the phase will be executed. To exemplify concurrency we should understand that even if a new phase is running, the current phase could still exist for a while. Of course, the variables in these two concurrent phases are not shared (are just copies) but this mechanism usually serve us well without any risks of interferences or performance penalties. In this article we will not go into further details of implementation, but we want to exemplify the business use cases for integration and long-lived business processes.

3. Extending Swarm Choreography with Long-lived Processes

We have already explained how swarm communication could be useful to create business process for software integration use cases. Before this paper, swarm communication were envisioned as short-lived processes that visit various nodes (adaptors) and the use cases of long-lived processes were not swarms' concern. The obvious method in obtaining long-lived processes with swarms is to save the state of a swarm message until some specific event or change happens. When such event appears, the swarm is awaked in a form of a message that gets sent and the desired phase will be executed. To preserve scalability and to have control on error management, we decide that swarm persistence should not be available to all nodes, but only in dedicated nodes that perform only this thing. We consider for this proposal an adapter named SwarmBPM is in charge with persisting in a waiting list all the swarm messages used for representing steps in long lived processes.

We are aware that BPM technologies can have three different directions: human-centric BPM, integration-centric BPM and document-centric BPM and we present in this article results that can cover the software architecture aspects for creating systems for these directions. If various automated business events or human interaction with business processes are reflected in software, we can safely assume that they change the state of some identifiable resources accessible for SwarmBPM adapter. Such resources will be formalized in our proposal as *global objects*. A global object is identified by a *global type* (a string that can be a schema URI or other similar identifier) and a unique id value. A long-lived process is usually connected to one or more entities (global objects) used in the integrated system (like a document, a command from a customer and any other entities relevant for business processes).

SwarmBPM implements three functions available to swarms: *registerSwarm* (*swarmSerialisation*) persist the swarm message that represents a step in a long-lived process until a relevant event occurs, *globalObjectChanged(objectType, objectId, serialisedValue)* inform the engine that a global object changed its state (some of its properties changed), *wakeUp(swarm)* launch a sleeping swarm and remove from its waiting list.

An infrastructure swarm description named *GlobalObjectChange.js* is used to inform the SwarmBPM on changes in the state of the global objects by calling *globalObjectChanged()* when the state of global objects changes. The components that are launching

GlobalObjectChange.js swarms in execution are usually the persistence layer part of various integrated sub-systems (using Aspect Oriented Programming techniques, database change monitoring or other techniques that are usually used in BPM implementations to create relevant higher level events). Until now, SwarmBPM have a list of sleeping swarms and is notified about changes in global objects. In order to map global objects changes to sleeping processes we extend swarm descriptions with an additional construction: *global* sections.

global sections is an object having as properties objects with two members: *objectTypeName*, *objectIdField*. The *objectTypeName* take as value a string specifying a *global type* and the *objectIdField* specifies the field name in the global object that is used as the *id* of the global object. Those properties are named with the same names as a swarm variable that is available for phase's code.

In order to make the difference between phases used in short-lived processes and those belonging to long-lived processes we extend phase declaration with an optional function declaration named *watch*. We have the convention that a phase that have a watch is sent first to the SwarmBPM and only SwarmBPM can decide to proceed further with the swarm phase execution. The *watch* function is called automatically by the SwarmBPM engine at any state change in an global object from the list of the global objects declared in the global section of the swarm. If the watch function is calling *wakeUp(this)* function then the swarm is awaked and delivered to other adapter. For complex cases requiring coordination between multiple global objects, our extension provide support for implementing complex business rules and complex workflows at the level of integration between services or application modules without other orchestration mechanisms in place.

In the next example, we assume that in the swarm variables we have a *document* variable representing a document instance belonging to a Document Management application and a *crmRecord* belonging to a CRM (Customer Relationship Management) application. This swarm description presents a long-lived process that automatically updates secrecy behavior in a CRM application when the secrecy field in the document permissions is modified in the Document Management.

```

secrecyWatcher = {
  vars: {document:null, crmRecord:null},
  global:{
    document:{
      objectTypeName: 'Document Management/Document',
      objectIdField: 'documentId'},
    crmRecord :{
      objectTypeName: 'CRM/RelatedDocument',
      objectIdField: 'relatedDocumentId' }},
  createCRMSecrecyProcess:function(document, crmRecord){
    //launched once for every document
    this.document      = document;
    this.crmRecord     = crmRecord;
    swarm("establishDocumentSecrecyInCRM");},
  establishDocumentSecrecyInCRM:{
    node:'CRM',
    watch: function () {
      if (!this.savedDocument ||
          this.document.isSecret != this.savedDocument.isSecret) {
        //the document has a changed status about secrecy
        wakeUp(this); //wake up and execute this phase },
    code: function () {
      //update the state using the API provided by the CRM adapter
      crmApi.makeUpdateRecordSecrecy(this.crmRecord,
        this.document.isSecret);
      //save the document for future comparations
      this.savedDocument = this.document;
      this.savedDocument.isSecret = this.document.isSecret;
      // keep the process alive, watch for future changes in secrecy
      swarm("establishDocumentSecrecyInCRM"); }}}

```

The previous example can be also interpreted as a business rule, implemented as a long-lived process at the level of the ESB. When the business analysts are more inclined to model business processes as rules and not as long-lived processes, the swarm descriptions will have a circular structure to keep the rule active as in above example. Complex cases could be eventually accompanied by another level of modeling the logic and dependencies in global objects belonging directly to SwarmBPM using the data structures and imperative or functional code.

4. Comparison with Existing Approaches

There is no shortage of standard techniques and programming models for integration (Enterprise Integration Patterns), orchestration (WS-BPEL) and various workflow programming models (as executable Business Process Management), choreography (WS-CDL). The swarm communications and the extension proposed in this article, offers a unified programming model that is capable to tackle all these aspects. These unifications provide a new programming technique with low learning curve for creating systems that have the benefits of being scalable in performance, flexible in adding or removing components, having a loosely coupled design. Mastering all the existing different techniques for integration, orchestration, choreography and composing them in a distributed system takes years of study. With swarm communication we envision that we can get the same benefits after only a few weeks of learning. With less than ten new concepts that are based on an intuitive abstraction over asynchronous messages, the learning curve for swarm communication is an order of magnitude lower. The number of concepts of the stand technologies compared with the number of concepts proposed by swarm communication represents a good indicator for the learning curve. Mastering EIP concepts alone require understanding of at least 56 abstract concepts [13].

Swarm communications provide the additional benefit of reducing application development efforts, because provides a natural environment for creating and composing microservices [8]. Microservice architectural style is an approach to develop applications as a suite of small services, each running in its own process. Microservices can be created independently by different teams with different technologies and can be tested in isolation. Redundancy and recovery from failures can be more easily implemented because the application is broken in small, independent processes. Heterogeneous systems integration and implementations of business processes and business rules can be performed by swarm communication between processes (called adapters) that are holding microservices.

5. Conclusions

This paper presents swarm communication as an alternative representation of asynchronous message communication in a distributed system. We emphasize that swarms are not only a set of related messages but a powerful mechanism to describe short and long-lived business processes. A swarm can be regarded as a choreography mechanism for services or adapters located in a distributed system. Apart of performance and scalability benefits obtained by having asynchronous messages at runtime, a swarm description is an abstraction that will provide a single place where complex processes get described. Swarm based systems are constructed as two definite layers: infrastructure source code found in swarm adapters and code implementing rather ephemeral integration and business process requirements. Thus we will maintain the original architectural clarity even in the presence of numerous business changes in requirements that is an expected reality in the applications lifetime. The source code in swarm adapters is an instance of following Open/Closed principle [15] which is an important predictor for reducing costs in development of the software systems.

As in any distributed system, failures can be a problem for swarm communication too. Redundancy and fail recovery support in our implementation consists now in an experimental mechanism that is based on the idea that the node sending a child swarm waits for a confirmation. This mechanism will be extended and future studies of the swarm systems in

the presence of failures will be conducted. In this paper we are extending the swarm communication to support long-lived processes and we opened also an opportunity to study distributed transactions for swarm based systems.

References

1. Alboaie, L., Alboaie, S., Panu A.: Swarm Communication - a Messaging Pattern proposal for Dynamic Scalability in Cloud. In: Proceedings of the 15th IEEE International Conference on High Performance Computing and Communications (HPCC 2013), Zhangjiajie, China, (2013)
2. Carzaniga, A., Gian Pietro P., Vigna, G.: Designing distributed applications with mobile code paradigms. In: Proceedings of the 19th international conference on Software engineering, ACM, (1997)
3. Curry, E., Chambers, D., Lyons, G.: Extending message-oriented middleware using interception. In: Proceedings of the 26th International Conference on Software Engineering - W18L Workshop "International Workshop on Distributed Event-based Systems (DEBS 2004)", pp. 32 – 37, (2004)
4. Chappell, D.A.: Enterprise Service Bus: Theory in Practice, Publisher: O'Reilly Media, (2009)
5. Erl, T.: SOA Design Patterns, Publisher Prentice Hall, ISBN: 0136135166, 9780136135166, (2009)
6. Fiammante Marc, Dynamic SOA and BPM: Best Practices for Business Process Management and SOA Agility, Publisher: IBM Press, ISBN-10: 0-13-713084-8 (2009)
7. Fowler Martin, Domain-Specific Languages, Publisher Pearson Education, ISBN: 0131392808, 9780131392809, (2010)
8. Fowler Martin, <http://martinfowler.com/articles/microservices.html> (2014)
9. Gert, F., Meijers, M., Pieter Van Winsen: Tool support for object-oriented patterns, Object-Oriented Programming. Springer Berlin Heidelberg, 472-495, (1997).
10. Hewitt, C.: Actor model of computation: Scalable robust information systems, preprint arXiv:1008.1459, (2010)
11. Hewitt, C., Bishop, P., Steiger, R.: A universal modular actor formalism for artificial intelligence. Proc. of 3rd Conference on Artificial Intelligence, pp. 235-245, (1973)
12. Hintjens, P.: ZeroMQ: Messaging for Many Applications, Oreilly and Associate Series, Publisher O'Reilly Media, Inc., ISBN: 1449334067, 9781449334062, (2013)
13. Hohpe G., Woolf, B.: Enterprise Integration Patterns: Designing, Building, and Deploying Messaging Solutions, Publisher Addison-Wesley, (2012)
14. Kessin, Z.: Building Web Applications with Erlang: Working with REST and Web Sockets on Yaws, Publisher O'Reilly, ISBN 1449309968, 9781449309961, (2012)
15. Meyer, B.: Object-oriented software construction, Vol. 2, New York: Prentice Hall, pp. 331-410, (1988)
16. Odersky, M., Spoon, L., Venners, B.: Programming in Scala, Publisher Artima Inc, ISBN: 0981531601, 9780981531601, (2008)
17. Open Group Base Specifications Issue 6, IEEE Std 1003.1, 2004 Edition, <http://pubs.opengroup.org/onlinepubs/009695399/functions/fork.html> (2004)
18. Peltz Chris: Web Services Orchestration and Choreography, Journal Computer, Volume 36 Issue 10, pp. 46-52, IEEE Computer Society Press Los Alamitos, CA, USA (2003)
19. Sanjiva, W., Curbera, F., Leymann, F., Storey, T., Ferguson, D.: Web Services Platform Architecture: SOAP, WSDL, WS-Policy, WS-Addressing, WS-BPEL, WS-Reliable Messaging, and More, Publisher: Prentice Hall; ISBN-10: 0131488740, (2005)
20. SwarmESB, <https://github.com/salboaie/SwarmESB>, (2013)
21. Qusay, M. (Editor): Middleware for Communications, pub. John Wiley & Sons, ISBN: 978-0-470-86206-3 (2004)

Business Process Event Log Transformation into Bayesian Belief Network

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Abstract

Business process (BP) mining has been recognized in business intelligence and reverse engineering fields because of the capabilities it has to discover knowledge about the implementation and execution of BP for analysis and improvement. Existing business knowledge extraction solutions in process mining context requires repeating analysis of event logs for each business knowledge extraction task. The probabilistic modelling could allow improved performance of BP analysis. Bayesian belief networks are a probabilistic modelling tool and the paper presents their application in BP mining. The paper shows that existing process mining algorithms are not suited for this, since they allow for loops in the extracted BP model that do not really exist in the event log, and presents a custom solution for directed acyclic graph extraction. The paper presents results of a synthetic log transformation into Bayesian belief network showing possible application in business intelligence extraction and improved decision support capabilities.

Keywords: Process Mining, Bayesian Belief Networks, Business Process Analysis.

1. Introduction

Business processes (BP) are the most important aspect of every business as they define an activity or a set of activities that must be accomplished to achieve the organizational goals. Modelling and analysis of the processes is critical in identifying existing processes and understanding the contributions of new processes to the system [1]. An important facility in analysis of BP is the BP simulation. It is an aid to decision making, it helps in risk reduction and helps management at the strategic, tactical and operational levels [4].

Real processes encountered in real systems contain characteristics that make them complex by nature [4]:

- System uncertainty and stochastic nature is at the core of the business and has to be understood and evaluated;
- Dynamic behaviour – business processes tend to change over time;
- Feedback mechanisms – behaviour and decisions made at one point in the process impact others in complex or indirect ways.

While there are many existing solutions for the business process analysis, most of them require a lot of preparation to be capable of obtaining any meaningful knowledge. Existing simulation tools require manual creation of custom simulation models. Analysts have to prepare business process models and manually transform them into custom simulation models annotated with data required for simulation.

Process mining techniques are used to discover and analyze business processes in an automated way. Using all kinds of recorded process data, process mining techniques attempt to automatically discover the structure and properties of the business processes that can be visualized in business process models.

Existing process mining solutions extract information from event logs and, for each business intelligence question, they require to iterate through the log each time. Also, the existing methods often extract models that do not semantically conform to existing processes as they allow transitions between activities that do not exist in the existing business process.

Bayesian belief network based approach could solve these problems, where Business process model is extracted from an event log in the form of directed acyclic graph and annotated with data contained in event log to obtain a Bayesian belief network to facilitate BP analysis and decision making.

The paper is structured as follows: Section 2 provides a high-level view of the overall framework for the proposed approach with the emphasis on the parts reflecting the research presented in this paper. Section 3 formulates a background for the approach by revising process mining principles and theoretical foundation for constructing Bayesian belief networks. Then, Section 4 describes problems with existing process mining algorithms for Bayesian belief network extraction and presents directed acyclic graph extraction of the proposed approach. Section 5 defined Bayesian belief network over extracted directed acyclic graph and its event log and Section 6 presents experimental results of an exemplary case. Section 7 provides some insights on the validity of the approach. The paper concludes with related works in Section 8 and conclusions with future research in Section 9.

2. Proposed Approach

This research focuses on transformation of event logs into directed acyclic graph and then into Bayesian belief networks. The algorithm is presented in Fig. 1.

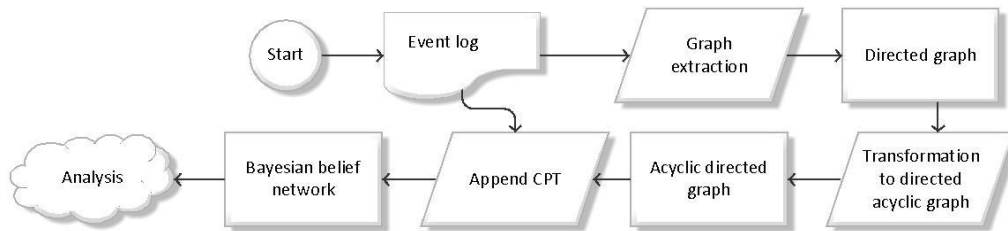


Fig. 1. Algorithm for event log transformation into belief network

The proposed approach starts with an event log (for details, see 3.1) extracted from existing information systems. The steps of the approach are:

1. Graph is extracted from the event logs. The graph contains all sequences of the traces in the event log. The graph is not really suitable for business intelligence extraction, because it might contain edges between nodes (transitions between activities) that are semantically incorrect (i.e. it allows for a possible loop in the process when there are no individual process instance traces allowing it. For details, see section 4).
2. The directed graph is transformed into directed acyclic graph to remove any loops (transitions for instance level loops are simply removed while model level loops are removed using an algorithm explained in section 4. Instance level loops are removed, because Bayesian network is directed acyclic graph. Model level loops are removed to make the model conform to the existing business process.
3. The data in the event logs is transformed to conditional probability tables (CPT) and appended to the directed acyclic graph.

The result is a Bayesian belief network ready for business process analysis.

3. Background

This section's purpose is to present background information on elements used in the approach – event logs and Bayesian networks.

3.1. Event Logs

Process mining focuses on extraction of knowledge from event logs commonly available in today's information systems. One of the purposes of business process mining is to discover business process models or to check conformance of/enhance existing models [7]. The process mining starts from the events stored in information systems (i.e. transaction logs, audit trails, etc.). Event logs used in process mining can be two kinds – MXML [14] and XES[15].

For this paper, van Dogen definition of event logs [12] is adapted. Two additional elements – M and δ – are introduced. The definition is as follows:

Definition 1. An event log over a set of activities A and time domain TD is defined as $L_{A,TD} = (E, C, M, \alpha, \gamma, \beta, \succ)$, Where:

- E is a finite set of events
- C is a finite set of cases (process instances),
- M is a finite set of attributes,
- $\delta: M \rightarrow E$ is a function assigning each attribute to an event,
- $\alpha: E \rightarrow A$ is a function assigning each event to an activity,
- $\gamma: E \rightarrow TD$ is a function assigning each event to a timestamp,
- $\beta: E \rightarrow C$ is a surjective function assigning each event to a case,
- $\succ \subseteq E \times E$ is the succession relation, which imposes a total ordering on the events in E

3.2. Bayesian Belief Networks

Since business processes are by nature complex and stochastic, it's useful to analyze those using probabilistic methods. Probabilistic methods, if used right, can greatly support decision making and answer questions with uncertainty.

One of such tools is Bayesian network, whose purpose is to model and reason with uncertain beliefs [2]. Bayesian networks can be defined as:

Definition 2. A Bayesian network over variables X is a pair (G, θ) , where:

- G is a directed acyclic graph over variables X ;
- θ is a set of conditional probability tables (CPTs).

Bayesian network inference can be used to answer questions important to business. Bayesian network inference can be related to business questions as follows:

- Probability of evidence $P(X|e)$. It Can be used to answer „What's the chance to see a claimant aged 10-20 years old“?
- Most probable explanation $MPE(\mathbf{e}) = \operatorname{argmax}_{\mathbf{x}} \Pr(\mathbf{x}, \mathbf{e})$. It can be used to answer „What is most probable explanation for declined claims“?
- Maximum a Posteriori Hypothesis $MAP(\mathbf{e}, \mathbf{M}) = \operatorname{argmax}_{\mathbf{m}} \Pr(\mathbf{m}, \mathbf{e})$. It can be used to answer “What's the most probable outcome of a claim if the claimant is aged 23 years old and made the claim in the district of Vilnius?”;

4. Directed Acyclic Graph Extraction

The goal of the first step is to extract a directed acyclic graph from an event log. An acyclic graph is extracted, because Bayesian belief network is an acyclic graph. The graph is associated with the event log, but leaves out data attributes for the next step.

Directed acyclic graph in this context is defined as follows:

Definition 3. Directed acyclic graph over event log L is defined as $T_L = (N, D)$, where:

- $N = \{n \in E\}$ is a set of nodes found in an event log,
- $D = \{N \times N: n_i, n_j \in N, N \in c, c \in C, n_i > n_j \& n_i \not\prec n_j\}$ is a set of edges connecting nodes, whose representative events follow each other but do not form a loop and exist in the same trace;

Existing business process mining approaches are not suitable for Bayesian belief network creation. This is because they allow edges in the graph that would form a loop. The loops in those graphs appear because:

- The business process contains a loop and it is extracted as such from the event log;
- The business process contains parallel activities which are extracted as sequences from the event log. This extraction renders the model semantically incorrect and modelled activities become causally dependent, while in reality they are independent.

For example, there may be traces “ABCD”, “ACBD” and “ABBCD”. The first two traces do not allow for the loop to exist, but standard process mining tools would extract it in a way to allow a loop (Fig. 3a). The correct way would be to model them as independent activities (Fig. 3b). For the third trace, the process allows the loop and it would look like shown in Figure 3c.

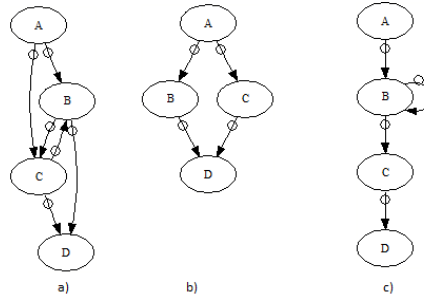


Fig. 2. Incorrect (a) and correct (b) graphs for traces “ABCD” and “ACBD”; graph of trace “ABBCD” (c)

In case of the presented approach, loops at the process instance level are simply ignored and left out of scope of this paper. This is done for two reasons – to simplify the task for initial research and because loops make up small part in business processes. The analysis of business process loops are left for future research. For the first case of loops, they need additional processing. The algorithm used in the approach to remove loops from a directed graph is shown in pseudo code below:

```

foreach (Trace t in EventLog)
  foreach (Event e in t)
    Graph.AppendNode(e, e.previousEvent, t)
Function AppendNode(Event e, Event previousEvent Trace t)
  if (TraceHasALoop(e, previousEvent, t))
    RemoveTransition(e, e.previousEvent) //instance loops are ignored
    if (ModelHasALoop(e, previousEvent)) //splits are added for model
      loops
        possibleLoop=GetLoopPath(e, e.PreviousEvent)
        commonNode=GetNodeInPathToEprev(e, previousEvent, possibleLoop);
        commonNode.TransitionTo(e)
  else
    AddSimpleTransition(e, e.PreviousEvent);

```

The input for the algorithm is an event log with traces and it works on a directed graph. The output is a directed acyclic graph usable for Bayesian belief network generation. The generation is presented in the next section.

5. Bayesian Belief Network Generation

Directed acyclic graph is extracted from the event log, because the goal is to transform it into a Bayesian belief network and Bayesian belief network is a directed acyclic graph. The Bayesian Belief network itself in this context is defined as follows:

Definition 4. *Belief network over event log L is defined as $B_L = (G, \theta, \varepsilon)$, where:*

- G is a directed acyclic graph T_L ,
- θ is a finite set of conditional probability tables for nodes of graph G and their attributes M ,
- $\varepsilon: \theta \rightarrow N$ is a surjective function assigning each conditional probability table to its corresponding node;

In the step 1, the extracted directed acyclic graph contains all the information necessary for Bayesian belief network, but the attributes are not aggregated into CPT. The second step creates a framework of the belief network - only the graph is extracted and the attributes are left out. The third step creates the CPTs and assigns them to the belief network. The final product of the process is a belief network ready for business process analysis.

6. Experimental Results

At the moment it is hard if not impossible to find publicly available event log with annotated data suited for business intelligence. Therefore, for experimental testing synthetic event logs were used. The logs were in XES format. The log is composed of 3437 traces consisting of up to 11 events. For the sake of simplicity, each event in the XES file was annotated with `<string key="data" value="xxx">`, where the value describes the data involved in the activity (i.e. age group of a client, call center location).

First, the directed acyclic graph using the presented approach and process model using PRoM framework were extracted to make sure the results are correct. The result of the proposed approach (Fig. 3 a) presented the most suitable graph for Bayesian belief network. Heuristics miner [16] (Fig. 3 b) contained loops both at trace level and model level. It was possible to tune the mining algorithm to remove the single activity loop, but the algorithm does not allow for complicated loop removal. Fuzzy miner [10] was also tested, but did not manage to achieve suitable level of detail because of looping or lack of connections. At the moment, there seems to be no mining algorithm suitable for the directed acyclic graph extraction, because they do not enforce model level loop checking.

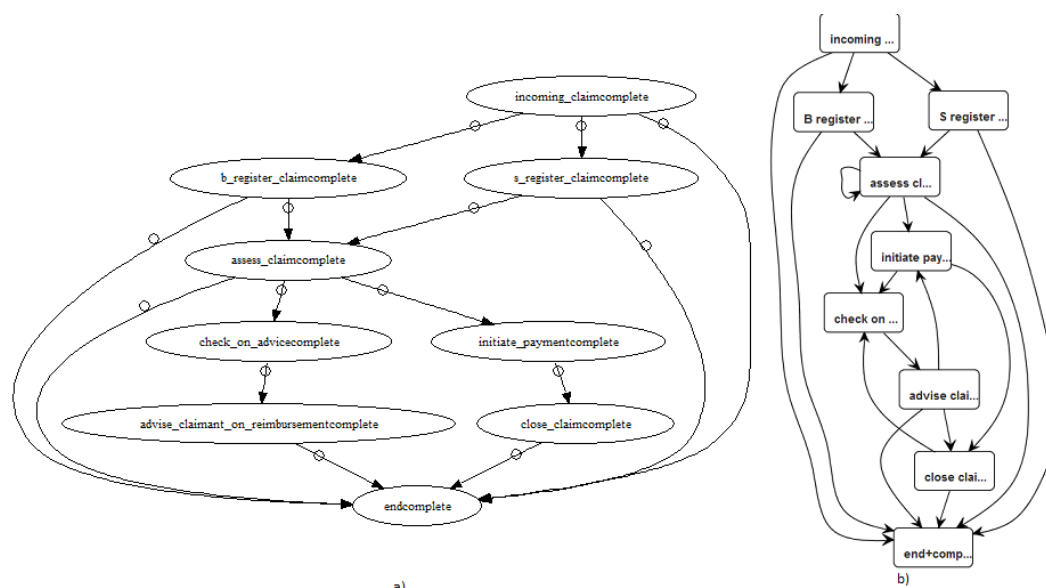


Fig. 3. Extracted graph from the synthetic log. a – proposed approach, b – heuristics miner.

The next step was to create a Bayesian belief network. To test the proposed approach, directed acyclic graph was transformed into factor graph and annotated with data existing in the event logs. For creation of the Bayesian network, Infer.NET framework [6] was used. The transformation went as follows:

1. Each node in extracted graph was directly transformed into a variable node in the factor graph;
2. CPTs were created by analysing input edges of the nodes of the Bayesian network and extracted probabilities from process instance traces related to the particular nodes;

For readability purposes, only fragment of the resulting Bayesian network in factor graph form is presented. It is depicted in Fig. 4.

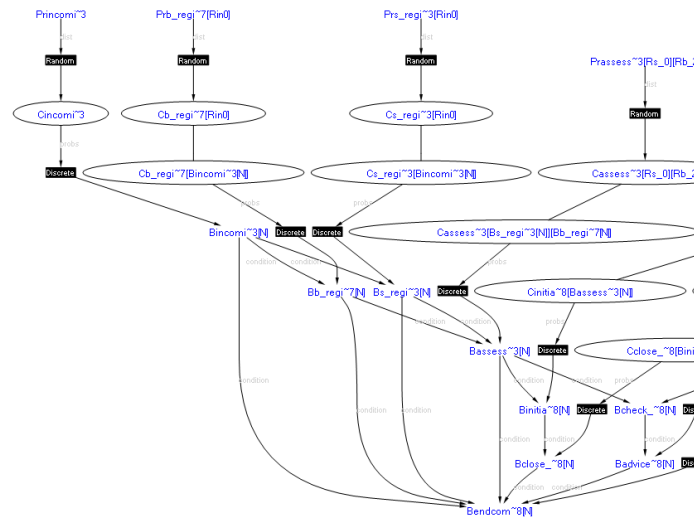


Fig. 4. Bayesian belief network in factor graph form

Finally, some possible questions about the process were answered. The questions about the process were chosen that would interest analysts and managers. The questions and results are presented in Table 1.

Table 1. Bayesian belief network inference results

Question	Result
Free form question: What's the chance of a claim to be declined? Formal definition: $P(endcomplete.data = 'declined')$	Answer: 0.36
Free form question: If the claim was registered in Klaipėda and it was declined, what's the most probable age group that claimed the insurance? Formal definition: $argmax P(incoming_claim.data assessclaim.data = 'Klaipėda', endcomplete.data = 'declined')$	Answer: age 20-29
Free form question: If insurance was claimed by someone aged 50-59 years and the claim was registered in Vilnius, what are the possible outcomes? Formal question: $P(end incoming_claim.dat = '50-59', register_claim.Data = 'Vilnius')$	Declined: 0.43 Paid: 0.57

The questions that could be answered using the proposed approach could lead to the improvement of the business processes. For example, if the analysis of the business process shows that people aged 20-29 more often than not have unsuccessful insurance claim and people aged 50-59 more often than not have successful insurance claim, the designers of the business process or the managers could reallocate resources to make additional checks for younger people and less checks for the older people. The belief network could also be used to make temporal analysis and reduce the time it takes to complete the business process by making the necessary changes to the business process.

7. Validity

As it can be seen from the experimental results, the proposed approach allows automatic transformation of event logs into Bayesian belief network to support decision making. The approach shows promising results, but still needs formal validation. Some possible concerns for the experiment and the approach:

- The directed acyclic graph extraction algorithm worked for this scenario, but still needs additional checking and formal validation against existing techniques;
- Synthetic data was used and the process model is relatively simple. The approach needs to be checked against event logs that contain information about execution of dynamic processes or processes with a lot of loops;
- The proposed approach ignores any kind of loop at the process instance trace level. Analysts might want to know what causes the loops, but at the moment the proposed approach is not capable of incorporating information about loops in the extracted Bayesian Belief network.
- The proposed approach has not been validated against existing approaches therefore the conclusions of the performance of the approach are preliminary and shows linear scaling.

8. Related Work

The paper proposes custom graph extraction algorithm with a purpose of loop removal. There are many process discovery algorithms [13], but existing algorithms, i.e. HeuristicsMiner [16] or Fuzzy miner [10], extract graphs with loops that do not actually exist in the process rendering them unusable for generation of Bayesian belief networks.

Process mining has seen quite a few applications in business process analysis. It has been used for time prediction – in [12] authors use regression equations based on event logs to prepare model for prediction on when the process instance (case) will be finished; in [11] authors generate transition system from an even log which is used for time prediction of a case. Authors of [5] propose to simulate discovered models for use in decision support.

Process mining has also seen application in decision mining. In [8] authors attempt to extract rules for control flow point in the process model based on data in event logs. The rules are extracted using classification algorithms such as C.45. In [3], authors use alignment in business processes to extract data flow rules between activities.

Bayesian networks is not a new research area, but it's application in process mining has not been widely researched. In [9], authors extract Bayesian network from an event log. The authors do not take into account the possible extracted structure, but rather attempt to extract it by analyzing dependency between events in the log. The approach presented in this paper uses custom network structure extraction to model dependency.

9. Conclusions and Future Work

This paper presented an approach for process analysis using process mining in combination with Bayesian belief networks. The paper highlighted problems with existing process mining algorithms and a custom solution for directed acyclic graph extraction which does not allow for any loops not existing in the event logs. For the scope of this paper, loops that do exist in the event log were ignored. It was shown how to transform the directed acyclic graph into Bayesian belief network to make decision support and analysis of the process simpler. The main conclusions are:

- The proposed directed acyclic graph extraction method allows extraction of process model that avoids loops at the model level. Further evaluation still needs to be done to check if it works for more complicated scenarios.
- The proposed Bayesian belief network transformation method shows promising results – the network can be created automatically from a BP event log; moreover, it allows for fast insight into process execution.

The approach presented in the paper is feasible; therefore, it can be further applied to more complicated case studies for verification. The future research involves validation using real life logs and improvement of Bayesian belief network transformation by using classification algorithms to account for continuous value ranges (i.e. age, currency, time values). The extracted Bayesian belief network shows only the data as seen by the execution of the process, it does not take into account “invisible data” (associated with activities but not shown in the event logs). It would be practical to combine the proposed approach with reverse engineering field to extract possible values, but not seen in the execution of the process. Finally, Bayesian belief network is a probabilistic model and it might have uses for simulation improvement.

References

1. Aytulun, S.K., Guneri, A.F.: Business process modelling with stochastic networks. *Int. J. Prod. Res.* 46(10), 2743–2764 (2008)
2. Darwiche, A.: Bayesian Networks. In: Van Harmelen, F., Lifschitz, V., Porter, B. (eds.) *Handbook of Knowledge Representation*, pp. 467-509. Elsevier, Amsterdam (2008)
3. De Leoni, M., Van der Aalst, W.M.P.: Data-aware process mining: discovering decisions in processes using alignments. *Proceedings of the 28th Annual ACM Symposium on Applied Computing*, pp. 1454–1461. ACM, Coimbra (2013)
4. Kellner, M.I., Madachy, R.J., Ra, D.M.: Software process simulation modeling: Why? What? How? *J. Syst. Software* 46(2-3), 91-105 (1999)
5. Liu, Y., Zhang, H., Li, C., Jiao, R.J.: Workflow simulation for operational decision support using event graph through process mining. *Decis. Support Syst.* 52(3), 685-697 (2012)
6. Minka, T., Winn, J.M., Guiver, J.P., Knowles, D.A.: *Infer.NET 2.5* (2012)
7. Rozinat, A., Mans, R.S., Song, M., Van der Aalst, W.M.P.: Discovering simulation models. *Inf. Syst.* 34 (3), 305–327 (2009)
8. Rozinat, A., Van der Aalst, W.M.P.: *Decision Mining in Business Processes*, http://www.processmining.org/_media/publications/beta_164.pdf
9. Sutrisnowati, R.A., Bae, H., Park, J., Ha, B.-H.: Learning Bayesian Network from Event Logs Using Mutual Information Test. *Proceedings of the IEEE 6th International Conference on Service-Oriented Computing and Applications*, pp. 356–360. IEEE, Koloa (2013)
10. Van Der Aalst, W.M.P., Rubin, V., Verbeek, H.M.W., Van Dongen, B.F., Kindler, E., Günther, C.W.: Process mining: a two-step approach to balance between underfitting and overfitting. *Softw. Syst. Model.* 9(1), 87–111 (2010)
11. Van der Aalst, W.M.P., Schonenberg, M.H., Song, M.: Time prediction based on process mining. *Inf. Syst.* 36(2), 450–475 (2011)
12. Van Dongen, B.F., Crooy, R.A., Van der Aalst, W.M.P.: Cycle Time Prediction: When Will This Case Finally Be Finished? In: Tari, Z., Meersman, R. (eds.) *On the Move to Meaningful Internet Systems (OTM)*. LNCS, vol. 5331, pp. 319-336. Springer, Heidelberg (2008)
13. Van Dongen, B.F., De Medeiros, A.K.A., Wen, L.: Process mining: Overview and outlook of petri net discovery algorithms. In: van der Aalst, W.M.P., Jensen, K. (eds.) *Transactions on Petri Nets and Other Models of Concurrency II*. LNCS, vol. 5460, pp. 225–242. Springer, Heidelberg (2009)
14. Van Dongen, B.F., Van der Aalst, W.M.P.: A Meta Model for Process Mining Data. *Proceedings of the CAiSE Workshops* (2005), http://tmpmining.win.tue.nl/_media/publications/dongen2005.pdf
15. Verbeek, H.M.W., Buijs, J.C.A.M., Van Dongen, B.F., Van der Aalst, W.M.P.: XES, XESame, and ProM 6. In: Proper, E., Soffer, P. (eds.) *Information Systems Evolution*. LNBIP, vol. 72, pp. 60-75. Springer, Heidelberg (2011)
16. Weijters, A.J.M.M., Van Der Aalst, W.M.P., Alves de Medeiros, A.K.: *Process Mining with the HeuristicsMiner Algorithm*. BETA Working Paper Series, WP 166, Eindhoven University of Technology, Eindhoven (2006) <http://is.tm.tue.nl/staff/aweijters/WP166.pdf>

Examining the Relationship between Contribution Behaviours and Knowledge Sharing in Software Development

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Abstract

This paper presents a conceptual model that depicts the relationship between contribution behaviours and knowledge sharing. The research argues that contribution behaviours are essential to knowledge sharing. Due to their high degree of team interaction, agile software development environments may help in examining contribution behaviours and their role in knowledge sharing and in this study are used as a lens to examine the relationship. A qualitative, case study approach was utilised where research findings indicate that in many instances, knowledge sharing cannot occur in absence of contribution behaviours.

Keywords: Knowledge Sharing, Contribution Behaviours, Agile Software Development.

1. Introduction

As a term, ‘contribution’ has many different meanings. In project team environments, contribution typically refers to the role an individual plays in achieving a particular outcome. Individuals, teams, organisations and other entities have very diverse and polymorphous expectations as to what they consider to be a *contribution*. Olivera, Goodman et al. [19] define contribution behaviours as “voluntary acts of helping others by providing information.” This research investigates the role contribution *behaviours* play in impacting knowledge sharing within the context of project teams. The paper argues that contribution behaviours are essential to knowledge sharing and that knowledge sharing may not occur in the absence of contribution behaviours. Contribution in the context of sharing information is intrinsically linked to concepts embedded in knowledge management literature because a contribution act associated with coworkers is ultimately any way in which *information* is shared and communicated with another individual. In the context of IS, a model of contribution behaviours was initially proposed by Olivera, Goodman et al. [19]. In the pages that follow we argue that an intrinsic link exists between contribution behaviours and knowledge sharing to the extent that these behaviours drive knowledge sharing in organisations.

1.1. Research Motivation

Olivera, Goodman et al. [19] outline how contribution behaviours can improve organisational effectiveness and, whilst there is growing research on knowledge sharing, little work has focused on understanding the contribution act in detail. Understanding the role of contribution behaviours in knowledge sharing is imperative in IS for many reasons, one of which is that it “can inform the development of future technologies and practices to improve knowledge

management” [19]. It is well established that knowledge management practices can be a source of competitive advantage and yet while many organisations have invested heavily in knowledge sharing technologies few systems have met their expectations or objectives [19]. From a broad perspective, there is an increased likelihood for innovation, effectiveness and competitive advantage within an organisation if there are high levels of contribution. For these reasons, there is a need to *understand the role contribution behaviours play in knowledge sharing*. In doing this, organisations can subsequently develop better systems to support and facilitate them. In addition, understanding how *contribution behaviours can be facilitated* within ISD project teams is imperative in mobilising the sharing of knowledge.

The distinction between data, information and knowledge has long been established. Some distinctions across literature propose that if knowledge is not different to data or information “then there is nothing new or interesting about knowledge management” [9] and knowledge items are not distinctive from what is already known in data or through information. Data is defined as “raw facts that describe the characteristics of an event” [4]; information is when data are “converted into a meaningful and useful context” (such as a best-selling product) [4], and knowledge occurs when the collected pieces of information provide valuable insight that enables decision-making for example, “information about customers becomes knowledge when decision makers determine how to take advantage of the information” [9]. If contribution behaviours surfaces information among team members, then it follows that continuous contributions enable knowledge sharing.

Knowledge in organisations is “rooted in the expertise and experience of its individual members” [7] and can be tacit or explicit in nature. While tacit knowledge is not easily definable because it “involves intangible factors embedded in personal beliefs, experiences and values” [13], explicit knowledge is easily expressed and communicated because it can be “shared in the form of hard data, scientific formulas, codified procedures or universal principles” [12]. An organisation cannot create knowledge by itself; it must “mobilise tacit knowledge created and accumulated at the individual level” [12] by facilitating and promoting the occurrence of contribution behaviours.

This research paper draws on existing literature to construct a conceptual model showing the relationship between specific stages of contribution behaviour (awareness, searching and matching, formulation and delivery [19]) and knowledge sharing.

2. Defining Contribution Behaviour

Olivera, Goodman et al. [19] define contribution as “voluntary acts of helping others by providing information.” In software development contribution behaviours can also relate to employees contributing to team decision making *<removed for referring>*. Olivera, Goodman et al. [19] explain how “there is a decision-making process about whether, what and how to contribute” which involves “cognitive motivation theories” of *awareness, searching and matching, formulation and delivery* to “explain why individuals decide to allocate time and effort to the contribution act.” Awareness is “a cognitive activity through which a person recognises an opportunity to contribute” and it determines whether an individual “has generated information that is worth sharing, with whom it should be shared and how it should be communicated” [19]. Once an opportunity to share is recognised (either through a direct request for help or proactively seeking to contribute), an individual must then decide whether to act on this opportunity. The motivation and ultimate decision to contribute is in the hands of the employee [1]. The decision to act may also be influenced by the IS facilities available that help maximise the degree of social interaction [19].

Searching and Matching is the next stage of contribution behaviour. It is the stage where an individual determines “whether and how the knowledge domain of the help request matches their own personal knowledge” [19]. Here an individual uses personal or *individual knowledge* (a combination of explicit and tacit knowledge to help address the request. It is primarily through searching and matching that the potential for knowledge sharing is at its highest as knowledge sharing often “involves identifying matches between personal knowledge and the situations described by those who request help” [19]. Technology that

provides efficient searching and indexing capability will assist in the searching and matching process. This is particularly true if the individual is seeking additional explicit knowledge in their quest to address the request for help. As Griffith, Sawyer et al. [11] explain, “individuals are the most effective media for acquiring and storing tacit knowledge; technology, best for explicit knowledge; while structures and routines are most effective for transferring knowledge.”

Formulation and Delivery is the final stage described by Olivera, Goodman et al. [19] as “a cognitive and behavioral activity through which a contribution is articulated and communicated.” The formulation aspect derives exactly what it is that needs to be delivered or communicated while delivery involves the means by which information or knowledge is transferred or shared. Delivery can take place through multiple mediators such as “oral communications, e-mail or posting to a discussion forum or corporate database” [19]. This stage conveys strong associations with the concept of *externalisation* whereby a certain amount of individual knowledge may be translated into a wholly explicit form. The availability and suitability of technologies to support the individual in formulating and delivering a response (particularly in distributed environments) increase the likelihood of the contribution occurring [19].

2.1. Contribution Behaviours and Knowledge Sharing

The primary object of knowledge sharing research and practices is to facilitate effective knowledge flow among organisational members [6]. Knowledge sharing is the fundamental basis for creating collective knowledge in intra-organisational networks [6]. This paper argues that an intrinsic link exists between contribution behaviours and knowledge sharing to the extent that these behaviours drive knowledge sharing. Contribution behaviours can be considered as ‘out-of-the-role’ help or ‘extra-role behavior’ which has been defined as “activity that is beyond the prescribed requirements of one’s job or role” [2]. This ‘feeds’ directly into knowledge sharing which implies a conscious act by an individual to participate in a knowledge exchange even though there is no compulsion to do so [14].

A frequent concern for organisations is how to effectively bring people together so that expertise can be shared. There is an assumption that if organisations are successful in creating an environment for knowledge networks and if they can provide the technology to support such networks then it will naturally emerge [18]. Creating a technical solution to support knowledge sharing and best practices therefore is often the first attempt in developing a knowledge-based firm [18]. IT is often the primary mediator for sharing and communicating information and therefore has “an important role in effectuating the knowledge-based view of the firm” [1]. However, the incentives for and barriers to sharing knowledge are not really technical [18] and while technology’s role cannot be underestimated, it is but one facet of knowledge sharing. This paper proposes that in order for knowledge sharing to emerge, contribution behaviours must initially occur. Whilst effective knowledge management systems and networks are important for maximising opportunities to contribute within and across teams in organisations, it is equally important to recognise that “technology by itself is not knowledge management” [4]. There is an increasing danger that organisations hide the concept of knowledge sharing behind the systems that support it where excessive emphasis on the technology “shifts the focus of knowledge and knowledge work away from individuals – without whom knowledge can be neither generated, transmitted, nor used” [9].

By focusing our attention on contribution behaviours as an underlying driver for knowledge sharing we can gain better understanding of how we can (and should) promote and facilitate contribution behaviours within organisations and among project teams. Ichijo and Nonaka [12] explain that “sharing knowledge in an organisation or a network is a trigger and a first step of knowledge creation.” Likewise, contribution behaviours are a trigger and a first step in sharing knowledge. Figure 1 depicts the conceptual model which combines primary elements of knowledge sharing research (by Ipe [14]) and contribution behaviour research (by Olivera, Goodman et al. [19]).

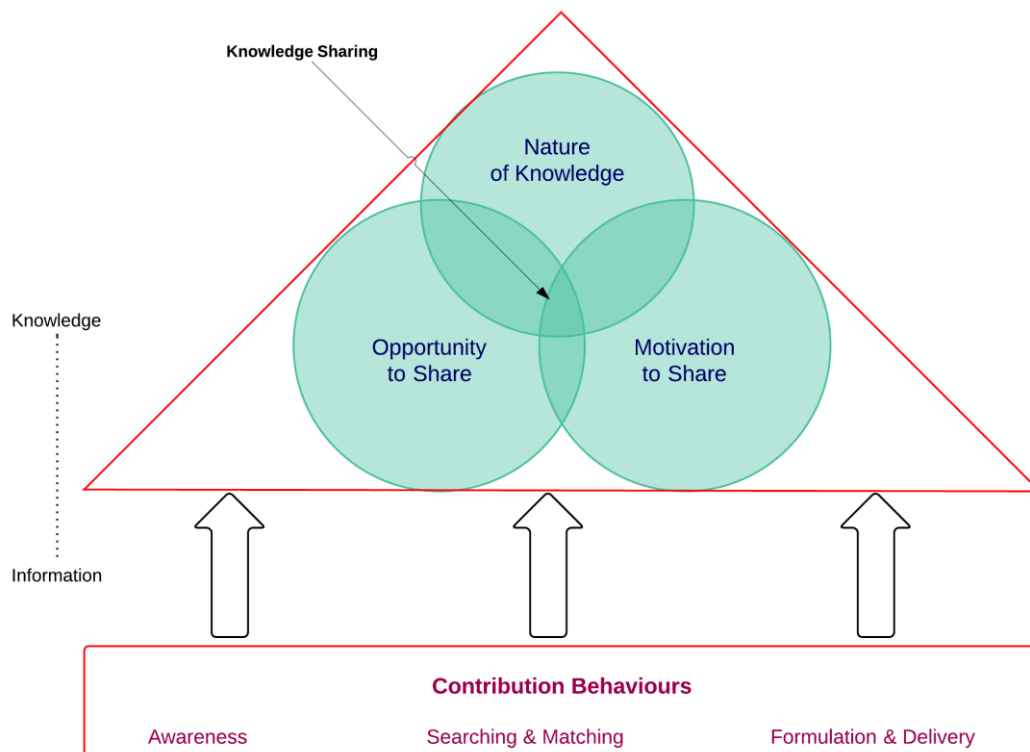


Fig. 1. Conceptual Model: Contribution Behaviours and Knowledge Sharing [14, 19]

The top half of the model is based on research by Ipe [14] which proposes that the *nature of knowledge*, *opportunity to share* and *motivation to share* are interrelated and create an ideal environment for knowledge sharing between individuals. The bottom half of the model shows the three stages of contribution behaviour proposed by Olivera, Goodman et al. [19]. This model indicates that an intrinsic relationship exists between contribution behaviours and knowledge sharing. We propose that individuals engage in contribution behaviours by sharing information and when such contributions have been initiated, knowledge sharing can occur. Therefore, contribution behaviours may drive knowledge sharing. To the left of the model, the *information-to-knowledge* slider indicates that as individuals engage in contribution behaviours, pools of contributions (consisting of information) are combined which results in knowledge being shared.

3. Contribution Behaviours in Software Development

Research highlights a “growing recognition that ISD is a knowledge-intensive process that requires the integration of specialised stakeholder knowledge” [20]. Patnayakuni, Rai et al. [20] express an ever-growing theme emerging in ISD projects whereby “IS units in similar organisations, with similar skill sets, comparable practices, capability maturity (CMM) levels, and software development tools seem to have markedly different abilities to develop systems.” There are many individual and specific organisational factors influencing this trend however, “a central challenge is that of integrating specialised knowledge necessary to develop the system that is dispersed across stakeholders with business and technical domain knowledge” [20]. Therefore, creating an environment in ISD that promotes contribution behaviours that results in knowledge sharing is imperative in enabling the successful development of systems.

Due to the complex nature ISD, the move to team-based work is something that IS organisations and researchers are long familiar with [15]. In ISD “the tacit nature of user

requirements, project design specifications and overall project understanding cannot be fully captured in formal documents” [16], so project team members must expose information and share knowledge. Teams are capable of creating “synergistic knowledge” which is developed through their interaction [11]. For example, if two team members each know different ways of solving a problem, together they may be able to develop an even better solution [11]. Even greater emphasis is placed on group-driven work in the context of agile software development (ASD), where teams are characterised as self-organising and projects are renowned for their high degree of interaction among team members. As a result, ASD has greater potential and opportunity for contribution behaviours to emerge. ASD methods provide an alternative to traditional software development lifecycle (SDLC). In contrast to the SDLC or ‘waterfall’ model, ASD involves “the integration of various approaches of systems analysis and design for application as deemed appropriate to the problem being solved and the system being developed” [21]. Essentially, agile methods carry out analysis, design, test and implementation stages in short increments placing a strong emphasis on user interaction throughout each phase. There is increasing emphasis placed on personal communication, community, morale, talent, skill and individual competency when it comes to agile methods [8].

Due to their high degree of interaction, ASD project environments are capable of creating greater amounts of “synergistic knowledge” [11]. ASD environments may help in recognising the factors which assist in increasing levels of contribution in a software development context because “agile methods derive much of their agility by relying on the tacit knowledge embodied in the team rather than writing the knowledge down in plans” [5]. Therefore, ASD teams are suitable for providing a lens to examine contribution behaviours and their role in knowledge sharing.

4. Research Method

The purpose of this study is to examine the relationship between contribution behaviours and knowledge sharing. Over the last decade or so, both IS academics and practitioners “have begun to realise it is more appropriate to extend the focus of study to include behavioural and organisational considerations” in order to “improve the effectiveness of IS implementations in organisations and to assess that impact on individuals or organisations” [10, 17]. These are relevant considerations for this study. Given a lack of prior research on the relationship between contribution behaviours and knowledge sharing, a qualitative case study research approach was chosen. The unit of analysis was the ASD team because the level of inquiry as it relates to contribution behaviours and knowledge sharing is at a team level.

The research involved two case studies across two organisations. InvestCo Ltd. is a leading multi-national provider of security software solutions while SoftCo Ltd. is a leading multi-national provider of financial service solutions. In total, ten one-to-one, hour-long interviews were conducted over a three-month period. Five interviews were held with SoftCo team members, whose goal was to develop, test and integrate new functionality. Five team member interviews were also held in InvestCo Ltd. This team was responsible for system maintenance and handling of software release updates.

The units of analysis of a study are often the units of observation, whereby we examine them and often create summary descriptions of such units to explain differences between them [3]. A total of six observations of team meetings were conducted. These are denoted as Obs. C1, Obs. C2 where C1 and C2 represent the cases studied. Each observation was documented and provided valuable insight into the relationship between contribution behaviours and knowledge sharing.

Table 1. Research Participants

Code	Role	ASD Experience (years)
D1	Developer	2
SM1	Scrum Master	3.5
QA1	Quality Assurance	1.6
SD1	Senior Developer	2
PO	Product Owner	2
SD2	Senior Developer	2.5
SM2	Scrum Master	3
D2	Developer	1.5
D3	Developer	0.6
QA2	QA Lead	0.5

All interviews were recorded, transcribed, analysed and coded using NVivo. Both organisations provided access to documentation relating to project plans and meeting protocols all of which were also analysed using NVivo. As depicted in Table 1, the study involved a diverse mix of research participants.

5. Findings

The findings of this study show a strong relationship between the stages of contribution behaviour and knowledge sharing. In particular, the stage of *awareness* links directly to that of *opportunity to share* and *motivation to share* shown in the conceptual model (Figure 1). As explained by SM1, “some team members aren’t as vocal as others and generally don’t contribute unless they are asked to do so” while D3 explained, “because I’m new to the team, I don’t contribute information as much as others.” SD1 explained how “in agile you have more than enough opportunities to share information with your team. We have dedicated team meetings every day that allow for this and we’re constantly interacting on the floor” while D3 stated; “if individuals don’t contribute it’s really down to them and not the project environment.” This shows that while *motivation* and *opportunity to share* may exist, particularly in ASD environments, sharing may not occur if team members don’t act on *awareness*.

In addition, PO stated that “when we’re in the middle of really complex development and trying to get a piece of working software out the door quickly, everybody has to pitch in” while QA2 explained that under such circumstances “it is vital to share the information we have so that we can generate viable and often really unique solutions quickly.” This highlights that under periods of time pressure, team members are most likely to be motivated to share information and by doing so, they *search and match* for information across the team, sharing knowledge to inform the solution. This was observed frequently during meetings within SoftCo where the team was under pressure to deliver to their client. The findings show an inherent relationship between the contribution behaviour stage of *searching and matching* to that of *knowledge sharing*. Furthermore, findings confirm an *information-to-knowledge* progression (Figure 1) in that once individual contributions are combined (to constitute collective contribution behaviours) they result in knowledge sharing. For example, SD1 explained, “certainly during complex development, two heads are better than one. When we combine pieces of information across the team and even with other teams we get much ‘cleaner’ solutions” which SM1 described as, “an intensive process when it happens but definitely one where information turns into something invaluable.” This shows a potential to convert information to knowledge via cross-team collaboration where teams engage in contribution behaviours with each other.

Formulation and delivery was evident during two team meetings in InvestCo (Obs. C1) where team members D1 and SD1 shared information relating to very specialised areas of coding (e.g. Linux kernel module). Their formulation and delivery resulted in other members sharing their knowledge of similar complex coding modules. In this instance, formulation and

delivery resulted in knowledge sharing among the team. This observation was supported further when QA1 stated, “sometimes a team member goes into detail about their work explaining everything in a piecemeal manner and this triggers something with someone else who’ll share their ideas.” However in SoftCo, it was found on occasion that formulation and delivery didn’t occur effectively (Obs. C2) and as a result, prevented the sharing of knowledge. D3 explained, “a lot of opportunities to share get missed because I’ve experienced first hand that if somebody isn’t a good communicator then nobody really *gets* what it is they’re doing so we end up not sharing simply because we didn’t know or understand the problem to begin with.” This indicates that ineffective formulation and delivery can prevent the sharing of knowledge.

Table 2. Summary of Findings

Contribution Behaviours	Relationship to Knowledge Sharing	Primary Implication
1. Awareness	Links directly to <i>opportunity to share</i> & <i>motivation to share</i>	While motivation & opportunity may exist, sharing may not occur if team members do not act on awareness.
2. Searching & Matching	Links strongly to knowledge sharing	Under periods of time pressure, team members are most likely to be motivated to share information; they <i>search and match</i> for information across the team, sharing knowledge to inform solution(s). An information-to-knowledge progression may also occur.
3. Formulation & Delivery	Impacts knowledge sharing	Effective formulation and delivery may result in other team members sharing their knowledge of similar concepts. Conversely, ineffective formulation and delivery can inhibit the sharing of knowledge.

6. Conclusion

This research presents an intrinsic relationship between contribution behaviours and knowledge sharing to the extent that contribution behaviours drive knowledge sharing. The stages of contribution behaviours consisting of awareness, searching and matching and formulation and delivery show clear links to concepts embedded in knowledge sharing literature including elements such as *opportunity* and *motivation* to share. A conceptual model depicting this relationship is presented in this paper. Furthermore, the model proposes that an *information-to-knowledge* ‘slider’ exists between contribution behaviours and knowledge sharing respectively, so that as individuals engage in contribution behaviours, pools of contributions (consisting of information) are combined which results in knowledge being shared. Some of the research findings have indicated that contribution behaviours are a driver of knowledge sharing and knowledge sharing cannot occur in the absence of contribution behaviours. For example, ineffective *formulation and delivery* can inhibit knowledge sharing and while *motivation* and *opportunity* to share may exist, this will not occur if individuals fail to act on *awareness*. While this research was conducted in ASD environments to serve as a lens for investigating the research phenomena, further research is needed to determine the generalisability of these findings. Future research could examine this relationship within traditional ISD project teams and draw comparisons to that of ASD teams, which may help in informing the facilitation of contribution behaviours for the purpose of knowledge sharing.

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References

1. Alavi, M.m Leidner, D.E.: Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues. *MIS Quarterly* 25(1), 107-136 (2001)
2. Anderson, S.E., Williams, L.J.: Interpersonal, Job, and Individual Factors Related to Helping Processes at Work. *Journal of Applied Psychology* 81(3), 282-296 (1996)
3. Babbie, E.: *The Practice of Social Research*. Thirteenth ed. Wadsworth, Cengage Learning, Belmont (2010)
4. Baltzan, P., Phillips, A.: *Business Driven Information Systems*. McGraw-Hill / Irwin (2008)
5. Boehm, B.: Get Ready for Agile Methods, With Care. *Computer* 35(1), 64-69 (2002)
6. Chen, S.-S., Chuang, Y.-W., Chen, P.-Y.: Behavioral Intention Formation in Knowledge Sharing: Examining the roles of KMS quality, KMS self-efficacy and organisational climate. *Knowledge-Based Systems* 31, 106-118 (2012)
7. Choo, C.W.: *The Knowing Organisation*. Oxford University Press, Inc. (1998)
8. Cockburn, A., Highsmith, J.: *Agile Software Development: The People Factor*. *Computer* 34(11), 131-133 (2001)
9. Fahey, L., Prusak, L.: The Eleven Deadliest Sins of Knowledge Management. in 1st Annual University-of-California-Berkeley Forum on Knowledge and the Firm. Berkeley, California (1997)
10. Galliers, R.D., Land, F.F.: Choosing Appropriate Information-Systems Research Methodologies. *Communications of the ACM* 30(11), 900-902 (1987)
11. Griffith, T.L., Sawyer, J.E., Neale, M.A.: Virtualness and Knowledge in Teams: Managing the Love Triangle of Organizations, Individuals, and Information Technology. *MIS Quarterly* 27(2), 265-287 (2003)
12. Ichijo, K., Nonaka, I.: *Knowledge Creation and Management: New Challenges for Managers*. Oxford University Press, Inc. (2007)
13. Inkpen, A.C.: Creating Knowledge through Collaboration. *California Management Review* 39(1), 123-140 (1996)
14. Ipe, M.: Knowledge Sharing in Organisations: A Conceptual Framework. *Human Resource Development Review* 2(4), 337-359 (2003)
15. Janz, B.D.: Self-Directed Teams in IS: Correlates For Improved Systems Development Work Outcomes. *Information & Management* 35(3), 171-192 (1999)
16. Janz, B.D., Prasarnphanich, P.: Freedom to Cooperate: Gaining Clarity Into Knowledge Integration in Information Systems Development Teams. *IEEE Transactions on Engineering Management* 56(4), 621-635 (2009)
17. Myers, M.D., Avison, D.: *Qualitative Research in Information Systems: A Reader*. Sage Publications Ltd., London (2002)
18. O'Dell, C., Grayson, C.J.: If Only We Knew What We Know: Identification and Transfer of Internal Best Practices. *California Management Review* 40(3), 154-174 (1998)
19. Olivera, F., Goodman, P.S., Tan, S.S.L.: Contribution Behaviors in Distributed Environments. *MIS Quarterly* 32(1), 23-42 (2008)
20. Patnayakuni, R., Rai, A., Tiwana, A.: Systems Development Process Improvement: A Knowledge Integration Perspective. *IEEE Transactions on Engineering Management* 54(2), 286-300 (2007)
21. Whitten, J.L., Bentley, L.D., Dittman, K.C.: *Systems Analysis and Design Methods*. 2004: McGraw Hill (2004)

A Comparative Analysis of Linked Data Tools to Support Architectural Knowledge

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Abstract

Architectural Knowledge (AK) has been an integral part of Software Architecture specification since its original inception, but it has not been explicitly managed until recently. It can be described as a computational structure composed of design decisions and rationales. Recent research emphasizes that availability must be complemented by an effective use of this information. We propose the use of Linked Data techniques to define and manage AK, thus achieving flexible storage and scalable search. Our approach suggests storing the network of decisions in RDF format to be retrieved efficiently by means of SPARQL queries. As a side effect, many different AK structures can be described in this way, which then becomes a general format to describe AK. Using this approach, this work analyses some significant features regarding AK of several Linked Data tools, in order to determine which ones are the best/worst for sharing and reusing AK as Linked Data.

Keywords: Architectural Knowledge, Linked Data, Ontology, RDF, SPARQL, AK Network.

1. Introduction

In recent times, *Architectural Knowledge* (AK) has become one of the most popular topics in the Software Architecture (SA) field. AK has an organizational perspective, but it can also be described as a computational structure, composed of assets of design knowledge, tracing back to specific requirements and forward towards an implementation: that is, it describes the extended history of the system's design [10]. Then, from this perspective, AK is composed of architectural elements, requirements, and a number of design assets. When the specification just provided the final architecture, all this information was *unrepresented design knowledge* [21]; but now the architecture includes this information as part of the *rationale*.

Although AK was considered as an integral element of the SA specification since the very beginning of the discipline [14], it has been only recently [3] that both researchers and practitioners have become aware of its importance. The importance of AK goes beyond merely documenting the architecture; it is one of the vehicles for ensuring the quality of the software development process. For instance, Bratthall et al. [4] carried out a survey with several subjects from both industry and academia. They concluded that most of the interviewed architects considered that by using the AK they could shorten the time required to perform the change-tasks. Interviewed subjects also concluded that the quality of the results, when they had to predict changes on unknown real-time systems, was better using AK. Ozkaya et al. have also concluded, during their interview study [13], that the difficulties during both the initial phases and the evolution of systems are not only due to the availability

of AK, but depend on its effective use. However, despite these difficulties, interviewed architects have also remarked that they perceive AK to be essential when evolution happens. Feilkas et al. [6] have also carried out a case study on three industrial information systems highlighting the relevance of AK as one of its research questions. Authors have detected that one of the problems in these projects was that developers were not aware of the intended architecture because the AK was not properly described. Moreover, the case study also exposed that both a machine-readable form of the AK and the introduction of automatic analysis techniques are keys to achieve architecture-awareness in the development team.

We believe that a relevant conclusion can be extracted: it is a *must* to facilitate the management of AK, not only during the development process, but especially during the evolution of systems, in order to provide them with certain quality levels. The proposal presented in this work paves the way to satisfy this need by using a *Linked Data* (LD) [2] approach. In general, Linked Data [2] is referred to use the Web to create typed links between data from different sources. In this manner, the main purpose of our approach is to provide architects with abilities for both documenting the AK and exploiting it, regardless of the architecture-centric practices already used by their organization.

Therefore, our initial hypothesis is that LD provides a good basis for software architects to describe and manage the AK, and that this technology provides an adequate toolset which can be exploited by them in a flexible way. In this line of research, it is followed the *design science research* method [7] that involves the design of novel artifacts whose use and performance let improve/understand the behavior of Information Systems. In this work, we have selected some LD tools which seem to be particularly relevant, and examine their features from an AK perspective. Our purpose is to decide (a) whether these features seem to be adequate enough for supporting AK, thereby justifying this approach; and (b) which one of these tools, if any, seems to be more promising from an AK perspective.

Our approach tries to contribute to the emerging *Organizational Social Structures* (OSS) [18] perspective. An OSS can be seen as a dynamic interplay of people, e.g. stakeholders or developers. From this perspective, we can find two alternatives: *Communities of Practice* (CoP), where people share/learn a common practice, and *Strategic Communities* (SCs), where people share experience and knowledge with the aim of achieving strategic business advantage. Both of them have a common need: the need of sharing knowledge to achieve their goals. This work intends to establish a foundation for them by means of the LD approach.

The remainder of this paper is organized as follows. Section 2 outlines some Linked Data tools that are able to manage AK as Linked Data. All of these tools are afterwards analysed in Section 3, according to different features, in order to find out which ones seem to be the best/worst for sharing and reusing AK in a Linked Data format. Finally, Section 4 presents our conclusions and future work.

2. Linked Data Tools

This section presents some of the most widely used Linked Data tools (a more detailed description about their features, installation, etc., can be found in [16]). Initially, they have been selected with the following requirements: they can handle LD and they must have a wide support. Furthermore, all these tools have been selected because they have support for almost all the features that we have considered in the analysis presented in Section 3. Some of these features are of vital importance to manage AK, such as the SPARQL query language, RDF and OWL schemas, RDF input data format, and RDF/XML as serialization format. In particular, these four features are compulsory in our analysis so that those tools that do not support them will be penalized regarding to their total score.

2.1 Virtuoso

It is a single data server, developed by *OpenLink Software*, that offers functionality for both a traditional Relational data management server and a Linked Data server [12]. Namely, it provides RDF, Relational and XML data management, document and Linked Data server, as

well as a web application server, among others. In order to use this server with Linked Data, we may use *OpenLink Data Spaces* (ODS) [11][12] that allows one to establish and manage data on the web, as an extension of the emerging Semantic Web. It includes the platform *ODS Briefcase* which enables users to control file access rights, content-based search and metadata. In addition, all resources are exposed as RDF data sets, so that the file server functionality can be exploited by means of the SPARQL query language for the Semantic Web. ODS Briefcase offers several features especially suited for managing LD, such as (i) uploading RDF files and validating their format according to a particular syntax, e.g. XML; (ii) editing these files; (iii) consuming data uploaded to the server by means of SPARQL [11]; and (iv) showing query results in different formats (HTML, XML, JSON, Javascript, NTriples, RDF/XML or spreadsheet). In addition, it is able to define SPARQL queries using a specific graphical representation, and to run them using *OpenLink iSPARQL* [11].

2.2 Linked Media Framework (LMF)

LMF [17] is an easy-to-setup application server which packages Semantic Web technologies to offer advanced services. This framework consists of two main elements: *LMF Core* and *LMF Modules*. The LMF Core component is a LD server that exposes data following LD Principles. In addition, it also offers a highly configurable Semantic Search service and a SPARQL endpoint. Moreover, some other elements which can be used are [17]: (i) *LMF Semantic Search*, that offers a highly configurable Semantic Search service; (ii) *LMF Linked Data Cache*, which implements a cache to the LD Cloud, to be used transparently when querying the contents of the LMF. In the case of querying a local resource that links to a remote resource in the Linked Data structure, the remote resource will be retrieved in the background and cached locally.

2.3 Apache Jena & Fuseki

Apache Jena [19] is a Java framework for building Semantic Web applications, and specially *Jena* is a Java API for these kind of applications that can be used to create and manipulate RDF graphs. Jena provides a collection of tools and Java libraries to develop semantic web and LD applications, tools and servers. Namely, Jena includes an API for reading, processing and writing RDF data in XML, N-triples and Turtle formats. It has also an ontology API for handling OWL and RDFS ontologies and a rule-based inference engine for reasoning with RDF and OWL data sources. It is able to efficiently store large numbers of RDF triples on disk. It has a query engine compliant with the latest SPARQL specification and a server to allow these RDF data to be published so that they can be used by other applications using a variety of protocols. In addition, it provides constant classes for well-known schemas (RDF, RDFS, RDFa, Dublin Core or OWL) and also has some methods for reading and writing RDF as XML. On the other hand, *Fuseki* is a SPARQL server that offers services for SPARQL update and file upload to a selected dataset, validators for SPARQL query and update, and for non-RDF/XML formats.

2.4 TopBraid Suite

TopBraid Suite [20] offers semantic technology applicable in several scopes, such as to connect data, systems and infrastructures or to build flexible applications from LD models. All components of the suite work within an open architecture platform built specifically to implement W3C standards for the integration and combination of data obtained from diverse sources. These components are *TopBraid Composer*, an Eclipse plug-in that provides complete support for developing and managing ontologies and LD; *TopBraid Ensemble* [20], a semantic web application assembly toolkit for rapid configuration and delivery of dynamic business applications, suitable to create model-driven applications; and *TopBraid Live* (TBL), a server to deploy flexible, model-driven applications and dynamic, on-demand integration of data from diverse sources.

2.5 Sesame

Sesame is an open source Java framework for storing and querying RDF data, similar to Jena (Section 2.3). This framework is fully extensible and configurable with respect to storage mechanisms, inference engines, RDF file formats, query result formats and query languages. The core of the Sesame framework is the *RDF Model API*, which defines how the building blocks of RDF (statements, URIs, blank nodes, literals, graphs and models) are represented. Sesame also provides the *Repository API*, which describes a central access point for Sesame repositories. Its purpose is to give a developer-friendly access point to RDF repositories, offering various methods for querying and updating the data in an easy way. Additionally, Sesame supports the use of SPARQL for querying memory-based and disk-based RDF stores, RDF schema inference engines, as well as explicit support for the most popular RDF file formats and query result formats.

2.6 Mulgara

Mulgara [9] is a scalable open source RDF datastore written in Java, under the Open Software License 3.0. This tool can be considered akin to a relational database, as the information can be stored and retrieved via a query language. But unlike a relational database, Mulgara is optimized for the storage and retrieval of RDF statements, i.e. subject-predicate-object. Some of its main features are native RDF support, multiple databases per server, a simple SQL-like query language (similar to SPARQL), large storage capacity or low memory requirements. Moreover, Mulgara provides mechanisms for ensuring *reliability* (full transaction support, clustering and store level fail-over, permanent integrity), *connectivity* (using SOAP, Jena, etc.), *manageability* (near zero administration, web based configuration tools) and *scalability* (via XA Triplestore engine) of our system.

2.7 RedStore

RedStore [8] is a lightweight RDF triplestore written in C, which uses the Redland library, a set of free software libraries that provides support for RDF. It supports, in addition to native persistence and in-memory storage, a variety of storage backend adapters, including MySQL, Postgres and Virtuoso. In native mode, RedStore uses hashtables to store RDF data. Its main features are: SPARQL over HTTP support, a built-in HTTP server, support for a wide range of RDF formats, and a test suite for unit and integration testing.

2.8 Callimachus

Callimachus [1] is a framework for data-driven applications based on LD. It enables web developers to quickly create web applications based on LD, as they only need a web browser to develop a data-driven application. In addition, Callimachus uses either Sesame (Section 2.5) or Mulgara (Section 2.6) for RDF storage, AliBaba (a RESTful object-RDF library), and a proprietary template-by-example technique to view and edit resources. One of the most interesting features of Callimachus is that it is able to execute queries using RDF itself.

3. Feature Analysis

This section presents a detailed analysis of the LD tools from the previous section in order to compare their features and determine what the best ones are. This analysis was performed using the examples of AK networks described in <http://goo.gl/NJD2Ft> to illustrate the power of LD. Some of these features have been chosen because we consider them of vital importance for solving the following deficiencies which often make even more difficult the exploitation of AK:

- i. There is not a standard for representing AK, but multiple approaches.
- ii. Not every decision and rationale throughout the lifecycle (the history of AK) is recorded.

- iii. There is not a standard language for querying AK.
- iv. There is not a scalable solution able to manipulate the historical AK.

Therefore, the features selected from the *point of view of managing AK as LD* are:

- *Data persistence*: indicates if the LD tool provides persistence for its stored data. It is related to deficiency (ii), as this feature is desirable to access the history of AK over time.
- *Query languages*: identifies the different query languages that can be used to manipulate LD. It is related to deficiencies (iii) and (iv), as we want to store AK and the volume of such information can rapidly increase, it is also desirable to have a query language that allows us to navigate AK efficiently.
- *Supported schemas/vocabularies* by the LD tool, like XML or RDF. It is related to deficiency (i), as we are looking for a standard schema to represent AK, such as RDF.
- *Federated queries*: indicates if the LD tool supports data searching across multiple servers. It is related to deficiencies (iii) and (iv), as AK may be stored in different locations, following a LD approach.
- *Input data formats* supported by the LD tool in order to store and manage LD. It is related to deficiency (i), so that the standard for storing AK could be RDF.
- *Query output formats* provided by the LD tool when a query is executed. It is related to deficiency (iii), as we are looking for a standard query language that provides different output formats when querying AK.
- *RDF serialization formats* supported by the LD tool, like RDF/XML, Turtle, etc. It is related to deficiency (i), as we want to represent our AK with a standard such as RDF.

On the other hand, we also take into account some technical features that are relevant when choosing a software tool. They are not directly related to the AK field and its management as LD, but to the software itself. In this way, features selected from the *point of view of software* are:

- *Type of tool*: specifies the type of the analyzed LD tool.
- *Interaction UI* (User Interface): indicates whether the LD tool has a friendly UI.
- *License*: informs of the type of license that the LD tool has.
- *Security*: indicates how the LD tool guarantees that the information is always safely stored.
- *SDK*: indicates if the LD tool can be used to create other applications.
- *Complexity*: how complex is the *Installation*, *Start-up* and *Data management* of the tool.

A detailed analysis is presented in [16], providing a thorough analysis of all these features (both from the point of view of managing AK as LD and from the point of view of software) with regard to each tool. Notice that almost all LD tools are able to provide federated queries, as they all support SPARQL 1.1 [22]. This language can be used to express queries across diverse data sources, regardless of whether the data are stored natively as RDF or retrieved as RDF via middleware. *SPARQL 1.1 Federated Query extension* has been created to execute queries distributed over different SPARQL endpoints.

In order to decide which the best/worst LD tools are with regard to the analysed features, the following formula (which maximizes the global contribution) is used:

$$\text{Total score} = QL1 \cdot SS1 \cdot IDF1 \cdot RSF1 \cdot (IUI + DP + QL2 + SS2 + FQ + IDF2 + QOF + Li + Sec + RSF2 + SDKS + CI + CSU + CDM)$$

Each one of these parameters is calculated using the rules presented in Table 1, namely in column *How to score*. Parameters QL1, SS1, IDF1 and RSF1 are compulsory features, and therefore their values will be either 1 or 0, depending on their support. The reasons to consider them as necessary features are the following:

- QL1 establishes that the tool supports at least SPARQL as a query language, due to the fact that it is the standard query language used in LD.
- SS1 determines if the tool supports RDF, because this is the standard representation schema accepted for LD. It also determines that the tool supports OWL, which is widely

used for reasoning in the context of LD, because it enables to connect different datasets, located in different data stores, using different schemas. Moreover, both RDF and OWL can help architects to obtain more complete answers for queries over LD, as stated in [15].

- IDF1 establishes that the tool provides RDF as input data format, as it is the standard input data format for LD.
- RSF1 indicates that the tool provides RDF/XML as a RDF serialization format, as it has been defined by the W3C in the original specification.

Initially, we did not consider these four compulsory parameters within the formula, but only the sum of the remaining ones. Finally, we noticed that this was a wrong choice, given that some tools obtained better scores than others, despite they lacked an adequate support for LD, e.g. lack of schemas for RDF and OWL. This led us to mark them as compulsory. This way, the tool with the highest score must be considered as the best analysed LD tool and conversely, the one with the lowest score will be considered the worst. Notice that the remaining features are still considered equally important; therefore they are equally scored, namely *1 point* per each feature at most –so the score of each feature ranges between 0 and 1. Moreover, in order to facilitate this normalization, some of these features, such as QL2 or SS2, are calculated by dividing the number of supported query languages or schemas by the number of query languages or schemas offered by the tool with the highest support.

Table 2 shows the marks for each LD tool. Notice that we have omitted the feature that is

Table 1. Features preferences.

Analysed feature	Parameter	Preferences	How to score
Type of tool	-	(Without preferences)	(Not scoring, only informative)
Interaction UI	IUI	A User Interface that allows users to interact with the Linked Data tool.	1 If the tool has a UI 0 Otherwise
Data persistence	DP	A platform that provides data persistence over the time.	1 If the tool provides data persistence 0 Otherwise
Query languages*	QL1	A tool that supports, at least, SPARQL.	1 If the tool supports SPARQL 0 Otherwise
	QL2	The more query languages supported, the more preferable.	(Number of supported query languages)/5
Supported schemas/vocabularies*	SS1	A tool that supports, at least, RDF and OWL as schemas.	1 If the tool supports RDF and OWL as schemas 0 Otherwise
	SS2	The more schemas are supported, the more preferable.	(Number of supported schemas)/13
Federated queries	FQ	A tool that supports federated queries.	1 If the tool provides federated queries 0 Otherwise
Input data formats*	IDF1	A tool that supports, at least, RDF as an input data format.	1 If the tool supports RDF as an input data format 0 Otherwise
	IDF2	The more input data formats supported, the more preferable.	(Number of input data formats)/11
Query output formats	QOF	The more query output formats supported, the more preferable.	(Number of query output formats)/17
License	Li	A tool with an Open Software license.	1 If the tool has an Open Software license 0 Otherwise
Security	Sec	A tool with security services.	1 If the tool has security services 0 Otherwise
RDF serialization formats*	RSF1	A tool that supports, at least, RDF/XML as a RDF serialization format.	1 If the tool supports RDF/XML as a RDF serialization format 0 Otherwise
	RSF2	The more RDF serialization formats are supported, the more preferable.	(Number of RDF serialization formats)/10
SDK support	SDKS	A tool that provides SDK support.	1 If the tool has SDK support 0 Otherwise
Complexity	Installation	It is desirable a Low complexity in all cases.	0.2 Low 0.1 Medium 0 High
	Start-up		0.3 Low 0.15 Medium 0 High
	Data management		0.5 Low 0.25 Medium 0 High

(*) These features are compulsory.

Table 2. Scores of Linked Data tools.

Analysed features	Par.	Virtuoso	LMF	Apache Jena & Fuseki	TopBraid Suite	Sesame	Mulgara	RedStore	Callimachus
Interaction UI	IUI	1	1	1	1	1	1	1	1
Data persistence	DP	1	1	1	1	1	1	1	1
Query languages	QL1 QL2	1 5/5=1	1 1/5=0.2	1 2/5=0.4	1 1/5=0.2	1 2/5=0.4	1 2/5=0.4	1 3/5=0.6	1 1/5=0.2
Supported schemas/vocabularies	SS1 SS2	1 4/13=0.31	0 4/13=0.31	1 9/13=0.69	1 5/13=0.39	1 12/13=0.92	1 4/13=0.31	0 1/13=0.08	1 13/13=1
Federated queries	FQ	1	1	1	1	1	0	1	1
Input data formats	IDF1 IDF2	1 4/11=0.36	1 4/11=0.36	1 2/11=0.18	1 11/11=1	1 1/11=0.09	1 4/11=0.36	1 1/11=0.09	1 1/11=0.09
Query output formats	QOF	7/17=0.41	5/17=0.29	6/17=0.35	4/17=0.24	5/17=0.29	1/17=0.06	17/17=1	1/17=0.06
License	Li	1	1	1	0	1	1	1	1
Security	Sec	1	1	1	1	1	0	1	1
RDF serialization formats	RSF1 RSF2	1 5/10=0.5	1 5/10=0.5	1 8/10=0.8	1 4/10=0.4	1 9/10=0.9	1 3/10=0.3	1 10/10=1	1 3/10=0.3
SDK support	SDKS	0	0	1	0	1	0	0	0
	CI	0.2	0.2	0	0.2	0.1	0.2	0	0.1
	CSU	0.3	0.3	0.15	0.3	0.15	0.3	0.15	0.3
	CDM	0.5	0.25	0.25	0.25	0.5	0.5	0.5	0.25
TOTAL SCORE		<i>8.58</i>	<i>0</i>	8.82	<i>6.98</i>	9.35	<i>5.43</i>	<i>0</i>	<i>7.3</i>

not scoring, i.e. *Type of tool*. As a result, the first position is for *Sesame* (9.35), the second is for *Apache Jena and Fuseki* (8.82), then *Virtuoso* (8.58), *Callimachus* (7.3), *TopBraid Suite* (6.98) and *Mulgara* (5.43). The last ones are *RedStore* (0) and *Linked Media Framework* (0), which have no score because they do not support OWL (a compulsory feature represented as parameter SS1). As we can see, the best LD tools, between the analysed ones and according to our ranking, are *Sesame* and *Apache Jena & Fuseki*. In this sense, these two tools are really similar, given that both provide a Java framework to manage LD. Their strength with respect to the others comes from the large number of supported schemas and vocabularies and RDF serialization formats, in addition to the SDK support, which is exclusive of them.

4. Conclusions and Future Work

As already indicated, AK provides the basis to guide architects in many decisive processes, such as evolution [5], and to achieve certain levels of quality during these processes. However, as mentioned in Section 3, there are several shortcomings that can prevent organizations from exploiting AK, such as the variety of formats for documenting and representing it, or the difficulties in meeting its requirements for evolution.

In this paper, we suggest the use of LD techniques to solve these shortcomings. These techniques allow one to define and query AK in an easy and effective way, providing a flexible storage and scalable search. In this sense, our approach recommends storing the network of decisions using RDF, to be efficiently retrieved by means of SPARQL queries. It is worth noting that this proposal does not depend on any particular AK tool or model, or on any RDF triplestore or serialization format: we are considering the benefits of the LD approach itself. Furthermore, we have presented several tools for managing LD and we have analysed some relevant features of these tools with regard to AK, with the purpose of deciding to which extent they provide relevant features, and which ones are the best/worst for sharing and reusing AK as LD. Our results show that the best LD tools for this specific goal, among the analysed ones, are *Sesame* and *Apache Jena & Fuseki*. Therefore, given these outcomes, we conclude that the best choice to handle and share AK is to use a LD tool with some SDK support, such as *Sesame* or *Apache Jena & Fuseki*, to build some specific tool or interface which simplifies the use of this tool in an AK context. In summary, the LD approach offers important advantages in terms of scalability, as it has been defined to manage great amounts of data thanks to its index-based structure. This facility is being widely used within the open data initiative, to make data available to everyone. This approach makes possible to define and implement a shared repository of AK available to every architect, without compromising specific approaches.

Several ideas outline the path for our future work, due to the possibilities offered by LD. One of them is related to the social part of the proposal. Even though OSS are already gaining a growing attention, and practitioners are becoming more aware of the need of sharing the knowledge, we are planning to carry out several case studies in order to evaluate the degree of acceptance of the ideas presented in this work.

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References

1. 3 Round Stones, I.: Callimachus, <http://callimachusproject.org/>.
2. Bizer, C., Heath, T., Berners-Lee, T.: Linked Data - The Story So Far. *Int. J. Semant. Web Inf. Syst.* 5 (3), 1–22 (2009).
3. Bosch, J.: Software Architecture: The Next Step. 1st European Workshop in Software Architecture (EWSA'04), pp. 194–199. Springer (2004).
4. Bratthall, L., Johansson, E., Regnell, B.: Is a Design Rationale Vital when Predicting Change Impact? – A Controlled Experiment on Software. 2nd Int. Conf. on Product Focused Soft. Process Improvement (PROFES 2000). pp. 126–139, Springer (2000).
5. Cuesta, C.E., Navarro, E., Perry, D.E., Roda, C.: Evolution styles: using architectural knowledge as an evolution driver. *J. Softw. Evol. Process* 25 (9), 957–980 (2013).
6. Feilkas, M., Ratiu, D., Jurgens, E.: The loss of architectural knowledge during system evolution: An industrial case study. 17th IEEE International Conference on Program Comprehension (ICPC'09). pp. 188–197, IEEE CS Press (2009).
7. Hevner, A.R., March, S.T., Park, J., Ram, S.: Design Science in Information Systems Research. *MIS Q.* 28 (1), 75–105 (2004).
8. Humfrey, N.J.: RedStore, <http://www.aelius.com/njh/redstore/>.
9. Mulgara Project: Mulgara, <http://www.mulgara.org/>.
10. Navarro, E., Cuesta, C.E.: Automating the Trace of Architectural Design Decisions and Rationales Using a MDD Approach. 2nd European Conf. on Software Architecture (ECSA 2008). pp. 114–130, Springer (2008).
11. OpenLink Software: OpenLink Virtuoso, <http://my.openlinksw.com>.
12. OpenLink Software: Virtuoso Universal Server, <http://virtuoso.openlinksw.com/>.
13. Ozkaya, I., Wallin, P., Axelsson, J.: Architecture knowledge management during system evolution. 2010 ICSE SHARK '10. pp. 52–59, ACM Press (2010).
14. Perry, D.E., Wolf, A.L.: Foundations for the Study of Software Architecture. *ACM Softw. Eng. Notes* 17 (4), 40–52 (1992).
15. Polleres, A., Hogan, A., Delbru, R., Umbrich, J.: RDFS & OWL Reasoning for Linked Data. Reasoning Web. Semantic Technologies for Intelligent Data Access. pp. 91–149, Springer (2013).
16. Roda, C., Navarro, E., Cuesta, C.E.: Analyzing Linked Data tools for SHARK. TR#DIAB-13-09-1. Computing Systems Department, Albacete, Spain (2013).
17. Semantic Web: Linked Media Framework, http://semanticweb.org/wiki/Linked_Media_Framework.
18. Tamburri, D.A., Lago, P., Van Vliet, H.: Organizational Social Structures for Software Engineering. *ACM Comput. Surv.* 1–34 (2012).
19. The Apache Software Foundation: Apache Jena, <http://jena.apache.org/>.
20. TopQuadrant Inc.: TopQuadrant, <http://www.topquadrant.com>.
21. Tyree, J., Akerman, A.: Architecture Decisions: Demystifying Architecture. *IEEE Softw.* 22 (2), 19–27 (2005).
22. W3C: World Wide Web Consortium, <http://www.w3.org/>.

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$$x + y = z \tag{1}$$

Program commands in the text should be set in typewriter font:

```

j=n;
for (i=0; i<j; i++) {
    if (a[i]%2) {
        k=i;
        p=a[i];
        while ((--k>=0) && (a[k]>p))
            a[k+1]=a[k];
        a[++k]=p;
    }
    else {
        k--j;
        p=a[i];
        a[i--]=a[j];
        while ((++k<n) && (a[k]<p))
            a[k-1]=a[k];
        a[--k]=p;
    }
}

```

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References

1. ISD2014 Conference (2014), <http://isd2014.foi.hr>. Accessed January 15, 2014
2. Lang, M., Plantak Vukovac, D.: Web-based Systems Development: Analysis and Comparison of Practices in Croatia and Ireland. In: Papadopoulos, G.A., Wojtkowski, W., Wojtkowski, W.G., Wrycza, S., Zupancic, J. (eds.) *Information Systems Development: Towards a Service Provision Society*, pp. 90-100. Springer, Heidelberg (2009)
3. Orehovački, T., Granić, A., Kermek, D.: Evaluating the Perceived and Estimated Quality in Use of Web 2.0 Applications. *J. Syst. Softw.* 86 (12), 3039-3059 (2013)
4. Stapić, Z., Vrček, N., Hajdin, G.: Evaluation of Security and Privacy Issues in Integrated Mobile Telemedical System. In: *Proceedings of the 30th International Conference on Information Technology Interfaces*, pp. 295-300. IEEE, Cavtat (2008)
5. Strahonja, V., Varga, M., Pavlić, M.: *Information Systems Development (in Croatian)*. INA-INFO, Zagreb (1992)

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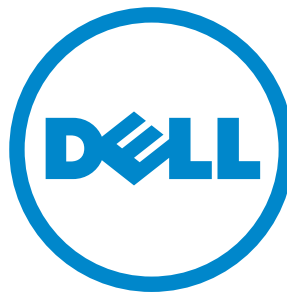


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