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Methods for architecting E/E-systems

"Metoder för utveckling av E/E-systemarkitekturer i tidiga faser"

Software-intensive systems are increasingly part of new products, which leads to significant business impact. This is especially true for the automotive industry where a majority of new innovations are realized through the use of software. The architecture of the software-intensive system will enable value creation when working properly or, in the worst case, prevent value creation. Lean Thinking is about focusing on the increase of customer value and on the people who add value. This project investigates how system architecting is performed in industry and how it can be improved through the use of Lean Thinking. This thesis provides a toolbox of knowledge on how Lean Thinking can be applied to system architecting and also presents how architecting is performed in industry today.

Objective

Architectural changes to distributed embedded systems are either evolutionary or revolutionary. The main objective of this research project is to understand the evolutionary architecting process and its contribution to lean values. The lean philosophy is basically common sense that is packaged so it can be applied to different domains. The project will thereby provide an understanding of the process and the value of the deliverables coming out of the architecting process.

Results and deliverables

The system development process at Scania was studied to identify current practice within the automotive industry. The result of this project is presented in the Ph.D. thesis which is based on four publications summarized below. Paper A presents how the architecting process can be improved by the use of Value Stream Mapping. The different tasks found in an architecting process are presented in Paper B. The successes of different methods related to the context in which they are used are discussed in Paper C. Paper D presents how flexibility can be economically valued, thereby relating to the business dimension.

Paper A: Improving the system architecting process through the use of Lean tools
This paper is based on a case study at Scania and Volvo Cars and presents how Value Stream Mapping can be used to analyze the architecting process. Furthermore, it presents in general terms what types of wastes and improvements could be found. One result of this paper is to show how waste can be eliminated and maximize the value creation of the process through the use of Value Stream Mapping. An adapted version of Value Stream Mapping is found to be a suitable method for identifying improvement in the architecting process.

Paper B: Architecting automotive product lines: industrial practice
The study has been performed at Scania and Volvo Cars. The striking conclusion is the similarity between the two companies in the tasks performed when maintaining and changing architecture. The tasks do not seem to be different for architecture maintenance compared to developing a new architecture. Likewise, they seem to be the same whether it is updating a product line architecture or updating the architecture of a single-shot system. The study indicates what effect differences, such as a strong line organization or a strong project organization, have on the architecting process. It also shows what consequence technical choices and business strategy have on the architecting process.

Paper C: A comparative case study of architecting practices in the embedded software Industry
The methods used to solve the tasks within the architecting process are mapped to the context used in the industry. The paper studies the current state of architecting practices in three different industrial segments that are characterized by being software-intensive. An analysis of the case study indicates how different methods are more suitable to different environments. The context of the different companies, as well as the architecting practices, are compared and analyzed. Many of the successful practices found in the study can be explained by the context of the different companies.

Paper D: Evaluation of design options in embedded automotive product lines
Decision-making under uncertainty is influenced by a number of factors, and some of them lead to less rational decisions. The use of structured methods is one way to improve decision-making. A method and process is developed to improve decision making. The developed method evaluates flexibility, using a concept called Real Options. The method is motivated and described by using an example from automotive embedded systems. To improve the usability of the method, a structured evaluation process is defined to aid practitioners such as developers and architects. The evaluation process provides a way of valuing system designs and enables the practitioner to think about the future in a systematic manner.

Project realization

The project was carried out during 2006 - 2011 in a collaboration between Scania CV AB and Mälardalen University. The Ph.D. student has shared his time between the university and Scania. Knowledge transfer through presentations and reports has been made continuously during the project. The research results have been presented both internally at Scania and externally at various conferences. The licentiate thesis was defended in October 2008 and the Ph.D. thesis in March 2011.

Project outcomes

Some time has elapsed since some of the studies included in the research project were finalized. Below is my understanding of the changes that have been made since the studies were presented. Paper A presented how Value Stream Mapping could be used to improve the architecting process. Since that time there have been various efforts to use Value Stream Mapping for different processes within system development. A paper co-authored by me shows how Value Stream Mapping can be implemented in practice at Scania. One and a half years after the case study leading to Paper B was finalized and presented at the two companies, some interesting changes have taken place. The architecting group at Scania has grown, both in the number of architects and their experience. Tool support for the architects has been significantly improved. The two separated architecting groups at Volvo Cars have merged into one, resulting in only one single architectural description. The group responsible for testing and validation at Volvo Cars is now part of the same section as the architecting group. I do not believe the changes were made because of the results presented from those two studies, even if I hope the ideas presented due to the studies inspired the change. It does however indicate the correctness of the results or at least indicate that the results correspond to industrial reasoning. An evaluation process using Real Options was presented and tested in Paper D. The evaluation process provides a way of valuing system designs. I believe that the method is correct and will provide improved decisions support. The problem, as with many other methods, is that the information needed is rarely available in industry. When presenting the evaluation process, I have often been given a positive response to the thoughts behind the method. Architects and people responsible for parts of the system like the idea that the increased cost of a flexible design could be argued using financial measures. To be used in industry it would need to be even more lightweight and used to guide discussion, rather than the decision itself. The greatest contribution to industry is probably a structured way of reasoning about design alternatives as options that can be valued.

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Publications and dissemination of results

In total eleven articles has been presented and published in conference proceedings. The main findings from the licentiate thesis was published as a book chapter and one journal article is submitted and under review. All publications can be found at the university website[1]. The licentiate thesis and Ph.D. thesis are listed below:

- Lean Thinking Applied to System Architecting, Håkan Gustavsson, Ph D Thesis, Mälardalen University, February, 2011
- Economical valuation of architectural decisions within automotive, Håkan Gustavsson, Licentiate Thesis, Mälardalen University Press, October, 2008

[1] http://www.mrtc.mdh.se/index.php?choice=staff&id=0237