Assignment 3, Research Planning Course

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## Contents

1 The COSY project .................................................. 4
   1.1 Background .................................................. 4
   1.2 Automotive electrical/electronic architecture .............. 4
   1.3 Partners and project goal ................................... 4
   1.4 Research method ............................................ 5
      1.4.1 Semi-structured interviews .......................... 5
      1.4.2 Case studies ........................................... 6

2 Current research issues ........................................... 6
   2.1 Autosar ....................................................... 6
   2.2 AHP and CPC ................................................ 6
   2.3 ATAM and CBAM ............................................. 7

3 Central literature and seminal papers .......................... 8

4 Key conferences .................................................. 8
   4.1 INCOSE ...................................................... 8
   4.2 ICSE ........................................................ 8
   4.3 ESEC/FSE .................................................... 8
   4.4 SAE ........................................................ 9

5 Research groups and institutes ................................ 9
   5.1 Applied software engineering group ....................... 9
   5.2 Center for Systems and Software Engineering .......... 9
   5.3 Embedded control systems group .......................... 9
   5.4 Carnegie Mellon Software Engineering Institute ........ 9

6 Ideas and preliminary and result .............................. 10
   6.1 Research questions ......................................... 10
   6.2 Paper A: Making Decisions in Integration of Automotive Software and Electronics: A Method Based on ATAM and AHP 10
   6.3 Paper B: Challenges in Automotive Electrical/Electronic Architecture Design .................................................. 11
   6.4 Paper C: A Decision Support Method for System and Software Architecture in Software Intense Products ........... 12
7 Milestones and time plan

7.1 Milestones .......................... 12
7.2 Courses ............................. 13
1 The COSY project

1.1 Background

The automotive industry has in the last years witnessed a dramatically increase in the use of electrical end electronic components. In the premium segment 23 % of the total manufacturing cost is related to the Electrical/Electronic (E/E) system and 80 % of all new innovations stems from electronics [14]. One of the reasons for the large increase of electronics are partly to save cost. Expensive mechanical components can be replaced with cheaper electronic controllers. Also many of the new innovations demand the use of advanced electronics. Examples of these new systems are adaptive cruise control, blind spot detection, forward collision avoidance, lane departure warnings, and many more. Some parameters that makes it even harder to develop the E/E system is the assumed long operational life time and a complex supplier structure. At the same time many of the functionality controlled by electronics are safety critical and you can’t assume that regular maintenance is performed. Also many different variants with many different configurations exists partly due to different customer demands but also due to the legal requirements in the country the product is sold.

1.2 Automotive electrical/electronic architecture

According to IEEE the definition of architecture is ”The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution” [1]. The E/E architecture in vehicles includes sensors and actuators control units as well as other hardware components. Also the physical network and wiring is part part of the E/E architecture as well as the software. A reason for this is the tight coupling between hardware and software. For instance, a braking application is very tightly bound to the hardware for which it is tested and developed. A change of sensors or other hardware components in such an application would likely generate a change of software functionality.

1.3 Partners and project goal

The aim of the project is to see what methods that are used in the early faces of development, regarding the Electrical/Electronic architecture, today in the automotive industry. Survey the benefits and drawbacks on these methods and also
how well they connect to the business drivers. Use this information to develop methods and models that better support the systematic reasoning around the many uncertainties that exists in the early phases of development. Also a better understanding on how each phase in the life-cycle can be connected to the early phases and thereby increase traceability of decisions.

As a first step an extensive set of semi-formal interviews will be outlined to get an understanding on what the key factors are when taking E/E system design decisions. We are interested in technical decision factors as well as non-technical decisions factors.

The research project is a joint project between industry and academia. Industrial partners are:

- Volvo Construction Equipment Components (VCEC) is a division that works as an internal supplier for Volvo Construction Equipment (VCE). VCE develops and manufactures wheel loaders, excavators, articulated haulers, graders, backhoe loaders and compact equipment. VCE is a part of the Volvo Group.

- Volvo 3P is responsible for product planning, product development, purchasing and product range management for the three truck brands that are owned by the Volvo Group (Mack Trucks, Renault Trucks and Volvo Trucks).

- Volvo Car Corporation (VCC) is a subsidiary of Ford Motor Company and manufactures cars in the premium segment.

Chalmers University of technology and Mälardalen University are the academic partners in this project.

1.4 Research method

There are a few different research methods that are planned to be used within this project. Most research approaches that are planned to be used are qualitative methods. Typical for qualitative research is that they aim to investigate and understand social and cultural phenomena in the context where they exist [10].

1.4.1 Semi-structured interviews

Semi-structured interviews is one of the research methods that will be used within this project. Semi-structured interviews has predetermined questions, but the order can vary based on the interviewers perception of what seems most appropriate
Additional question can also be constructed during the interview and it is also possible to remove questions that seems inappropriate.

1.4.2 Case studies

Case studies is another method that is most likely to be used in the project. Case studies aims at looking into a project, active or finished, and in this case projects at the industrial partners will be used. Interviews are usually part of the case studies as well as looking at documentation for that particular case. To gain validity it is preferable to have multiple cases to base the conclusions upon.

2 Current research issues

For the automotive industry, and more specifically the E/E system, it is the handling of increasing complexity that is one of the main issues [16]. Also the introduction of more safety critical functionality is an issue repeatedly mentioned. How to predict cost and business values in the early phases of development is another issue discussed in [8].

2.1 Autosar

A big standardization effort called the AUTomotive Open System ARchitecture (AUTOSAR) [3] is an initiative supported by all major automotive manufacturers and supplier. The goal of AUTOSAR is to standardize basic system functions and functional interfaces.

This will make it easier for Original Equipment Manufacturers (OEM) to change software supplier or even purchase hardware and software from different suppliers. Today the most common way, when for example a breaking system is bought, that both hardware and software are purchased from the same supplier.

2.2 AHP and CPC

Two methods that can aid in the decision process are the Analytical Hierarchy Process (AHP), and the Chainwise Paired Comparison (CPC) method. These methods are general decision methods and can be applied in any area when different factors is to be weighted against each other. The AHP is a multi-criteria decision making approach in which factors are arranged in a hierarchic structure.
In AHP all elements are compared against each other which yield a robust result but also time consuming due to the large number of comparisons. Elements are compared according to Table 1. CPC [15] is an AHP based method but CPC only requires the same amount of comparisons as the number of elements. However the consistency needs to be validated to ensure the same result as with AHP.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance of one over another</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
</tr>
<tr>
<td>7</td>
<td>Very strong importance</td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
</tr>
<tr>
<td>2,4,6</td>
<td>Intermediate values</td>
</tr>
</tbody>
</table>

2.3 ATAM and CBAM

ATAM and CBAM are two other methods that is specifically developed for software intense systems. One such method is the Architecture Tradeoff Analysis Method (ATAM) developed by Carnegie Mellon Software Engineering Institute. The goal of ATAM is to assess the consequences of architectural decisions in the light of quality attribute requirements [12]. Typically there exist competing quality attributes such as modifiability, security, reliability and maintainability that different stakeholders consider to be the most important. These quality attributes are broken down into scenarios. ATAM is divided into nine steps. These steps involve eliciting a utility tree and identifying risks, sensitivity and tradeoff points.

The Cost Benefit Analysis Method (CBAM) is an extension of the ATAM and is also developed by the Carnegie Mellon Software Engineering Institute [11]. It uses the quality attributes from the ATAM but also consider cost when reasoning around the most suitable architecture. As well as ATAM this method is developed for software but it is believed to be easily adapted for use on the complete E/E architecture. The use of ATAM for a complete E/E architecture is suggested in [9], and a combination of ATAM and AHP to use as decision support when integrating new functionality in the automotive domain is outlined in [19]. It is important to point out that neither ATAM or CBAM takes any decisions, it works more as
aiding in the decision process.

3 Central literature and seminal papers

One seminal paper is the description of the AHP method by T.J Saaty [18]. As central literature the descriptions on ATAM [12] and CBAM can be mentioned [11]. Larses is in his thesis discussing the architecting and modeling of automotive embedded systems [13]. He suggests a quantitative approach for architecture design and evaluation of modular architectures.

4 Key conferences

Below are some of the conferences that will be considered when submitting papers.

4.1 INCOSE

The international council on systems engineering (INCOSE) [4] holds an annual symposium that is considered among the biggest although the academic quality is shifting due to the large number of papers submitted by industry. Many of them are more experience paper from industry and the academic value can sometimes be questioned. This year the annual symposium is held in San Diego [5].

4.2 ICSE

The International Conference on Systems Engineering (ICSE) is the most well merited conference within software engineering. This year the conference is held in Minneapolis [2] and also holds an automotive workshop.

4.3 ESEC/FSE

European Software Engineering Conference (ESEC) and Foundations of Software Engineering (FSE) are held in conjunction in Croatia this year. This is also considered to be one of the key conferences within software engineering.
4.4 SAE

The Society of Automotive Engineers is an organization arranging a few conferences. The biggest is their world congress [6] held in Detroit annually. A more academic SAE conference is the SAE convergence [7].

5 Research groups and institutes

5.1 Applied software engineering group

The applied software engineering group at Chalmers University of Technology is one of the research groups in the area. They aim at providing industry with more dependable software at lower development and maintenance cost.

5.2 Center for Systems and Software Engineering

The Center for Systems and Software Engineering at the University of Southern California has a software architecture group studying software architectures and their impact on the overall life-cycle of software systems.

5.3 Embedded control systems group

The embedded control systems group at the Royal Institute of technology focuses on architectural design within mechatronic products.

5.4 Carnegie Mellon Software Engineering Institute

The Carnegie Mellon Software Engineering Institute is a US government funded research institution with a software engineering process management program. They have developed both ATAM and CBAM and are also authors of the Captivity Maturity Model (CMM) and its successor the Captivity Maturity Model Integration (CMMI) that is a process improvement approach that provides organizations with the essential elements of effective processes.
6 Ideas and preliminary and result

In this section the research questions that will be addressed are discussed, together with the papers that are planned as answers to these questions.

6.1 Research questions

Below are the research questions that will be discussed in the licentiate thesis.

RQ1: How to make decisions when adding new functionality within the electrical/electronic system architecture?

RQ2: What are the key factors when taking decisions regarding an automotive electrical/electronic system architecture?

RQ3: How to make architectural decisions in a software intense products?

The licentiate thesis will probably include three papers. Each paper will address one of the research questions stated above. Below are motivation for each paper and also some expected results.

6.2 Paper A: Making Decisions in Integration of Automotive Software and Electronics: A Method Based on ATAM and AHP

This paper is already accepted and will be presented in May 2007 at the 6th International ICSE workshop on Software Engineering for Automotive Systems in Minneapolis.

Design of automotive in-vehicle electronic systems is a challenge for Original Equipment Manufacturers, OEMs, due to a large set of functional requirements and stringent quality goals. The system is required to deliver its many functions in a dependable and safe manner, and product costs are to be kept low. The system must fulfil business and life-cycle goals such as being simple to maintain, service, and produce. The resulting system architecture is often complex and system architecture design is a process with many stakeholders. One way of reasoning around architectural choices is to estimate quality attributes of the envisioned system and then try to quantify the impact of different choices.
The design of automotive in-vehicle electronic systems includes joining together or integrating functionality developed by several organizations. These sub-systems can be purchased off-the-shelf from a supplier or developed specifically for its purpose by the OEM or the supplier, or a combination of the two. Functionality for sub-systems can be pure software like algorithms or it can be offered with hardware including computer nodes, sensors, actuators, connectors, etc. Integrating an electronic subsystem is the effort of making it conform to the decided architecture. Thus the integration is concerned with finding a design solution so that the component comply with, e.g. diagnostic strategy, system state management and fault handling. More precisely, integration could mean developing glue code or gateway functionality or it could mean to specify to a component supplier the system functionality to which the component must conform.

Paper A suggests a combination of the AHP based method, the Chainwise Paired Comparison method, and the ATAM. The approach is to use scenarios from the ATAM and analyze them with the AHP to evaluate different integration strategies in the context of an automotive electronic system. To further validate the method it will be applied to at least two different integration projects within the automotive industry hopefully resulting in another paper.

6.3 Paper B: Challenges in Automotive Electrical/Electronic Architecture Design

In the early phases of development many stakeholders have opinions on the E/E architecture. Different stakeholders has different needs of the proposed system and many compromises must be made in order to comply with all different requirements of the complete vehicle. The quality is one important factor that needs to be considered and time to market another. Both this factors are affecting each other, e.g. if you want to increase quality there is also a big risk that the time to market will be longer.

Stakeholder tends to think that their particular area is the most crucial regarding the success of the project. How is it possible to elicit the stakeholders that are the most important ones for the E/E system. This will be addressed with semi-structured interviews. Around 30 interviews will be conducted at the three different industrial partners. We believe that even if the decisions that are made, can be considered to be technical it might not only be technical factors that actually affects the decisions. Examples of non-technical factors that might influence the decision are factors such as company policies, distributed development, and
The interviews will be in three parts where the first one is to elicit what an architectural decision really is. This is done to get a view on what the person interviewed actually puts into an architectural decision.

In the second part we will separate stakeholders in two categories. One that has direct affection on the architectural decision e.g. the actual decision maker of the architecture, and another group that indirectly affects the architecture. Stakeholder that indirectly affects the architecture is basically all stakeholders except the ones taking the actual architectural decisions. The outcome of this section is to see if there is a consistent view regarding how well different processes are followed, realistic requirements stated, and if the information is shared in a preferable way. We believe that there are different opinions when it for example comes to how the architecture affects the business drivers.

In the last part we will elicit both technical and non-technical factors that affects decisions regarding the E/E architecture. The respondent will also rate the most important factors and a possible conclusion might be that non-technical factors are the most important ones when taking technical decisions regarding the E/E architecture.

### 6.4 Paper C: A Decision Support Method for System and Software Architecture in Software Intense Products

The third research question will use findings from the interviews and see in what way the method from Paper A can be used when taking not only technical scenarios into consideration. In this paper the method developed in Paper A will be generalized to work for architectural decisions in software intense products. This will be the final contribution in the licentiate thesis.

### 7 Milestones and time plan

The goal is to present the licentiate thesis during the first half of 2008. To achieve this the time plan shown in figure 1 should be followed.

#### 7.1 Milestones

Here are some milestones until licentiate thesis. I have not included any milestones after licentiate since the direction thereafter is quite uncertain.
May 2007  Paper A will be presented in end of May at the 6th International ICSE workshop on Software Engineering for Automotive Systems in Minneapolis.

June 2007  Present licentiate thesis proposal.

July 2007  Validation and testing of the method described in Paper A. This will either be to follow an active case or use documentation and interviews from an already finished case resulting in a paper.

August 2007  During spring 2007 interviews for paper two will begin. Hopefully all interviews will be completed until the end of the summer. One problem can be to find persons at the different companies during summer and therefore there is a risk that the interviews won’t be completed until early this fall. The first set of interviews will be at Volvo Car Corporation.

September 2007  During the fall the results from the interviews will be analyzed.

November 2007  Before the end of this year one or two papers will be produced based on the analysis of the interviews.

March 2008  Writing licentiate thesis. The licentiate thesis will be based on the three papers described above. There can be some changes in titles and scope, especially Paper C is quite tentative at the moment.

April 2008  Presenting licentiate thesis. This is of course a somehow tentative date but the goal is to present the thesis in April 2008.

7.2 Courses

In table 2 the courses that will be included in the licentiate thesis are shown.
Table 2: Courses included in licentiate thesis

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>University</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety-critical system</td>
<td>5</td>
<td>Mälardalen University</td>
<td>Completed</td>
</tr>
<tr>
<td>Real-time Systems, advanced</td>
<td>5</td>
<td>Mälardalen University</td>
<td>Completed</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>5</td>
<td>Mälardalen University</td>
<td>Completed</td>
</tr>
<tr>
<td>Design of real-time embedded systems</td>
<td>5</td>
<td>Royal Institute of Technology</td>
<td>In progress</td>
</tr>
<tr>
<td>Research planning</td>
<td>3</td>
<td>Mälardalen University</td>
<td>In progress</td>
</tr>
<tr>
<td>System thinking</td>
<td>5</td>
<td>University of Skövde</td>
<td>In progress</td>
</tr>
<tr>
<td>Software Architecture and Process Relations</td>
<td>5</td>
<td>Mälardalen University</td>
<td>Not yet started</td>
</tr>
</tbody>
</table>

References


