Experiences from large embedded systems development projects in education, involving industry and research

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Agenda

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Project courses in Mechatronics and the capstone course

- 4th year course in Mechatronics for M.Sc. Students which started in the early 80ies
- Approximately one semester course load distributed over two semesters
- 40 students each year

- *After the course the student will have knowledge and skills to develop mechatronic products in small or large development teams.*

- The guiding principles for these projects are as follows:
  - Students manage the project and take own responsibility as far as possible. Students also manage contacts with industrial partners, suppliers and external contacts.
  - During the project, rotation of responsibilities among students takes place in terms of management and technical work roles.
  - The educational goal has priority during the project, but has to be balanced with the project/prototype goal
  - The project is coached by one to two persons from the academic staff.

Previous capstone projects

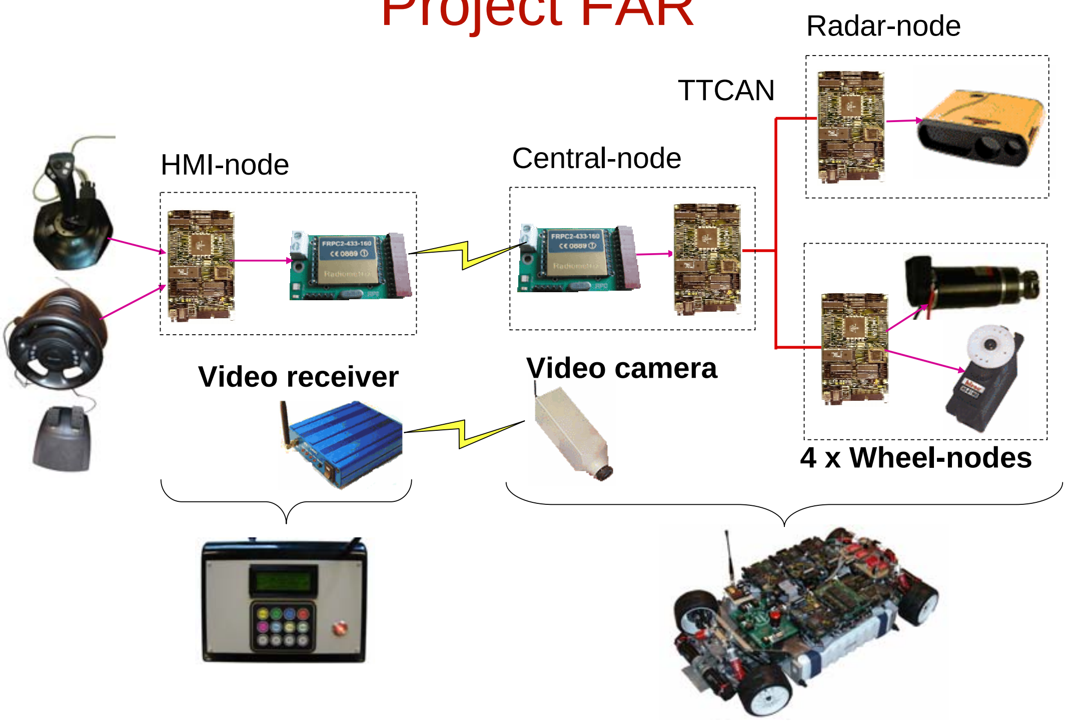
Project	Task	Provider (main)
SAINT1+2	Automotive software configuration and platforms	Scania / KTH
Mucca	Cow milking robot	De Laval
FAR	X-by-wire architectures and model based development	Volvo Car Corporation / KTH
WARP	Four-legged robot and its control system	KTH researchers
Xless	Wireless communication in train distributed control systems	Adtranz
Agilis	Fuel-efficient car	Shell-Eco Marathon
Balance	Prosthesis and aid for human balance control	Boston University / Harvard Medical School
PBLX	Reduction of wiring in cars	General Motors

Project FAR

- Demonstrate a suitable tool-chain environment, based on adapted existing environments.
- Model based development of embedded control systems and in particular Function and ARrchitecture (FAR) integration.
- X-by-wire car demonstrator and its distributed control system were developed.
- KTH, Chalmers and Volvo Car Corporation (VCC).
- The overall budget was approx. 40k€

- The students responded positively but also remarked that the workload and goals of the project were set too high.
- The desired application level functionality, e.g. collision avoidance could only be rudimentary completed.
- The tool-chain to support distributed control systems development could only partly be tested.
- Limited duration and resources of this project.

Project FAR



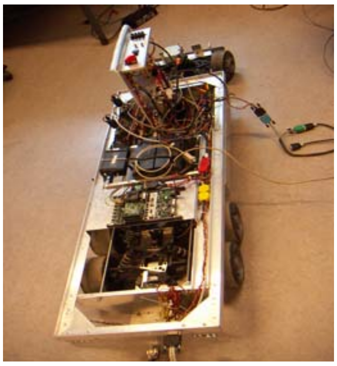
SAINT 1 & SAINT 2

- Self Adaptive INTelligent truck (SAINT) was formulated as a project between the industrial partner Scania and KTH with the experiences of the FAR project in mind.
- The development of a common demonstrator.
- It was early decided that the demonstrator and its environments would remain at KTH after development.
- The overall budget was limited to approx. 30k€.

- The main purposes of the project included to:
  - develop a truck model including its distributed control system.
  - evaluate the use of PDM tools for function and software configuration, mainly for the production process.
  - develop a prototype software platform supporting location transparent execution.

SAINT 1

- The truck and its control system, together with a middleware based on the ENEA OSE RTOS were developed together with basic functions.
- The chosen PDM system was adequate for software configuration purposes.
- In addition, the complete truck was made operational.
- Due to the time limitation only basic functionality and one simpler configuration scheme was possible to develop.



SAINT 2

- The goals were to develop more advanced vehicle functions and a more elaborated function/software configuration scheme
- Initial hesitation due to:
  - For some of the students the project appeared less interesting because the design was already to a large extent accomplished in SAINT1.
  - Same external partner in two consecutive years.
- The results clearly indicate the potential of incremental projects.
  - Educational viewpoint.
  - The students faced huge amounts of (not always up to date and consistent) documentation.
  - Quickly learnt the value of documentation.
- The functionality given the support from the existing platforms including the middleware grew faster than anticipated.
- Difficulties in distributed systems debugging (feature interaction and multiple fault sources). These problems can be alleviated with better support tools for development and debugging.

Boston balance projects

- An international setting, with a large number of spin-off projects and products during 4 years.
- The original project formulated in 2001 between KTH and two partner universities in Boston;
  - The Neuromuscular Research Center (NMRC) at Boston University.
  - Massachusetts Eye and Ear Infirmary (MEEI) at Harvard Medical School.
- The goal was to develop a prosthesis for use with people with a balance disorder.
  - Malfunctioning balance organ in the inner ear.
  - Loss of sensory impressions from the soles of the feet.
- Rudimentary prototypes realizing aspects of the prosthesis existed.
- The aim was to produce a wearable prototype.
- The balance prosthesis is constantly further developed

General experiences

- In general, the course is well received by the students.
- The students in the capstone course are both expected to take a large responsibility themselves, but also to the idea that students are expected to utilize knowledge and skills from previous courses.
- The course is also well received by the external partners providing the projects.
  - Means for recruitment
  - Connection with academic research
  - To obtain resources for (cheap) prototype development
  - Many of the prototypes developed are still in use

Conflicting goals: Prototype vs. education

- Students are eager to put more emphasis on the project goals than the educational goals.
- Project progress motivates the educational goals.
- A focus on project goals helps motivate students, which then become more easily subjected to learning.
- Team management is therefore crucial, which requires a skilled coach.

One key is to make sure that all students get enough time to **learn, reflect and practice** new ideas.

In a critical moment, the task of finalizing the software is given to the student most experienced in programming – not the student most in need of programming practice.

One key is to manage the **balance** between keeping a constant development pace in the project, and having all students subjected to exposure from unfamiliar areas.

Homogeneity/heterogeneity and sizes of groups

- Embedded systems course projects are facilitated by, and benefit from, diversity and heterogeneity.
- Students both learn from each others experiences and mainly from the larger number of courses and areas covered by the students combined backgrounds.
- The KTH projects usually attract students from at least three different M.Sc. Programs.
- When creating the teams, a large effort is also made on gender and cultural diversity.

Team work challenges

- Team work related aspects should be covered.
- With our strong technical background and educational traditions, it is sometimes hard to provide sufficient support for the students to cope with such things as time and resource planning and effective management of the teams.
- One of the major challenges is to find a balance between knowledge and capabilities about managing an R&D team and sophisticated technical knowledge.

International projects

- The aim is to have at least one international project every year.
- Collaboration with a foreign university or with a foreign corporate sponsor.

- The usual method to reach these aims is to spend some time abroad: as an exchange student, in an exchange project or to perform a Master's thesis project abroad.
- The capstone course project aims at giving all participating students a similar experience, but without the need to travel.

Coaching

- Faculty supervision has been replaced by team coaching.
- Transformation of higher education:
  - Faculty teaching to student learning
  - University- to student responsibility
  - Lecturing to problem based learning
- Coaching means guidance rather than directing, helping rather than telling and basically making the individual student perform at his or her best.
- The coach act as mediator between the faculty and the student team, provides resources and directs students towards appropriate faculty experts.
- A highly valuable property is experience of product development projects managing the team in the different phases of the project, both captured by participating students and faculty.

Industrial partner prerequisites

- Industrial partners vary from foreign to local partners, from one-man-companies to large global companies.
- Neither the locality nor the size of the company matters, neither the field of the company.
- The **engagement and interest** of the company and primarily the corporate liaison **matters**!
- The ability of the partner to **provide funding** for prototypes, tools etc as well as access to the companies own resources **matters**!

Running the projects connected to academic research

- Aligning the projects with research motivate and involve research staff and doctoral students in the projects.
- A student project can provide extra resources in developing a research prototype and motivates extra work in preparing and participating.
- The SAINT capstone projects were part of a larger research project with extensive involvement from senior researchers.
- Synergetic efforts can be very important today for the academic staff to achieve efficient economy and resource utilization.

Incremental projects

- Non-incremental projects provide a strong incentive and satisfaction for the students where they, starting from scratch, end up with a working product.
- The incremental projects provide the benefit of accomplishing a more complex and high quality prototype and meet the industrial need for this type of common development.
- As with all development processes though, incremental product development fosters incremental innovation rather than radical innovation.
- The aim is to provide projects varying on the scale from radical to incremental and to clearly express the differences to the students prior to choosing projects.

Conclusions

- The capstone course projects performed at KTH have varied from radical product development to incremental projects spanning over several years
- Balancing and incorporating appropriate amounts of advanced technology, methodology and organizational issues (team work).
- Incremental projects have proved greatly beneficial in terms of synergy with academic research and long-time collaboration with industrial partners.
- Students express initial concern at joining an incremental project rather than starting from scratch, but considered the incremental project advantageous.

Conclusions

- For incremental projects there is the need for long term arrangements thus a challenge if the projects involve external partners.
- Although the benefits with external providers of projects, incremental projects may still be valid given internal project providers.
- Achieving synergy between research, education and industry will be of increasing importance for the academic system – and that this topic also deserves further investigation.
- Students should be exposed to a mixture of build from scratch and incremental project.
- Problem based education should be adopted as one of the educational forms throughout the engineering education.