Understanding and Supporting Very Large-Scale Requirements Engineering: - How to Develop Sustainable Requirements Architectures for Embedded System Product Lines?

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Abstract

As complex sets of textual requirements grow large, hard challenges arise on how to visualize and characterize them as well as how to develop and maintain sustainable information architectures. This thesis plan summarizes on-going and planned studies that are carried out in an action research mode in close collaboration with industry in a product-line engineering context. Both descriptive and prescriptive research is included as well as a mix of qualitative and quantitative investigations. The main envisioned contributions are better understanding of the scalability of existing requirements engineering technology as well as new prototyped and validated technology for management of very large sets of requirements.

1. Introduction

The complexity and size of software-intensive systems continues to increase, which in turn gives increasingly large and complex sets of requirements. Some industrial cases present evidence of tens of thousands of textual requirements. This order of magnitude is denoted Very Large-Scale Requirements Engineering (VLSRE) [1]. Our main research question is: How can we better understand and support VLSRE? This general question is further refined in collaboration with process owners and line managers at Sony Ericsson (one of the world's leading mobiles phones developers), resulting in this thesis plan reaching from 2007 until 2012. We have also based the research plan on the expressed need of further research on tools and methods for visualization of requirements [7]. In general, we experience a growing demand from industry to handle bigger and more complex requirements sets, as a result of the ever increasing size of software-intensive systems [6][1].

The set of requirements information is becoming so large and complex that the classical document structures can not cope with it. Hence, there is a need for defining and managing a *sustainable requirements architecture*: a well-designed structure of requirements information that people can develop, manage and interact with effectively and efficiently without quality deterioration or overloading [14]. The requirement architecture should also cope with the added complexity of multiple product lines and multi-platform-based development that Sony Ericsson is facing [1, 8, 11]. In this context the need of having sustainable, stable but yet flexible requirements processes and tools is a key for succeeding in this rapidly changing industry. The ability to manage and visualize requirements dependencies and their impact on various parts of the projects and products is critical [2].

2. Main research questions

The general research question is described in [1] and is stated as follows: "Can we beat the complexity of very large scale requirements engineering?" Based on a preliminary literature study and initial results from an interview study with Requirements Architects (see Table 1 for more details) we have indentified three refined research questions:

- How to avoid the information overload in VLSRE and how to create sustainable requirements architectures (by requirements architecture we mean the structure and semantics of the requirements information in its usage context including people and processes)?
- How to fight the combinational explosions? – This is especially important in the context of

Table 1. Research plan, questions and methodology

Areas and actions	Start: 09.2007	Questions	Methodology	Status
Establishing a Research Baseline for VLSRE	Study 1	What is the current status of empirical research about management of quality attributes and dependencies among requirements? How is scalability addressed in reported empirical evidences?	Literature study using systematic review approach [13]	**Ongoing** An initial set of 2805 articles was evaluated by title and abstract. We are currently assessing the empirical quality of 88 articles using a *quality checklist*. [13]
	Study 2	What is the efficiency of the currently used requirement management commercial tool in the task of finding duplicates in two requirements sets? How the efficiency compares to a prototype tool that uses linguistic support to fin similar requirements?	Replication of Experiment in Requirements Consolidation [3], [12]	**Ongoing** An experiment has been executed, data have been partly analyzed, a first draft has been written.
	Study 3	What are the key issues in working with tens of thousands requirements and which issues should be addressed first? What is does it mean Requirements Architecture? What does it mean architecting requirements?	Qualitative Interview study with Requirements Architects at Sony Ericsson [4]	**Ongoing** An interview study has been executed, data have been transcribed and analyzed. Initial results were presented and evaluated at internal meeting at Sony Ericsson
Milestone A		**Submission of papers on step 1-3 Autumn 2008**		
Prototype Tools for Visualization and Characterization	Study 4	What are the key quantitative attributes of VLSRE and their dynamics over time? Which attributes impact the quality of the requirements process most and prevents the methods and tools from scalability?	Visualization and characterization of very large req. sets through statistical methods and measuring the dynamics aspects. (Case Study)	**Planned**
	Study 5	How do the variability and configurability data models impact dependencies in tens of thousands requirements set? Which configurability and variability processes and models can strive with the diversity of VLSRE?	Variability and Configurability in context of very large requirements sets (Case Study)	**Planned**
Milestone B		**Licentiate thesis Spring 2010**		
Development and validation of Methods for improving VLSRE efficiency	Study 6	How to improve visualization of the enormously complex mass of requirements and dependencies among them? Do we really need to rely on tables and tree lists?	Prototyping visualization and characterization of very large req. sets through statistic and measuring the dynamics.	**Planned**
	Study 7	How to improve current tools and methods for modeling requirements architecture in order to achieve robust and flexibility required by VLSRE?	Prototyping variability and configurability support for VLSRE.	**Planned**
	Study 8	Empirical evaluation of proposed solutions in steps 6 and 7	Empirical software eng. methods. [10]	**Planned**
Milestone C		**Doctoral Thesis Autumn 2012**		

inter-dependencies and leads to the question of effective requirements abstractions that are high enough to avoid unnecessary details but comprehensive enough to be relevant for the tasks that rely on the information.

- How to avoid over-scoping? – Large sets of stakeholders are demanding high quality products and solutions which may results in a shortage of resources. By visualizing the impact of dependencies on the decisions we can aim for an efficient allocation of limited resources [9].

As a long term goal we would like to address the following questions, which are related to the previously stated research issues:

- How can current tools in Requirements Engineering be strengthened in order to help to manage tens of thousands of requirements?
- Which processes or methods if any fit best to the scale of tens of thousands of requirements and how to design processes, methods and tools with a good trade-off between flexibility and scalability?

By trying to address the previously described problems we aim at making a significant contribution to the exploration of VLSRE. The results may help companies, which either are currently experiencing a switch from medium to large scale RE or have already passed the transformation and are facing results of VLSRE.

3. Research methodology and plan

Currently the research is in the advanced beginning phase. The area has been established, first research projects have executed and they are now in a reporting phase. Our research plan consists of three main phases: exploratory empirical studies, prototyping of new technology and case studies for validating of results.

As described in Table 1 the first phase that is almost completed is a descriptive exploratory interview study with Requirements Architects at Sony Ericsson [4]. The aim for this qualitative study is to define key issues in working with enormous masses of requirements by the same time empirically describing the terms *requirements architecture* and *requirements architecting*. In parallel with the interviews we are performing a quantitative literature study using the systematic review approach [13]. The aim of this study is to find empirical evidence in current research about the management of quality attributes and dependencies among requirements. The research is currently in the phase of assessing the quality of selected paper by using a *quality checklist* [13]. The third ongoing research study is an extended replication of an experiment on linguistic tool support in finding similar requirements [3][12]. The goal of the experiment is to empirically investigate potential benefits of extending current commercial requirements management tools by linguistic support for finding similar requirements. The experiment has been executed and data is being analyzed.

In the next phase we plane to work with prototyping of new tools for visualization and characterization of very large requirements sets. We are currently working on defining key quantitative attributes of requirement sets and ways of visualizing their dynamics over time. As a next study in this phase we plan to prototype new models for configurability and variability models that can handle thousands requirements.

Finally we plan to pilot and empirically evaluate the proposed technology from the previous steps. In this phase we will conduct case studies at Sony Ericsson to validate our results on real requirements. We believe that the nature of the requirements engineering in the mobile phones industry may play an important role in the investigation of future aspects of VLSRE.

Since the research will be conducted in mixed teams of researchers and practitioners the methodology of action research is applicable [4]. In this approach practitioners inform research about current issues and at the same time researchers apply their theories to practice. The term originates from social science but many studies confirmed its applicability to the field of information systems [5]. We have decided to use following references as most important: [1, 2, 3, 4, 6, 7, 10, 11, 12, 14].

4. Expected contributions and approach used for validation

We are expecting to significantly contribute in increasing the productivity of requirements engineering of very large requirements set. In particular we would like to make it easier to find duplicates, visualize relationships and characterize the quality of large requirements sets. Our initial results from an interview study revealed a strong need of tools and methods to support the previously described aspects. As a long term goal we would like to create tool support for managing thousands of requirements that can provide novel visualization technology and management approaches.

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6. References

[1] B. Regnell, R. Berntsson Svensson, K. Wnuk, "Can we beat the complexity of Very large Scale requirements Engineering", Accepted to the Requirements engineering Foundation of Software Quality Conference, Montpellier France, June 2008.

[2] P. Carlshamre, K. Sandahl, M. Lindvall, B. Regnell, J. Natt och Dag, "An Industrial Survey of Requirements Interdependencies in Software Product Release Planning", *Proceedings Fifth IEEE International Symposium on Requirements Engineering*, 2000, pp. 84-89.

[3] J. Natt och Dag, T. Thelin B. Regnell, "An experiment on linguistic tool support for consolidation of requirements from multiple sources in market-drive product development", *Empirical Software Engineering*, Kluwer Academic Publishers, Netherlands, June, 2006, pp. 303-329.

[4] D. Avison, "Action Research: A Research Approach for Cooperative Work", *7th International Conference on Computer Supported Cooperative Work in Design*, Rio de Janeiro, Brazil, 2002, pp. 19-24.

[5] Baskerville, R.L. and Wood-Harper A.T. "A Critical Perspective on Action Research as a Method for Information Systems Research", *Journal of Information Technology (11),* Chapman & Hall, UK, 1996, pp. 235-246.

[6] P. Sooyong, N. Jongho, "Requirements Management in Large Software System Development", *SMC'98 Conference Proceedings, 1998 IEEE International Conference on Systems, Man, and Cybernetics*, San Diego, CA, USA, 1998, pp. 2680-2685.

[7] O.C.Z. Gotel, F.T. Marchese, "On requirements Visualization", *Second International Workshop on Visualization in Requirements Engineering*, New Delhi, India 2007,

[8] P. Donohoe, "Introduction to Software Product Lines", *Proceedings - 10th International Software Product Line Conference, SPLC 2006, Proceedings - 10th International Software Product Line Conference*, Baltimore, United States, 2006, pp. 217.

[9] D. Sellier, M. Mannion, Visualising "Product Line Requirement Selection Decision Inter-dependencies" *Second International Workshop on Visualization in Requirements Engineering*, New Delhi, India 2007,

[10] Wohlin C., Höst M. and Henningsson K., "Empirical Research Methods in Software Engineering", *In Lecture Notes in Computer Science: Empirical Methods and Studies*, Springer Verlag, 2003.

[11] S. Marijanl, S. Petrovic, "Platform based development of embedded systems for traction and power engineering applications – experiences and challenges", *5th IEEE International Conference on Industrial Informatics*, Vienna Austria, 2007, pp. 371-376.

[12] Wohlin**,** C., Runeson**,** P., Höst**,** M., Ohlsson**,** M.C**.,** Regnell**,** B., Wesslén, A., *Experimentation in Software Engineering – An Introduction,* Kluwer Academic Publishers, London, 2000.

[13] B. Kitchenham, "Procedures for Performing Systematic Reviews" *Keele University Technical Report TR/SE-0401,* 2004.

[14] M. Host, B. Regnell, J. Natt och Dag, J. Nedstam, C. Nyberg, "Exploring bottlenecks in market-driven requirements management processes with discrete event simulation", *Journal of Systems and Software*, Elsevier, USA, 2001, pp. 323-232.