MÄLARDALEN UNIVERSITY

DEPARTMENT OF COMPUTER SCIENCE AND ELECTRONICS

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VÄSTERÅS ESKILSTUNA ÖREBRO STOCKHOLM SÖDERTÄLJE

ANNUAL REPORT

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MRTC
MÄLARDALEN REAL-TIME RESEARCH CENTRE

PROGRESS

ISS
Intelligent Sensor Systems

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Annual Report 2006
Summary

The Department of Computer Science and Electronics is the most research intensive department at Mälardalen University, with 12 professors, several additional senior researchers and more than 60 postgraduate students. The research is organized in two mutually supportive research profiles – Mälardalen Real-Time Research Centre (MRTC) and Intelligent Sensor Systems (ISS).

Mälardalen Real-Time research Centre (MRTC) was formally established January 1st 1999 as the result of a profile grant from the KK-foundation (KKS) and a focused effort on real-time related research since 1987 at the Department of Computer Science and Engineering (IDt).

The profile Intelligent Sensor Systems (ISS) has its origin from several years of collaboration between the participating research groups. In 2005 the faculty board decided to grant ISS status as an emerging profile and as such also receive dedicated funding.

This report presents the organisation, projects and achievements of IDE in 2006, with the following high-lights:

- 7 Ph.D. theses were successfully defended by Thomas Nolte, Gordana Dodig Crnkovic, Rikard Land, Frank Lüders, Ali Fard, Krister Landernäs and Javier Garcia Castaño.
- 3 Licentiate theses were successfully defended by Kaj Hänninen, Annika Jonsson and Jonas Neander.
- 14 new Ph.D.-students were enrolled, including 3 industrial PhD students.
- 77 MSc-theses, and 121 publications, many presented at leading conferences world-wide.
- The strategic centre PROGRESS (supported by SSF) was launched, resulting in recruitment of 9 new PhD students, several postdocs and other senior researchers.
- Two new professors were appointed: Mikael Nolin in Real-Time Systems, specializing in automotive software, and Paul Pettersson in Real-Time Systems, specializing in modeling and analysis.
- SSF decided to support the program SAVE with an additional 9.5 mnkr, resulting in an extended program called SAVE++.
- The two international scientific events were organized at MDH: 2nd International Conference on the Quality of Software Architectures (QoSA 2006) and the 9th International Symposium on Component-Based Software Engineering (CBSE 2006).
- ISS received four different EU-object-2-projects, resulting in strengthening of the regional cooperation with the industry.
- ISS was also supported from Robotdalen and Sparbankens Nya for research within robotics and biomedical engineering.

Preface

In 2006 we fully implemented the new organisation of research at the department, consisting of the two research profiles *Intelligent Sensor Systems* (ISS) and *Mälardalen Real-Time Research Centre* (MRTC). Both profiles were additionally fully recognised by the faculty board as being prioritised research directions at Mälardalen University. As a consequence of this and the new system for distribution of university funding for research we expect a positive development of the level of university funding for both profiles.

For ISS the year has brought a further integration and internal consolidation of activities, as well as many external contacts and discussions about co-operations, including discussions with industry and other regional actors. ISS is now established and known also externally. ISS was further strengthened by four new EU Objective 2 projects and the recruitment of 4 new PhD-students.

Within MRTC, the main development has been the establishment of the PROGRESS strategic research centre. A major effort has been spent on planning, recruitments, and launching new projects and activities. Four full professors have been recruited, together with six young PhDs and 10 PhD-students. A few more students and researchers will be recruited in 2007. It is definitely fair to say that PROGRESS brings a substantial vitalisation of the MRTC research. Also the industrial cooperation has developed within MRTC during 2006. 3 new industrial PhD students have joined the centre, and there are on-going discussions about cooperation with several companies, both about bi-lateral cooperation and larger initiatives, including a national initiative on Industrial Software Engineering.

Both within ISS and MRTC there have been multiple and conscious activities aiming at attracting funding from the EU Framework 7 programme. Such funding, or more specifically the cooperation it brings, is important for the further development of our research.

Compared to the two previous years, the number of post graduate degrees is lower in 2006. The main reason for this is that funding for recruitments has been lacking in recent years. This negative trend was broken in 2006, which makes us very optimistic about the future development of our research and graduate education.

Regarding the undergraduate education, important efforts have in 2006 been spent on conforming our education to the Bologna structure; including reforming our undergraduate programmes as well as extending our Masters programs to 2 years, and at the same time make them better connected to our research profiles. Unfortunately, there is still in a negative trend in recruitments; though we are doing better than most other comparable departments in Sweden. The low number of enrolled students has unfortunate consequences for the education programmes and courses that we are able to offer. A substantial effort is needed to change the negative trend. Several activities have been initiated in 2006, aiming at better care for the enrolled students and improved marketing. Since virtually all employees at the department are engaged in these efforts, and since the job-market is developing positively, we are optimistic about a positive development also in our undergraduate education.

Västerås, March 2007

Ylva Bäcklund	*Hans Hansson*	*Maria Lindén*
Head of dept., IDE	Research Director IDE Director MRTC	Director ISS

Table of Contents

1 Department of Computer Science and Electronics

In 2004 the dept. of Computer Science and the dept. of Electronics fused into one – the Department of Computer Science and Electronics (IDE).

IDE is the most research intensive department at MDH, with 12 professors, several additional senior researchers and approximately 60 postgraduate students. The research is organized in two separate research profiles – Mälardalen Real-Time Research Centre (MRTC) and Intelligent Sensor Systems (ISS).

The strategy for the development and expansion of research is based on the philosophy of relatively small and independent research groups with strong leadership, while maintaining a co-operative atmosphere and stimulating interaction between groups and individuals.

The single most important criterion for the success and stability of the expansion is strategic recruitment of senior researchers with scientific strength, leadership ability, and co-operation skills. Such researchers are all capable of independently establishing, developing and funding their own research groups, as well as contributing to the positive atmosphere and general development.

The following is a list and brief presentation of the current 10 research groups at IDE, including leadership, senior researchers, and sources of funding. The groups are in several cases co-operating, as they are all dealing with different (complementary) perspectives on either embedded systems (MRTC) or intelligent sensor systems (ISS).

MRTC

a) **Industrial Software Engineering group** – headed by Prof. Ivica Crnkovic; adjunct professor Heinz Schmidt, senior lecturer Sasikumar Punnekkat (appointed full professor in 2007), senior researcher Radu Dobrin, postdoc Cristina Seceleau, Dr Rikard Land, Dr Frank Lüders, 10 PhD students, one visiting PhD student 2 PhDs in 2006. The group is focusing on research related to software engineering in industrial settings, funding from ABB, Ericsson, EU, SSF, KKS, CC-systems and MDH.

b) **Embedded Systems Software Engineering group** – headed by Prof. Christer Norström; Prof. Jakob Axelsson, Senior Lecturer Dr. Kristian Sandström; Dr Anders Wall; 10 graduate students. The group is focusing on Embedded Systems Software Engineering (e.g. for automotive and industrial robotics systems); funding from SSF, ABB, Volvo, Ericsson, Saab, Level 21, KKS, Vinnova and MDH.

c) **The Programming Languages group** – headed by Prof. Björn Lisper; Senior Lecturer Docent. Jan Gustafsson, Dr. Andreas Ermedahl, Dr Christina Björkman and Dr Gordana Dodig Crnkovic; 8 graduate students (three external); 1 Ph D in 2006; the group is focusing on worst-case execution time analysis, as well as design and analysis of languages for real-time and embedded systems; funding from Vinnova,, CUGS, Ericsson, and MDH

d) **Real-Time Systems Design group** – headed by Prof. Hans Hansson; professor Mikael Nolin, professor Paul Pettersson, Senior Lecturer Dr Jukka Mäki-Turja, Dr Thomas Nolte, Dr Dag Nyström, post doctoral research fellow Dr Insik Shin, 5 graduate students; 1 PhD and 1 lic 2006; the group is focusing on design methods, architectures

and communication for real-time systems; funding from SSF, Vinnova, KKS, EU, and MDH.

e) **Monitoring and Testing group** – headed by Dr. Henrik Thane; 3 graduate students; the group is focusing on monitoring, testing, and debugging of real-time systems; funding from SSF, KKS, and MDH

f) **Adaptive Real Time Systems group** – headed by senior lecturer Dr. Damir Isovic, 2 graduate students; the group is focusing on flexible scheduling models and resource reservation mechanisms that are suitable for adaptive real-time systems; funding from EU, SSF, and MDH.

g) **Scalable Architecture for Real-time Application (SARA) group** – headed by Prof. Lennart Lindh; 3 graduate students; the group is focusing on scalable multiprocessor systems, system-on-chip, and moving software functions into hardware; funding from KKS and MDH.

ISS

h) **The Intelligent Systems group** - headed by Docent Peter Funk; Researchers Dr. Ning Xion, Dr. Gordana Dodig Crnkovic, MSc. Mobyhen Ahmed; Research coordinator BSc. Therese Jagestig Bjurquist, PhD students; Lic. Erik Olsson, MSc. Shahina Begum. (and 3 associated PhD students at IDP) in 2006. The groups' research targets applications of artificial intelligence methods and techniques in industrial and medical domains; funding from SSF, KKS and MDH.

i) **Communication Performance Predictability and Analysis group** – headed by Prof. Mats Björkman; Researcher Dr. Bob Melander; Researcher Svante Ekelin; 5 graduate students; 1 licentiate and 2 PhDs planned for 2007; focusing on communication for small embedded devices, and traffic measurement and analysis; funding from VR, Vinnova, KKS, CUGS, and MDH.

j) **Sensors and Mechatronics** headed by Dr. Maria Lindén; Dr Mikael Ekström; Professor Ylva Bäcklund; Dr Mia Folke, Dr Javier Garcia Castano; Dr. Mannan Mridha, Dr. Denny Åberg; Prof. Lars Asplund, 1 research engineer; 10 PhD students; two of them Industrial PhD student (2 leaving the group during 2006); focusing on wearable multisensor systems also including artificial intelligence, microwave sensors and imaging and robotics. 3 PhD and one licentiate during 2006. Funding from Vinnova, KKS, EU, Länstyrelsen, Robotdalen, Sparbanken Nya, and MDH.

1.1 Recent developments

This section highlights some of the new initiatives, decisions and projects during 2006 that we consider particularily important, and that will have impact on our future development. For a more complete presentation of all our research activities, please read the research profile and group presentations in subsequent chapters.

SAVE++

In April 2006 the Swedish Foundation for Strategic Research decided to support the SAVE programme with an additional 9.5 msek for 2006-2007. SAVE is a national project coordinated

by MRTC and with partners from KTH (Mechatronics), Linköping University (RTSLAB), MDH (SDL and SEL), and Uppsala University (UppAal group).

SAVE aims at establishing an engineering discipline for systematic development of component-based software for safety critical embedded systems. SAVE has during 2003-2005 made substantial progress, including development of

- The SaveCCM componet model, including integration in the UppAal/TIMES environment
- Component safety interfaces and a method for safety analysis based on components and fault modes
- A monitoring-based model synthesis method for real-time software components
- A formalisation of aspects and component reconfiguration by weaving
- An extension of the TIMES tool with schedulability analysis and code generation
- A component-based real-time database
- A hierarchical scheduling technique allowing non-interfering sharing of resources.
- A method for comparing different model-based and component-based development techniques

To further advance research in the area, the two year extension of SAVE – SAVE++ – will specifically focus on:

1. **Component model semantics and verification**, including the three main activities: (1) compositional semantics and verification, (2) safety modelling and verification, and (3) linking Component-based Development with model-based design.
2. **Integration-platform** including the two main activities: (1) a method and run-time system for integrating independently developed subsystems, guaranteeing temporal and functional isolation, and (2) a data-centric system abstraction and infrastructure.
3. **Tool integration and process**, including the three main activities: (1) tool integration reference platform, (2) instantiation of a SAVE++ tool-suite, and (3) a CBD-based development process for vehicular systems.
4. **The SAVE++ demonstrator**, aiming at demonstrating the integration of the results of sub-projects 1-3 in a simple, but realistic, case study.

PROGRESS – Strategic Centre for Predictable Embedded Software Systems

The PROGRESS strategic research centre for predictable development of predictable embedded software was formally launched January 1st 2006 as the result of a five year grant awarded (of 43 msek) to Mälardalen Real-Time Research Centre by the Swedish Foundation for Strategic Research. The work performed since then has been focused on bootstrapping the centre. In the spring of 2006 the focus was on organisation and recruitment, resulting in the establishment of research clusters and that a number of PhD-students, PostDocs and professors joined the centre. During the autumn of 2006 the focus has been on detailed planning of and initiation of research activities.

PROGRESS is more than an integrated part of Mälardalen Real-Time Research Centre; currently it provides a common thread and focus for essentially all research performed within MRTC. Though it is straightforward to identify the activities at MRTC being funded by the PROGRESS grant, it is not always obvious to define the boundaries of PROGRESS, as directly funded activities are conducted in conjunction with activities funded by other sources (including industry and other contracts with funding agencies).

PROGRESS is dedicated to find methods for cost-efficient handling of the increasing complexity of software in computer-based products. Adopting a software-component approach to engineering, and re-engineering, of embedded software systems, PROGRESS will provide theory, methods, and tools that increase quality and reduce life-cycle costs.

PROGRESS will act as a catalyst to strengthen Swedish competence in product development using embedded software. **PROGRESS' vision** is

> *"to be a world-wide recognized centre in engineering of predictable embedded software for primarily the vehicular, automation and telecom domains, with extensive contacts and exchange with other leading research centres, and to be the preferred research partner for industry in Sweden and Europe in this growing technology field."*

PROGRESS' mission is to advance the state-of-the-art in engineering of embedded software by providing methods and tools to help mastering current and emerging challenges in development of embedded software.

Further details about PROGRESS are provided in Section 2.3.

FLEXI ITEA

The goal of FLEXI ITEA is to realise a high performance business: From idea to product in six months. This project is innovative in that it addresses this challenge from three different perspectives:

1. Market shaping innovation: Exploit agility to create an innovative culture and a fast market introduction of innovations
2. Release definition: Realize a flexible market driven product portfolio management
3. Agile product development & integration: Develop new agile development solutions to large, collaborative, multi site teams of both SME's and large corporations.

More than 20 companies and research institutes participate in the project. MRTC and ABB Research are Swedish participants with focus on component-based development processes and verification of integrated systems.

Ericsson Lab

MDH and Ericsson AB have increased their research collaboration. In addition to several traditional research projects, the collaboration now includes extended support for high quality theses with new research projects as a possible side effect. To be able to perform these projects, MDH has been privileged with an Ericsson Lab, containing sophisticated telecom hardware. It is a multiprocessor system based on the real-time operating system OSE. The equipment also includes full support for test and development.

During 2006 the Lab has been set up and connected to Ericsson development system. Two master theses have been successfully performed and several more have been planned for 2007

and are now running in full scale. The first thesis has been a master thesis about performance analysis in a complex real time environment. The second is part of a research project in fault injection.

Robotics for SMEs- vision project

In the project Robotics for SMEs, funded by Robotdalen, the vision project is one project out of four. The ultimate goal is to make industrial robots more useful for small and medium sized enterprises. By putting the robot on a fully autonomous platform the robot can go from one working place to another without human interaction. This then require that the platform can navigate in an industry without any special rebuilding efforts.
The research project in the Robotics group is focused on vision system based on reconfigurable electronics. i.e. FPGAs. The current status is that one single FPGA can simultaneous handle four cameras, and from these four cameras in real time extract required information for both positioning the robot platform and possible the hand of the robotarm - the gripper.

ChipVision

In the EU-project ChipVision there is cooperation with several companies in the Objective-2 region, which can benefit from a fast vision system. One is building grapple harvesters, and a vision system can improve the working conditions for the person handling the system, and thus lessen the probabilities for RSI-injuries.
A couple of other companies need the vision system for Quality Assurance, i.e. inspecting the manufactured parts, to see that there are no defect parts.

EKEN-Efficient knowledge and experience reuse within the business world

The goal of the project is to offer the participating companies methods and tools for efficient knowledge and experience management. One of the benefits is also the opportunity and facility to identify people with similar tasks and problems at different companies and share their experience.

Competence center for microwave imaging

The aim of the project is to use the competence built up at Mälardalen University within microwave imaging to the benefit of the region. This can be achieved in two ways, one is by knowledge driven development to create new industry; another is through business development of existing companies. Business development through new possible products and new tehniques for raising the productivity can be achieved by companies facing novel technique at the competence centre for microwave imaging.

Competence center - Multisensors for better health.

In the project a network between clinics, manufacturers, developers and researchers is formed in order to strengthen the competences and competitiveness in biomedical engineering and sensor technology areas. New technologies, as wearable multisensor-systems for measurements of physiological parameters, as heart activity and breathing, are developed and spread within the areas preventive health care, health care and home care. The regional industry and society will benefit from the development of new technology by an increased competence and competitiveness. Further new products and manufacturing of products might occur, as well as up-starts of new companies.

Microwave project

The microwave project is a novel proof of principle project, for imaging of the human body with microwaves and here a close collaboration with a French research group (Supélec) has been established. The technique is model based and uses measurements as well as computer models to create a tomographic image of the object. The main application of this technique is breast tumour detection and a demonstration system is going to be built at Mälardalen University, using the hardware experience from other leading research groups together with some new ideas and a software algorithm developed together with Supélec.

High-five (A Holistic and Improved Infrastructure for Increased Industrial Impact of research)

MRTC was awarded a planning grant from Vinnova to prepare an application in the VinnPRO programme. The focus of this programme and the application is to strengthening the industrial impact of research and education as well as speeding up transfer of technology and knowledge from research to industry. The following novel instruments are proposed:

- An ***Industrial Pre-Doc programme*****,** packaged into a two year Master programme, featuring both theoretical courses to prepare students for graduate education and extended thesis work that will be performed as a joint effort between industry and academia.
- An ***Industrial Post-Doc programme***, including one or two years of post doctoral research performed partly in academia, partly at a hosting company, with the purpose of preparing the PhD for an industrial career and/or developing his/her research results into a successful innovation.
- A ***mobility programme***, including industrial stays for academic PhD students and researchers, as well as a dedicated Industrial Guest Professor programme.

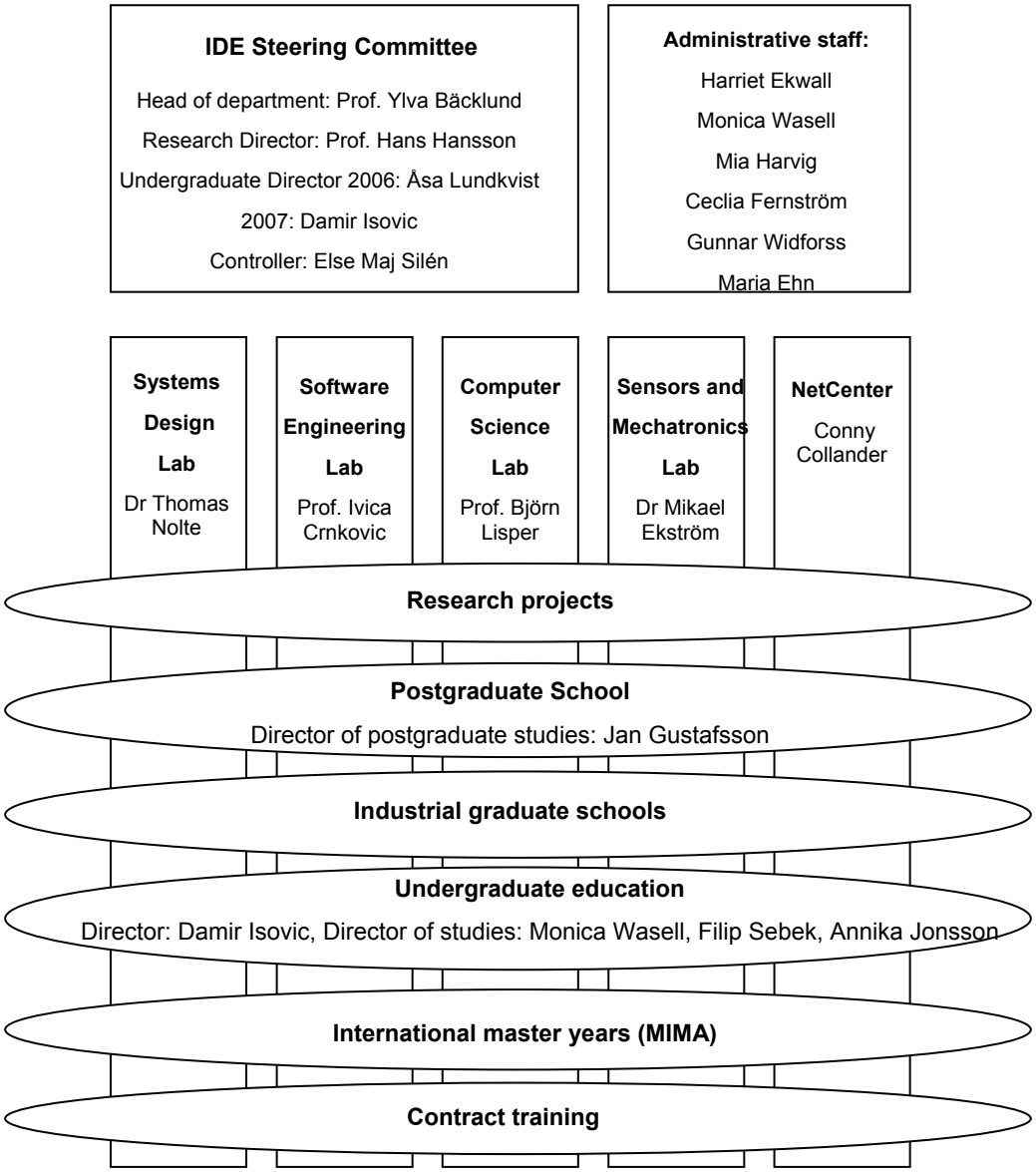
The proposed initiative will be based at MRTC and performed in conjunction with on-going and emerging research and graduate education programmes hosted by or involving MRTC (such as ARTES, SAVE-IT and PROGRESS). It will, however, be open for participation of other universities and research institutes.

1.2 Organisation and Management

IDE has a scalable matrix-organisation with 5 different laboratories as vertical entities, as shown below. A lab is an organisational unit headed by a lab coordinator (lab-leader) who has the responsibility of managing and developing the lab. This includes co-ordination and planning of activities in under graduate education and in research, as well as administration of the lab (e.g. handling the budget and representing the lab externally).

The following are labs at IDE:

- Systems Design Lab (SD Lab)
- Computer Science Lab (CS Lab)
- Software Engineering Lab (SE Lab)
- NetCenter
- Sensors and Mechatronics Lab (SM Lab)



The laboratories represent competence areas in which basic research, as well as postgraduate and undergraduate education is conducted. The laboratories are responsible for performing research and providing resources in terms of teachers and supervisors for the following horizontal entities:

Research projects, which are performed within the labs, between labs and/or with external partners. Each research project has a project leader responsible for the project budget and progress. The projects are carried out in a specific research group.

Postgraduate school, including Ph.D. and Licentiate programmes. The postgraduate school is responsible for the postgraduate courses not included in the MSc program, as well as admittance and progress of postgraduate students. The actual project work and supervision is performed within the research labs and projects.

The industrial graduate schools of which SAVE-IT is an important part is a separate programme within the postgraduate school. In addition to SAVE-IT, the department also has industrial PhD students in the research schools IRSED and RAP, read more in chapter 4.

The international master programmes at the department are one-to two year programmes that are oriented towards the research in one of the subjects defined by the programme. Closely connected to the department research, the students receive special guidance to be well prepared for research in scientific and industrial environments.

Undergraduate education is administrated by the directors of undergraduate studies, who assign courses to the different labs. The assignment of teaching staff to courses is decided within the labs. Course and curricula development is performed on initiative both from the research labs and the directors of undergraduate studies.

Contract training in 2006 include:

- The course Computer networks, step 3 (http://mdh.webbplats.se/mer_info.asp?Id=193) has been offered to ABB at three occations.
- Cooperations within Local Academies (i.e. upper secondary school and universities paying an annual fee for cooperation in the Cisco Networking Academy Program). Fore more information see: http://www.mdh.se/netcenter/LA.shtml

The management of IDE is handled by

The IDE Steering group consisting of the head of the Department, Prof. Ylva Bäcklund, the Research Director, Hans Hansson, and the Director of Undergraduate Education, Åsa Lundkvist (until dec 2006), and Damir Isovic (from feb 2007).

Main tasks include to

- Coordinate the research, education, administration and external contacts at the department.
- Be responsible for the long-term strategic planning of IDE.

The Lab coordinators (the lab-leaders), are responsible for managing and developing the labs. This includes co-ordination and planning of activities, as well as administration of the labs (e.g., handling the budget and representing the lab externally).

The research group leaders are responsible for the research projects carried out in their groups.

Staff

Management

Ylva Bäcklund Since December 1999, she has been appointed as a professor in Electronics at the former department of Electronics at Mälardalen University (MDH). After the merge with the dept of Computer Science she is now the head of the Dept. of Computer Science and Electronics. Since she joined MDH her first task was to build up research and research education in Electronics. Areas of particular interest are sensors for wireless patient monitoring in hospital and home health care, and microwave technology for biomedical engineering. The research has attracted funding from Vinnova and from the Knowledge foundation for the research projects ”Wireless Patient Monitoring Systems”, "Microwave technology for Biomedical Engineering", "Intelligent sensor systems for diagnosis, treatment and health care", and from the EU 6th framework programme in a CRAFT project entitled ”Multi-monitoring medical chip for homecare applications”. Ylva has been the chairman of a working committee for the Swedish research council, (2002-2003) and is a member of the board for ”Innovationsbron” (2003 – present). Before joining MDH, Ylva was research leader of the Micro System Technology group at the Electronics department, Uppsala University. She received her Master of Science (Engineering Physics), Licentiate degree (Electronics), PhD (Doctor of Technology in Electronics) and "Docent" (Associate Professor in Electronics) from Uppsala University in 1986, 1990, 1992, 1996 respectively.

Hans Hansson is professor in Computer Engineering, specialising in real-time systems, at Mälardalen University since 1997. He heads the MRTC, co-ordinates the national research initiative SAVE and the industrial graduate school SAVE-IT. He received an MSc (Engineering Physics), a Licentiate degree (Computer Science), a BA (Business Administration), and a Doctor of Technology degree (Computer Science) from Uppsala University, Sweden, in 1981, 1984, 1984 and 1992, respectively. He was appointed “docent” in Computer Systems at Uppsala University 1998. Hans was programme director for the national real-time systems research initiative ARTES 1998-2004, and was visiting professor at Uppsala University 1999-2004. Before joining MDH, Hans was department chairman at the Department of Computer Systems, Uppsala University, and researcher and scientific advisor at the Swedish Institute of Computer Science in Stockholm, Sweden. His current research interests include real-time system design, scheduling theory, distributed real-time systems, and real-time communications networks. He is co-founder of ZealCore Embedded Solutions AB.

Åsa Lundkvist was until dec 2006 a lecturer and director of undergraduate studies at IDE. She received her Masters of Mathematics at Stockholm University in 1986 and has worked in various companies in Sweden, United States, France and United Kingdom before taking a position as lecturer at IDE. Åsa teaches programming languages. Since February 2007 Åsa is the head of the Department of Innovation, Design and Product Development at MDH.

Damir Isovic, PhD, lecturer and researcher at SDL. He received his MSc in Computer Engineering and a Diploma of Higher Education in Natural Science Mathematics and Astronomy from MDH in 1998 and 1999, respectively. His research interests include real-time systems and scheduling theory, with a specific emphasis on combining flexibility and reliability in construction of schedules. Damir is also evolved in the development and the maintenance of the internal web pages of Department of Computer Science at MDH. In November 2004 he presented his PhD thesis "Scheduling for Media Processing in Resource Constrained Real-Time Systems".

Administrative staff

Here follows a short presentation of the administrative staff. The staff involved solely in Undergraduate Education is presented in section 1.4.

Gunnar Widforss is research co-ordinator

Harriet Ekwall is responsible for all traveling and personnel management and for maintaining and stimulating the good working environment

Maria Ehn is research co-ordinator

Ylva Boivie is research co-ordinator at MRTC, on leave of absence for work at Presidents office.

Else-Maj Silén is departmental bursar.

Mika Seppänen is laboratory assistant

Monica Wasell is executive administrator and director of undergraduate studies at IDE.

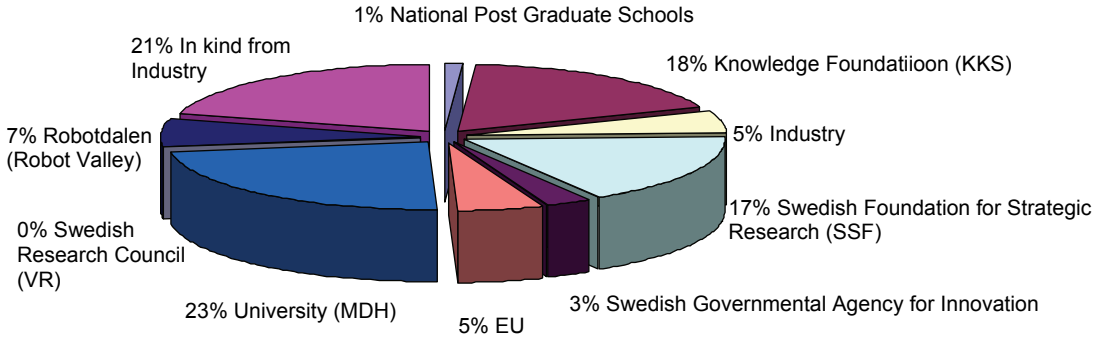
1.3 Funding

In 2006 the total funding for the department amounted to 72 MSEK. 60% (43 MSEK) of the revenues are related to research activities and the rest (29 MSEK) to undergraduate education (including Contract Teaching).

Within research there are mainly three types of funding:

- support from the University, originating from the government
- funding from traditional competitive sources of funding, such as the Swedish Foundation for Strategic Research (SSF), the Swedish Agency for Innovation Systems (Vinnova), The Swedish Research Council (VR), the European Union, and the Knowledge foundation (KKS)
- direct industrial funding

In addition to the direct funding there is also an important element of indirect funding, ie industry's involvement in different types of projects. This in-kind funding amounts annually to approximately 11 MSEK, and is typically funding of industrial graduate students, and expertise. The following graph shows the distribution among the different sources of research funding for 2006 including the in-kind funding from
industry



In Undergraduate education the main source of funding is the support from the University (92%, 27 MSEK), followed by the revenues from Contract Teaching (8%, 2,2 MSEK).

1.4 Undergraduate Education and International MSc Programmes

Undergraduate Education

The Department of Computer Science and Electronics is responsible for undergraduate education within Computer Science and Electronics at Mälardalen University and almost all personnel at the Department are involved in this education. There are some 100 different courses taught at the Department every year, approximately 60 of them at a basic level, and 40 at an advanced level. The courses given at the Department range from "Introduction to Computer Science" to courses such as "Software Engineering for High Integrity Systems" and "Medical measurement systems". In 2006 the Department admitted students to five different undergraduate programmes taught in Swedish:

- Civilingenjörsprogrammet i datateknik och systemteknik (Master of Science in Computer Engineering), 180 poäng (4,5 years)
- Civilingenjörsprogrammet i robotik (Master of Science in Robotics Engineering), 160 - 180 poäng (4 - 4, 5 years)
- Datavetenskapliga programmet (Computer Science and Engineering), 80 - 180 poäng (2 - 4,5 years)
- Mekatronikprogrammet (Mechatronics Engineering), 120 - 180 poäng (3 - 4,5 years)
- Programmet för Spelutveckling och interaktion (Game development and interaction), 120 - 160 poäng (3 - 4 years)

Besides these there are a few old programs in the pipeline including "Elektronikprogrammet" (Electronics), "Civilingenjörsprogrammet i datateknik och elektronik" (Master of Science in computer engineering and electronics), "Dataingenjörsprogrammet" (Computer Engineering), and "Datalogiprogrammet" (Computer Science), to which we no longer admit students.

NetCenter is a lab at the department which also performs contract teaching. One of the corner-stones for the activities at NetCenter is the fact that they are what is called a regional academy within the Cisco Network Academy Programme.

A lot of effort has during 2006 been invested in converting all courses and educational programs into the Bologna model (an European effort to harmonize higher education)– a difficult and huge task where both administrative and pedagogical issues must be considered.

More information about Undergraduate education is available at www.mdh.se/ide/.

International Master of Science Programmes

In 2004, a number of international Master of Science programmes (so-called "MIMA" programmes) were launched at MDH. These programmes target students who have a bachelor's degree, and want to obtain a Swedish Master's degree in the same field. During 2006, IDE was responsible for the following programmes in Computer Science and Electronics:

- Computer Science with Artificial Intelligence Profile
- Computer Science with Software Engineering Profile
- Electronics with Biomedical Engineering Profile
- Real-time Systems
- Robotics

The program in International Project Management that started 2005 has been discontinued.

Computer Science with Artificial Intelligence Profile

The main focus of this program is Embedded AI and is a programme the lasts 2 to 4 semesters. During the last semester the student carries out and writes a Master degree project. The degree project can specialize on e.g., intelligent systems, decision support system, embedded AI, AI in games, intelligent agents or in some other field or application of interest within the area. The project is typically carried out within the research group of AI, some of the other research groups or at some company the department and AI group collaborates with - there are several companies in the region with applications where AI is essential - ABB, Volvo, Bombardier, and Ericsson to mention some. The courses can be selected and combined in different configuration to give the profile the student prefers and courses from other programs may also be selected.

Computer Science with Software Engineering Profile,

International Master Education in Software Engineering lasts two to three semesters and includes advanced courses in software engineering and a master thesis. The students learn how to develop high quality complex software systems, which is invaluable for presumptive software architects, project leaders, and technical specialists. The laboratory's close cooperation with companies such as ABB, Volvo, and Bombardier is an additional strength and adds to the quality and relevance of the education.

Electronics with Biomedical Engineering Profile

The need of staff who is accustomed to the increasing number of technical implementations in today's healthcare situations can not be underestimated. The development of these solutions must be made by people who both understand the medical need and the technical possibilities.

This Master program includes 8 different courses and one full semester master thesis work and aims at learning the students about the possibilities of modern electronics and computer techniques, and how to implement this knowledge in practical situations. There are five compulsory courses, the student is free to choose 3 (or more) courses to complement there studies

The master program is finalized with a thesis project, which normally takes about 6 months to complete. Students are encouraged to find a company, which may offer interesting and projects related to Biomedical engineering. However, the department will offer a number of research related projects suited for program students. The projects are developed with purpose of mixing all the knowledge that is gathered from each course during the education, which are significant for the industry or research. Like all other courses, the projects are carried out either alone or in a small group of students.

Real-time Systems

The master's year in real-time systems provides education for students to pursue further careers in real-time areas, both academic and industrial. It provides a comprehensive set of introductory courses, forming a basis for real-time research, including real-time systems, hardware aspects, and safety critical systems. Furthermore, training is given for scientific methodology, to keep track of rapid developments in the field and prepare for conference publications and presentations. A master's project provides further insights in a specific area by working on a state-of-the-art research project.

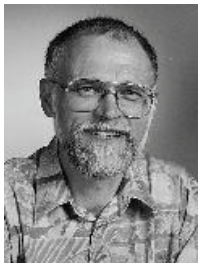
Robotics

Robotics will be one of the main areas of industrial and commercial growth in the coming years. Mälardalen University is part of an ambitious initiative in Sweden to further developed and strengthen the robotics industry. Robotics is based on knowledge in several disciplines, and the major ones are beside mathematics, that is always present, mechatronics, electric engineering, computer engineering and computer science.

The focus areas for the robotic initiative are industrial robotics, field robotics and robotics for health care. Västerås has one of the world's leaders in industrial robotics - ABB Robotics, and in Eskilstuna one can find one of the future main players in field robotics - Volvo Construction Equipment. The Master programme in Robotics at Mälardalen University is focused on a couple of areas that are central for all kinds of robotics, and that has an internationally recognized research

Staff

The following staff is dedicated to undergraduate education. In addition to these, most members of the research groups (presented later) are partially involved in undergraduate education.

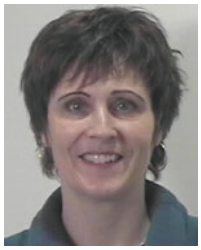


Olof Andersson is a lecturer at IDE in electronics.

Conny Collander is director of studies and leader of the NetCenter lab at IDE. He also teaches computer networking at NetCenter with focus on routing, switching and wireless networks. He is certified academy instructor via the Cisco Networking Academy program and holds courses both for university students and contract students.

Gunilla Eken is lecturer at Mälardalen University. Gunilla received her MSc 1978 at KTH (Engineering Physics). She has been working at MDH since 1990, and before that in industry, mostly at ABB.

Cecilia Fernström is student administrator



Mia Harvig is student counselor and lecturer in electronics.

Dan Levin is a lecturer. He received a Bachelor of Technology in Linköping (1972). He has worked as a teacher at different levels for many years. He teaches mainly Programming and Algorithms & Data Structures. He is also involved in a distance learning project at IDE.

Åsa Lundkvist is a lecturer and director of undergraduate studies at IDE. She received her Masters of Mathematics at Stockholm University in 1986 and has worked in various companies in Sweden, United States, France and United Kingdom before taking a position as lecturer at IDE. Åsa teaches programming languages.

Joop Lundqvist is lecturer at IDE in electronics and automatic control.

Stefan Lövgren is a lecturer at Netcenter. He recieved a BA in Swedish, History and Religion at Uppsala University 1985. He teaches different courses in computer networking with focus on routing, switching and security. He is certified academy instructor via the Cisco Networking Academy program and holds courses both for university students and contract students. His interests are in security and motorcycles.

Ingrid Runnérus is lecturer at NetCenter.

Joakim Rydén is lecturer at NetCenter.

Filip Sebek is a senior lecturer and director of undergraduate studies with focus on quality and pedagogic issues. He received his Bachelor of Science in Applied Computer Engineering from MDH (1995) and his Licentiate thesis with the title "Cache Issues in real-time systems" was defended in October 2002. He was promoted to assistant professor in December 2006 for his pedagogical skills.

Martin Skogevall is a lecturer at SEL. He received a Masters of Computer Science at Mälardalen University in 2001. He teaches Object Orientation (introduction and advanced course). His interests are in software development and computer graphics.

Petter Österlund teaches computer networking at NetCenter with focus on routing, switching and wireless networks. He is certified academy instructor via the Cisco Networking Academy Program and holds courses both for university students and contract students

Johan Stärner is a lecturer at SDL and post-graduate student. Johan received his B.Sc. in applied computer engineering from Mälardalen University in 1994. He teaches undergraduate courses in Unix/Linux and operating systems, and his current research interests include computer architecture, operating systems, and real-time systems. He is currently working on his Ph.D. thesis in predictable cache performance for preemptive real-time systems.

In addition to the staff above Ralf Elvsén was a lecturer at the department. Unfortunately, Ralf passed away in 2006. Ralf was a highly appreciated teacher and colleague.

1.5 Postgraduate Education

Postgraduate Courses

During 2006, IDE has offered 7 postgraduate courses:

- Advanced Topics in Component-Based Software Engineering, 5p
- Research Methodology for Computer Science and Engineering, 5p
- Professional Ethics in Science and Engineering , 5p
- Progress graduate course, 5p
- Legacy Issues in Industrial Software Development, 5p
- Project Course within minST, 10p
- Reviewing with pReview, 1p

The postgraduate students can also select courses from other universities, courses given by national networks and graduate schools, such as ARTES and CUGS, common postgraduate courses at MDH, and local D-level courses that are qualified enough to also serve as postgraduate level courses. During 2006 the following Computer Science and Engineering D-level courses were given by IDE-staff at MDH:

- Component-based Software Engineering, 5 p
- Computer Graphics, advanced course, 5p
- Component-based Design of Single-Chip Systems, 5p
- Wireless communication, 5p
- Safety-Critical Systems, 5p
- Software Engineering for High Integrity Systems, 5p
- Logic Programming, 5p
- Artificial Intelligence, 5 p
- Case-Based Reasoning, 5 p
- Engineering of Complex Embedded Systems, 5p
- Real-Time Systems, advanced course, 5p
- Component Technologies, 5p
- Distributed Software Development, 5p
- HW/SW Design of Embedded Systems, 5p
- Robotics - project course, 20 p
- Medical measurements systems, 5p
- Drives Control, 5p

Some of the postgraduate courses have also been offered to undergraduate students as D-level courses. More information about our postgraduate courses can be found at http://www.idt.MDH.se/phd/courses.

MRTC Theses (Computer Science and Engineering)

In 2006, four PhD theses and two Licentiate theses were presented by MRTC staff.

PhD theses:

- **Thomas Nolte,** *Share-Driven Scheduling of Embedded Networks*, Ph D Thesis, Mälardalen University Press, May, 2006.
- **Gordana Dodig-Crnkovic,** *Investigations into Information Semantics and Ethics of Computing*, Ph D Thesis, Mälardalen University Press, September, 2006.
- **Rikard Land,** *Software Systems In-House Integration: Observations and Guidelines concerning Architecture and Process*, Ph D Thesis, Mälardalen University Press, September, 2006.
- **Frank Lüders**, An Evolutionary Approach to Software Components in Embedded Real-Time Systems, Ph D Thesis, Mälardalen University Press, December, 2006.

Licentiate theses:

- **Kaj Hänninen**, *Introducing a Memory Efficient Execution Model in a Tool-Suite for Real-Time Systems*, Licentiate Thesis, MRTC, September, 2006.
- **Jonas Neander,** *Using existing infrastructure as support for wireless sensor networks*, Licentiate Thesis, Mälardalen University Press, June, 2006.

ISS Theses (Electronics)

In 2006, three PhD theses and one Licentiate thesis were presented by ISS staff.

PhD theses:

- **Ali Fard**, *Analysis and Design of Low-Phase-Noise Integrated Voltage-Controlled Oscillators for Wide-Band RF Front-Ends*, Ph D Thesis, Mälardalen University, January, 2006.
- **Krister Landernäs,** *Implementation of digital-serial LDI/LDD allpass filters*, Ph D Thesis, Västerås, Mälardalens University, September, 2006.
- **Javier Garcia Castaño**, Algorithms and Protocols Enhancing Mobility Support for Wireless Sensor Networks Based on Bluetooth and Zigbee, Ph D Thesis, Mälardalen Universtiy Press, September, 2006.

Licentiate thesis:

- **Annika Jonsson,** *Pressure Sore Etiology - Highlighted with Optical Measurements of the Blood Flow*, Licentiate Thesis, Mälardalen University Press, May, 2006

List of Postgraduate Students

The tables below list the MRTC and ISS postgraduate students and their advisory groups at the end of 2006. The list is sorted according to main advisor. Bold face marks the "de facto"-advisor (if not same as main advisor). The column "Enrolled at" indicates the university where the student is formally enrolled as a Ph.D.-student.

MRTC postgraduate students

Ph.D.-student	Formal main advisor	Advisor	Advisor	Employed at	Enrolled at
Susanna Nordström	Lars Asplund	**Denny Åberg**	Lennart Lindh	RealFast	MDH
Håkan Gustavsson	Jakob Axelsson	Christer Norström		Scania/SAVE-IT	MDH
Peter Wallin	Jakob Axelsson	Christer Norström		Volvo	MDH
Henrik Abrahamsson	Mats Björkman	Dr. Bengt Ahlgren (SICS)		SICS	MDH
Adam Dunkels (lic)	Mats Björkman	Dr. Thimeo Voigt (SICS)		SICS	MDH
Andreas Johnsson (lic)	Mats Björkman	Bob Melander		MDH	MDH
Daniel Flemström	Ivica Crnkovic	Anders Wall (ABB)		MDH	MDH
Johan Fredriksson (lic)	Ivica Crnkovic	**Kristian Sandström**		MDH	MDH
Stig Larsson (lic)	Ivica Crnkovic	Fredrik Ekdahl (ABB)		ABB	MDH
Goran Mustapic (lic)	Ivica Crnkovic	**Christer Norström**		ABB	MDH
Annita Persson-Dahlquist (lic)	Ivica Crnkovic	Christer Norström		Ericsson	MDH
Kurt Wallnau	Ivica Crnkovic	Hans Hansson		SEI/CMU	MDH
Mikael Åkerholm (lic)	Ivica Crnkovic	**Kristian Sandström**		CC-systems	MDH
Severine Sentilles	Ivica Crnkovic	Hans Hansson		MDH	MDH
Aneta Vulgarakis	Ivica Crnkovic	Paul Petterson	Cristina Seceleanu	MDH	MDH
Hongyu Pei Breivold	Ivica Crnkovic	Christer Norström		ABB/MDH/SAVE-IT	MDH
Larisa Rizvanovic	Gerhard Fohler	**Damir Isovic**		MDH	MDH
Pengpeng Ni	Gerhard Fohler	**Damir Isovic**		Ardendo AB	MDH
Andreas Löfgren	Hans Hansson	Mats Björkman		RealFast	MDH
Sigrid Eldh	Hans Hansson	Sasikumar Punnekkat,	Christer Norström	Ericsson	MDH
Joel Huselius (lic)	Hans Hansson	Henrik Thane	Sasikumar Punnekkat	MDH	MDH
Anders Pettersson (lic)	Hans Hansson	**Henrik Thane**		MDH	MDH

Johan Stärner	Hans Hansson	Lars Asplund	Andreas Ermedahl	MDH	UU
HuseyinAysan	Hans Hansson	Sasikumar Punnekkat		MDH	MDH
Daniel Sundmark (lic)	Henrik Thane	Hans Hansson	Andreas Ermedahl	MDH	MDH
Stefan Sjöholm (lic)	Lennart Lindh	Hans Hansson		RealFast	MDH
Stefan Stjernen	Lennart Lindh	Lars Asplund		RealFast	MDH
Markus Bohlin (lic)	Björn Lisper	**Per Kreuger** (SICS)	Mikael Nolin	SICS	MDH
Jan Carlson (lic)	Björn Lisper	Christer Norström		MDH	MDH
Johan Lindhult (former Erikson)	Björn Lisper	Jan Gustafsson	Janet Wennersten (Ericsson)	MDH	MDH
Roger Jonsson	Björn Lisper	**Jacek Malec** (Lund U.)	Peter Funk	MDH	MDH
Thomas Larsson (lic)	Björn Lisper	Dr. Tomas Akenine-Möller (Lund University)		MDH	MDH
Christer Sandberg	Björn Lisper	Jan Gustafsson	Andreas Ermedahl	MDH	MDH
Mikael Sandberg	Björn Lisper	Jan Gustafsson		-	MDH
Marcelo Santos	Björn Lisper	Jan Gustafsson	Andreas Ermedahl	MDH	MDH
Stefan Bygde	Björn Lisper	Jan Gustafsson	Andreas Ermedahl	MDH	MDH
Kaj Hänninen	Mikael Nolin	Jukka Mäki-Turja	Christer Norström	MDH/Arcticus	MDH
Moris Behnam	Mikael Nolin			MDH	MDH
Andreas Hjertström	Mikael Nolin	Dag Nyström		MDH	MDH
Markus Lindgren (lic)	Christer Norström	Anders Wall	George Fodor (ABB)	ABB	MDH
Johan Kraft (former Andersson) (lic)	Christer Norström	Björn Lisper	Anders Wall (ABB)	ABB	MDH
Joakim Fröberg (lic)	Christer Norström	Kristian Sandström		Volvo CEC	MDH
Mathias Ekman	Christer Norström	**Henrik Thane**	Erik Gyllenswärd (Bombardier)	Bombardier	MDH
Stefan Johnsson	Christer Norström	Anders Wall	Lars Cederblad	Level 21	MDH
Yue Lu	Christer Norström	Anders Wall		MDH	MDH
Farhang Nemati	Christer Norström	Anders Wall		MDH	MDH
Pia Stoll	Christer Norström	Anders Wall		ABB	MDH

ISS postgraduate students

Ph.D.-student	**Formal main advisor**	**Advisor**	**Advisor**	**Employed at**	**Enrolled at**
Jörgen Lidholm	Lars Asplund	Denny Åberg		MDH/Robotdalen	MDH
Ewa Hansen	Mats Björkman	Mikael Nolin	Dag Nyström	MDH	MDH
Jonas Neander	Mats Björkman	Mikael Nolin	Jukka Mäki-Turja	MDH	MDH
Christer Gerdtman	Ylva Bäcklund	**Maria Lindén**		Elektro Mekanik AB	MDH
Tommy Gunnarsson	Ylva Bäcklund	**Denny Åberg**	Hans Sköld	MDH	MDH
Tord Johnson lic)	Ylva Bäcklund	**Denny Åberg**		MDH	MDH
Nikola Petrovic	Ylva Bäcklund	Magnus Otterskog	Denny Åberg	MDH	MDH
Erik Olsson (lic)	Peter Funk	Ning Xiong	Mats Jackson (IDP)	MDH	MDH
Marcus Blom	Maria Lindén	Mikael Ekström	Javier García Castaño	MDH	MDH
Martin Ekström	Maria Lindén	Javier García Castaño	Mikael Ekström	MDH	MDH
Rikard Lindell (lic)	Jan Gustafsson	**Jonas Löwgren** (Malmö Högskola)	Jussi Karlgren (SICS), Morten Fjeld (Chalmers)	MDH/SICS	MDH

1.6 Industrial co-operation

One of the cornerstones of IDE is the extensive and close industrial cooperation. Almost all our projects and activities include industrial partners. The basic reason for this quite extensive range of collaboration is our partners' appreciation, not only of our competence, but also of our senior researchers' thorough understanding of industrial problems. We would in particular like to point out that

- Jakob Axelsson is responsible for long-term development of ECS at Volvo Cars, and has precious experiences from Carlstedt Research and Volvo Technical Development.
- Ivica Crnkovic has 10 years experience as development manager/project manager at ABB Automation.
- Christer Norström was manager for Motor Control and Applications at ABB Robotics 2001-2003, and has industrial experience also from four years at ABB Automation and from development work for Volvo and other companies.
- Sasikumar Punnekkat was the head of the software testing and reliability engineering division of Vikram Sarabhai Space Centre, and has 15 years of industrial experience in software development and testing.
- Peter Funk has worked for Ericsson with Research&Development for more than 10 years and for Vattenfall for 4 years. He is also helping national and multinational companies with turning research into profitable solutions.

It has been natural to build on these and other industrial contacts in the development of MRTC and ISS. We have adopted a strategy for our industrial cooperation in which we aim for establishing more long-term bilateral cooperation with our main industrial partners. These cooperation include a portfolio of activities, such as PhD-students, projects, case-studies, and courses, as well as persons responsible for maintaining the portfolio. Currently we have strategic long-term co-operations with five companies: ABB Corporate Research (maintained by Magnus Larsson at ABB and Ivica Crnkovic at MRTC), ABB Robotics (Staffan Elfving/Peter Eriksson, Christer Norström), CC-Systems (Jörgen Hansson, Hans Hansson/Mikael Nolin), Volvo Construction Equipment (Jonas Disman/Nils-Erik Bånkestad, Christer Norström), and Bombardier Transportation (Peter Oom/Erik Gyllenswärd, Ivica Crnkovic), and we have extensive cooperation also with Ericsson, within telecom platforms (Lars-Olof Gustafsson, Christer Norström), research (Anders Caspar, Christer Norström/Hans Hansson) and MICROWAVE (Anneta Persson-Dahlquist, Ivica Crnkovic). This strategy has resulted in substantial industrial support, including:

- a 9.6 MSEK donation from ABB for recruitment of a professor in industrial software engineering (Ivica Crnkovic) and for enforcing our research in this area
- a large number of graduate students funded by industry, including

Name	**Company**	**Company contact**	**Supervisor/initiator at IDE**
Håkan Gustavsson	Scania	Nils-Gunnar Vågstedt	Jacob Axelsson/ Chister Norström
Susanna Nordström	Prevas	Lennart Lindh	Lars Asplund/ Lennart Lindh
Stig Larsson (lic)	ABB Corporate Research	Fredrik Ekdahl	Ivica Crnkovic
Frank Lüders (PhD)	ABB Automation Products	Ulf Moberg	Ivica Crnkovic
Goran Mustapic (lic)	ABB Robotics	Peter Eriksson	Christer Norström
Annita Persson-Dahlquist (lic)	Ericsson	Ola Gustavsson	Ivica Crnkovic
Mikael Åkerholm (lic)	CC-systems	Jörgen Hansson	Ivica Crnkovic

Hongyu Pei Breivold	ABB	Magnus Larsson	Ivica Crnkovic
Pengpeng Ni	Ardendo AB	Isak Jonsson	Gerhard Fohler/ Damir Isovic
Andreas Löfgren	RealFast	Stefan Sjöholm	Hans Hansson
Sigrid Eldh	Ericsson	Mike Williams	Hans Hansson
Stefan Sjöholm (lic)	RealFast	Lennart Lindh	Lennart Lindh/ Hans Hansson
Stefan Stjernen	RealFast	Lennart Lindh	Lennart Lindh/ Denny Åberg
Kaj Hänninen	Arcticus	Kurt-Lennart Lundbäck	Mikael Nolin
Anders Möller (lic)	CC-systems	Jörgen Hansson	Mikael Nolin
Johan Fredriksson	CC-systems	Jörgen Hansson och Stefan Rönning	Mikael Nolin, Ivica Crnkovic och Kristian Sandström.
Johan Lindhult	Ericsson	Janet Wennersten	Björn Lisper
Markus Lindgren (lic)	ABB	George Fedor, Anders Wall	Christer Norström
Joakim Fröberg (lic)	Volvo CEC	Nils-Erik Bånkestad	Christer Norström
Mathias Ekman	Bombardier	Erik Gyllenswärd	Christer Norström
Stefan Johnsson	Level 21	Lars Cederblad	Christer Norström
Pia Stoll	ABB	Magnus Larsson	Christer Norström
Christer Gerdtman	Elektro Mekanik AB	Bertil Pettersson	Ylva Bäcklund/ Maria Lindén

- graduate students funded by the research institute SICS (which has established a branch at MRTC in Västerås):

  Markus Bohlin (contact at SICS: Björn Levin; supervisor at MDH: Björn Lisper)
  Waldemar Kocjan (Björn Levin; Björn Lisper)
  Henrik Abrahamsson (Bengt Ahlgren; Mats Björkman)
  Adam Dunkels (Bengt Ahlgren; Mats Björkman)

- a graduate student employed by the Software Engineering Inst., CMU, Pittsburgh, US:

  Kurt Wallnau (Linda Northrop; Ivica Crnkovic)

In addition to the extensive research cooperation with industry, IDE research has resulted in several spin-off companies, including the following product companies:

- Zealcore Embedded Solutions, which recently received venture capital to accelerate development and sales of its innovative embedded computer systems debugging technology. Henrik Thane, Hans Hansson, Christer Norström, and Kristian Sandström founded the company in 2001. [www.zealcore.com]
- The RealFast group, includes five companies, specializing in hardware accelerators and multiprocessor technology, as well as related education, operating system development support, software and hardware consulting) Lennart Lindh founded the first company in the group 1995. [www.realfast.se]
- Senseboard AB is a start-up company with its main product, virtual keyboard. Lars Asplund is the CTO of the company, and one of the major owners [www.senseboard.com].
- Dag Nyström Konsult & Utveckling, a spin-off company that together with Mimer Information Technology AB in Uppsala is developing the real-time database management system Mimer Real-Time Edition. SSF is funding this commercialization effort.

- Physiotest is a company founded by Mia Folke. The company aims to develop a product that athletes may use in order to identify their threshold of lactic acid.
- Asplund Data AB, founded by Lars Asplund, is active in the Scandinavian market for Ada-compilators. In addition the company is engaged in Inova AB which develops a underwater robot used for salvage of sunken ship cargos, especially metals.

1.7 External information

IDE has a responsibility to keep the scientific community, industry, funding agencies and the general public informed about its activities and developments. An important carrier of information is the IDE research web-site http://www.mdh.se/ide/forskning/. An associated database enables easy and convenient update and retrieval of information. Currently, the web contains information about ISS, MRTC and PROGRESS as well as the laboratories, projects, publications, seminars, and the staff.

The scientific community is informed via traditional dissemination channels, such as publications, participation in conferences, seminars, etc., and in direct co-operation with our partners. Participation in national and international research networks, such as ARTES, the European ARTIST2 network and the international Euromicro and IEEE committees on Real-Time Systems, are also very important.

Information exchange with industry comes in several forms, including

- Co-operation in joint projects
- Via the industrial postgraduate students
- Seminars, including both our own seminars and participation in industrial seminars organized by others.
- Involvement in technology transfer programmes. In 1999 MRTC was instrumental in winning the Expert Competence – Embedded Systems programme (TeknIQ) to MDH and in 2005 a sister program focusing on micro- and nanosystemtechnology (minST) was launched. Anders Martinsen is heavily involved in both these programs.
- Giving commercial courses on topics of our expertise. In 2006 the IDE staff has given several instances of shorter industrial courses on real-time systems, reliability and circuit design.

Funding agencies are informed via project proposals, evaluations and progress reports, but also via the web, and general material such as this report.

The general public, other departments at MDH, etc. are informed via the web, public lectures, articles in regional newspapers, regional TV and radio, articles in the trade-press, and the MDH periodical Delphi.

2 Mälardalen Real-Time Research Centre (MRTC)

Mälardalen Real-Time research Centre (MRTC) was initiated by a grant from the Swedish KK-foundation (Stiftelsen för Kunskap och Kompetensutveckling) to further develop the real-time research at Mälardalen University (MDH) in close co-operation with Swedish industry. As a result, a group of leading industries has joined the MRTC-effort by supporting industrial postgraduate students and participating in research projects. Strong support from MDH, the Swedish Foundation for Strategic Research (SSF), and other funding agencies has enabled a fast build up of a focused research programme with a healthy balance between applied and fundamental research.

The research plan for MRTC is based on a three-pronged vision:

1. To provide state-of-the-art competence for industry.
2. To advance basic and applied research in relevant areas.
3. Education for engineers and researchers.

The advancements of these are mutually supportive, in that insights gained in one will guide the advancement in the others.

On a more technical level the guiding vision is to

provide engineers with substantially better tools and methods for the development of real-time computer systems and applications.

Real-Time Systems

Real-time systems are computer systems that sense their environment and directly influence it through actions. Real-time systems must not only choose appropriate actions, but also choose them at appropriate times. Most real-time systems are embedded in products. For instance, an autonomous vehicle will have an embedded computer-based control system that has to respond in time to avoid collisions. Real-time computing is not about building "fast" systems; it is about building systems that are predictably "fast enough" to interact with their environments in well specified ways. Real-time systems are embedded in a multitude of applications and products, in areas such as multimedia, telecommunications, robotics, process control, flexible manufacturing, avionics, vehicular systems, air-traffic control, nuclear power plants, medical equipment and defense applications.

Developing real-time systems demands knowledge of and contacts with a number of research disciplines, including automatic control, computer science, computer engineering, software engineering, and electrical engineering. The MRTC research is covering various aspects of all these areas, and – what is more important – attempts to bridge gaps between disciplines to provide solid engineering solutions to real problems.

2.1 Industrial co-operation

One of the cornerstones of MRTC is the many close industrial co-operations. Almost all our projects and activities include industrial partners.

In 2006 we had concrete co-operations with the following companies:

- ABB (Automation, Robotics, and Corporate Research, Force Measurements)
- AbsInt Angewandte Informatik GmbH (Germany)
- Altera
- Arcticus Systems
- Ardendo AB
- Bombardier Transportation
- CC-Systems
- CompFab
- ENEA Real-Time AB
- Ericsson (Microwave, Radio Systems and Research)
- Gatorhole AB
- Hectronic AB
- IAR Systems
- Level Twentyone Management AB
- Mimer Information Technology AB
- Mecel AB
- Outocumpu, Avesta Steel Mill
- Philips Research, The Netherlands Prevas
- Protang AB
- RealFast AB
- Saab (Aerospace, Avionics)
- Scania
- Siemens Business Systems, Germany
- SKF
- TeliaSonera
- Thomson Multimedia
- Tieto Enator
- Tidorum Oy (Finland)
- Volcano Communication Technologies AB
- Volvo Cars
- Volvo (Construction Equipment, Technology Development, and Truck, and 3P)
- XILINX
- ZealCore Embedded Solutions AB

The co-operation with industry comes in many forms, including:

- Joint projects, with or without support from external funding agencies
- MRTC staff performing case-studies in industry
- MSc thesis projects
- Industrial graduate students
- Industrial engineers and researchers participating in MRTC projects
- Industry providing equipment and software
- Direct monetary support (donations)
- Guest lectures and field trips
- Spin-off companies

To further develop our interactions with industry we are establishing more long-term bilateral co-operations with some of our main industrial partners. It is our ambition to establish such co-operation with additional companies as well and also to make MRTC a “hub” for co-operations between groups of companies in specific areas. An example of the latter is our plans to establish an industrial competence centre in Software Engineering, allowing companies in different sectors to exchange experiences and ideas with MRTC as catalyst.

2.2 Research groups and scientific achievements

The following is a list and brief presentation of the current research groups at MRTC, including leadership, senior researchers, and sources of funding. Also, for each group some of the main scientific achievements in 2006 are listed. Details about projects, activities and achievements are provided in the following research group-specific chapters. Here the focus is on providing representative illustrations of the scientific progress in the different research groups.

Industrial Software Engineering group

Headed by Prof. Ivica Crnkovic; adjunct professor Heinz Schmidt, senior lecturer Sasikumar Punnekkat , 1 senior researcher Radu Dobrin; 1 postdoc Cristina Seceleau; Dr Rikard Land, Dr Frank Lüders, 10 PhD students; one visiting PhD student; 2 PhDs in 2006. The group is focusing on research related to software engineering in industrial setting, funding from ABB, Ericsson, EU, SSF, KKS, CC-systems and MDH.

Scientific achievements

The major results of this research in 2006 group were:

- Development of SAVE Component model (together with other groups), use of General-Purpose Component models in Embedded systems
- Work on Component-based development process
- Work in improvement of integration phase in a development process

Embedded Systems Software Engineering group

Headed by Prof. Christer Norström; Prof. Jakob Axelsson, Senior Lecturer Dr. Kristian Sandström; Dr Anders Wall, 10 graduate students; the group is focusing on Embedded Systems Software Engineering (e.g. for automotive and industrial robotics systems); funding from SSF, ABB, Volvo, Ericsson, Saab, Level21, KKS, Vinnova and MdH.

Scientific achievements

The major results of this research group in 2006 were:

- A method for model extraction has been developed, together with tools supporting the method. The purpose is to enable timing impact analysis during maintenance of complex embedded legacy systems. The approach was presented at the ICSEA ’06 conference, which resulted in a best paper award.
- The approach of “Model Synthesis” was evaluated industrially in an experiment at ABB Robotics. Models were successfully generated from recordings of their control system for industrial robots. The paper was presented at RTCSA ’06.
- a Monte Carlo simulation based approach to evaluation of electronic architectures in the early phases, with focus on explicitly capturing uncertainties in cost and performance.
- Success factors for efficient integration of mechatronics components in an automotive system were presented based on a number of case studies. Paper accepted to Journal.

The Programming Languages group

Headed by Prof. Björn Lisper; Senior Lecturer Docent Jan Gustafsson; Dr. Andreas Ermedahl; Dr Christina Björkman and Dr Gordana Dodig Crnkovic; 8 PhD students (three external); 1 PhD in 2006. The group is focusing on worst-case execution time analysis, as well as design and analysis of languages for real-time and embedded systems; funding from Vinnova, CUGS, Ericsson, and MDH.

Scientific achievements

- Further development of methods for automatic flow analysis in WCET analysis tools, in particular: methods for finding infeasible paths automatically, and speedup of the flow analysis by program slicing. The methods are implemented in our prototype tool SWEET.
- A classification of potential memory conflicts in PLEX programs, which can be used to guide the parallel execution of these programs.
- Faster intersection tests for collision detection of 3D-bodies in computer graphics.
- A new algorithm for the detection of composite events.

Real-Time Systems Design group

Headed by Prof. Hans Hansson and Prof. Mikael Nolin; senior researchers Dr. Thomas Nolte, Dr. Jukka Mäki-Turja, Dr. Dag Nyström, and Prof. Paul Pettersson; Post-doctoral research fellow Dr. Insik Shin; 4 PhD students; 1 PhD and 1 Lic exam in 2006. The group is focusing on design methods, architectures and communication for real-time systems; funding from SSF, KKS, EU, and MDH.

Scientific achievements

- Development of hierarchical scheduling techniques and corresponding analysis techniques allowing for sharing of logical resources, and supporting independent subsystem design and development.
- The SAVE component model (Save CCM) has been extended “subsystems”, i.e., using Save CCM, it now possible to reason about a system in terms of a number of subsystems.
- The work on server-based scheduling for embedded communication has been extended with formal proofs, as well as guidelines and techniques for designing Server-CAN based applications. Moreover, a Ph.D. thesis has been defended on the topic.
- The work on model-generation of legacy code has advanced substantially. A method for automatic model validation has been developed and evaluated. A coherent presentation of the approach will be included in the PhD-thesis of Joel Huselius, which will be presented Q2 2007.
- Development of an efficient technique to analyze stack memory usage in embedded real-time systems

Adaptive Real Time Systems group

Headed by lecturer Damir Isovic, 2 graduate students; the group is focusing on flexible scheduling models and resource reservation mechanisms that are suitable for adaptive real-time systems; funding from EU, SSF, and MDH.

Scientific achievements

- Work to support effective and quick browsing multimedia content over network. Methods for transcoding of H.264/AVC in order to support user-friendly browsing over networks presented. Published at a major international multimedia conference.
- Work on flexible media processing in resource constrained real-time systems. Real-time methods to provide Quality-of-Service in systems with highly fluctuating resources. Published in a major multimedia conference.
- Work on adaptive real-time systems for distributed, heterogeneous environments. Flexible scheduling and resource reservation mechanisms for networked multimedia streaming systems developed. Published at a conference workshop.
- Work on flexible scheduling of mixed task sets and constraints. Submitted to a major real-time journal.
- Work on supporting aperiodic tasks in offline scheduled systems. To be submitted to a real-time journal in 2007.
- Work on using real-time methods to support novel MP-SoC architectures initiated. A project proposal submitted (awaiting result).

Monitoring and Testing group

Headed by Dr. Henrik Thane; 3 graduate students; the group is focusing on monitoring, testing, and debugging of real-time systems; funding from SSF, KKS, and MDH.

Scientific achievements

- Translation of testteminology for the Swedish Software Testing Board's (SSTB), fall 2005/spring 2006.
- Final proposition and contents for Diseratations of Daniel Sundmark and Anders Pettersson during fall 2006.
- Successful theory development and prototype evaluations of dynamic (on-the-fly) instrumentation of software during runtime.
- Development of methods and evaluations of Datflow based testing of multitasking real-time software. Especially DefUSe based testing have been explored.
- Development of methods and evaluations of Regression and Confirmation based Datflow testing of multitasking real-time software.

Scalable Architecture for Real-time Applications Lennart

Headed by Prof. Lennart Lindh; 3 graduate students; the group is focusing on scalable multiprocessor systems, system-on-chip, and moving software functions into hardware; funding from KKS.

Scientific achievements

- Investigate modulation and configuration

2.3 The PROGRESS Strategic Research Centre

The PROGRESS strategic research centre for predictable development of predictable embedded software was formally launched January 1st 2006 as the result of a five year grant awarded (of 43 msek) to Mälardalen Real-Time Research Centre by the Swedish Foundation for Strategic Research. PROGRESS is more than an integrated part of Mälardalen Real-Time Research Centre; currently it provides a common thread and focus for essentially all research performed within MRTC. PROGRESS is dedicated to find methods for cost-efficient handling of the increasing complexity of software in computer-based products. Adopting a software-component approach to engineering, and re-engineering, of embedded software systems, PROGRESS will provide theory, methods, and tools that increase quality and reduce life-cycle costs.

PROGRESS will act as a catalyst to strengthen Swedish competence in product development using embedded software. **PROGRESS' vision** is

> *"to be a world-wide recognized centre in engineering of predictable embedded software for primarily the vehicular, automation and telecom domains, with extensive contacts and exchange with other leading research centres, and to be the preferred research partner for industry in Sweden and Europe in this growing technology field."*

Focusing on predictability of embedded software and predictability in development of embedded software, PROGRESS' research aims to provide a mature engineering discipline for development of embedded software. This includes theories, methods, and tools for (i) predictable embedded-software development from software components and legacy code, (ii) interfacing components with the underlying platform and synthesising platforms from application requirements, and (iii) adopting and applying real-time modelling and analysis techniques across all stages of the component-based design and development chain.

Concretely, the goals and activities of the PROGRESS centre are related to two separate but mutually supportive focus areas: (1) the specific scientific issues to be tackled, and (2) establishing a sustainable world-class research centre.

It is our hypothesis that reaching the vision will require substantial advancements in the areas illustrated in Figure 1. Equally important is to provide industrial strength results, i.e., research results that can be used in real industrial settings. To this end, a set of demonstrators will be developed, with the purpose of illustrating the integration and industrial applicability and relevance of the PROGRESS research, and with the ambition to provide basis for deployment and commercialisation of selected results.

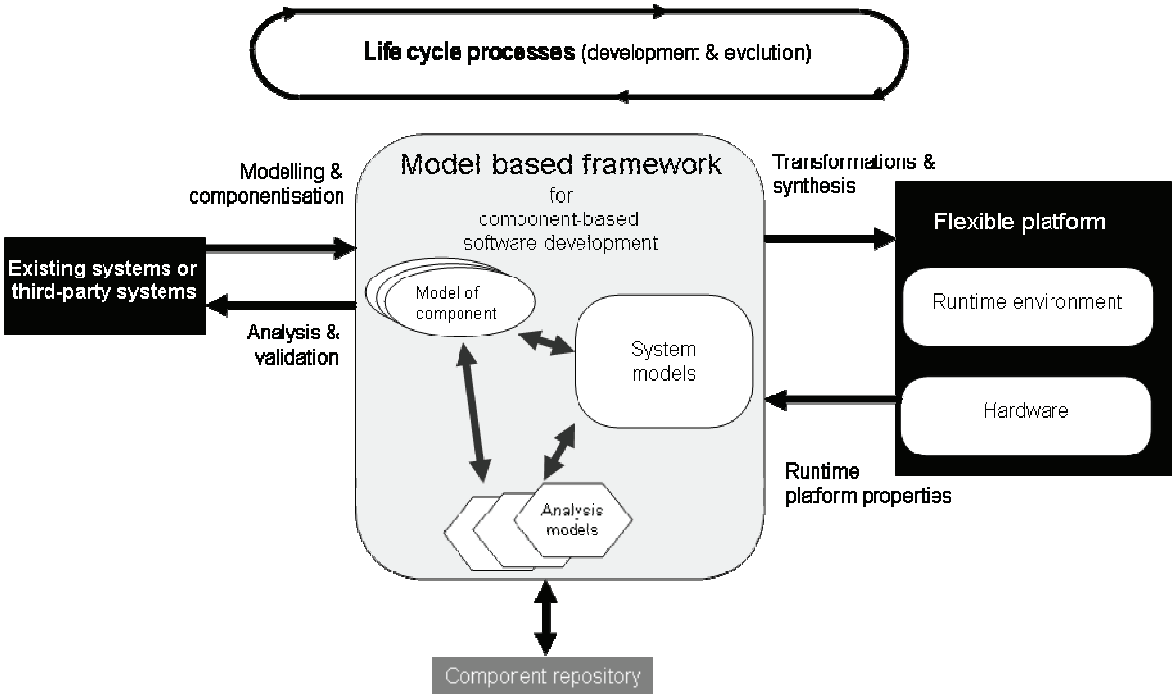


Figure 1. *Predictable development of Embedded Software in the PROGRESS framework*

The core constituent of our approach (as illustrated in Figure 1) is a model-based framework for predictable component-based development. The framework includes component models (that include component specification and interoperability rules and constraints), a set of analytical models of different component and system properties (with associated analysis and compositional theories for particular properties) and system modules (that includes synthesis, glue-code generation and system specifications). Components are the primary unit for reuse and components can be stored in and accessed from a component repository. System models are transformed to executable units and adjusted to hardware platforms and underlying operating systems. Different run-time platform solutions are provided for achieving certain properties (such as dependability, or real-time) and enabling flexible system integration. Evolution of existing - not necessary component-based - systems (legacy systems) is a part of PROGRESS focus with a goal of achieving predictable software maintenance and enabling their integration with components and systems developed in the PROGRESS development framework.

Although some elements of key areas already exist, they typically do not consider specific requirements of embedded systems. The goal of PROGRESS is to develop new theories, models and methods, but also to use and adopt existing solutions, standards and research results, with the aim of producing industry strength results.

As a consequence of the above, the following three main strategic scientific goals are identified for PROGRESS:

1. A model-based framework for predictable development of component-based predictable embedded SW.
2. Efficient and predictable mapping from the model-based framework to execution platform, including appropriate platform mechanisms.
3. Evolution and reuse of existing (legacy) systems, including integration of these in the model-based framework.

PROGRESS organisation

The main entities of the centre are shown in Figure 2 and detailed in subsequent sections.

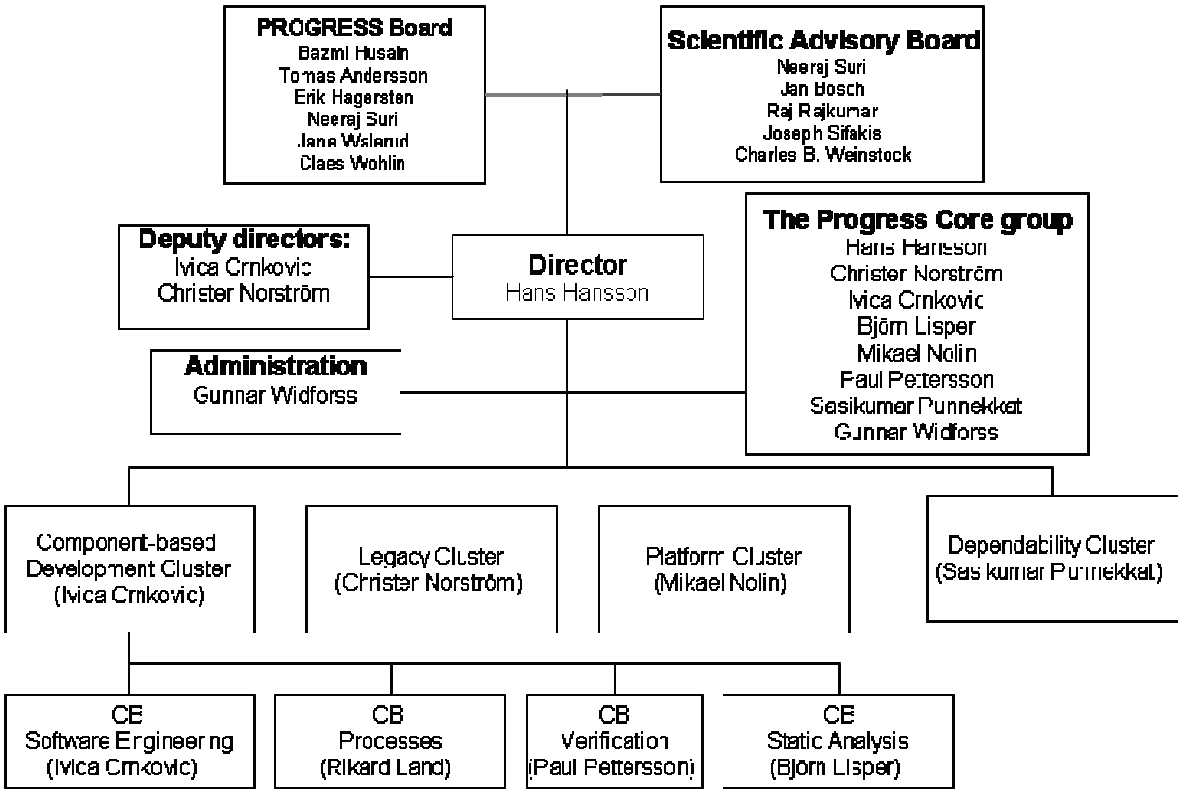


Figure 2. *The PROGRESS organisation*

The actual research and other activities are performed within the following research clusters :

- **The Component-based Development Cluster**, led by Prof. Ivica Crnkovic.
  Due to the importance and size of this cluster it is partitioned into the following four interrelated, but clearly identifiable, research directions:
  - **Component-based Software Engineering**, led by Prof. Ivica Crnkovic and dedicated to designing and modelling of component-based software systems, including topics such as topics: software architecture, architecture modelling and design, modelling languages, model-based development, component-based technologies, integrated development environments and tools interoperability.
  - **Life-Cycle Processes**, led by Dr Rikard Land and dedicated to software development processes and lifecycle models, with emphasis on component-based embedded software development and predictability of development efforts and time
  - **Component Verification**, led by Prof. Paul Pettersson and dedicated to modelling and analysis of component models for real-time and embedded systems, including formal models, as well as analysis techniques and model-checking tools applicable to industrial sized systems.
  - **Static Program Analysis of Component Models**, led by Prof. Björn Lisper dedicated to static timing analysis of reusable components, including analyzing such components in isolation, and analyzing systems built from such components.

- **The Legacy Cluster**, led by Prof. Christer Norström and dedicated to management and componentization of legacy software, with the aims to improve maintainability and allow reuse of legacy code in component-based frameworks.
- **The Platform Cluster**, led by Prof. Mikael Nolin and dedicated to platforms for execution and compilation of component-based software for embedded real-time systems, including both practical implementations of parts of the Progress-platform and specific research contributions in areas relating to platform technologies for embedded real-time systems.
- **The Dependability** Cluster, led by Dr. Sasikumar Punnekkat and dedicated to providing analysis techniques, guidelines and methods for ensuring predictably dependable performance of embedded systems built using component based development approaches.

Recruitment

As a result of PROGRESS a large number of new persons have been recruited, as indicated below.

- **PhD-students**: The following students have been recruited or have joined PROGRESS:
    - Marcus Bohlin, PhD-student (licentiate) employed by the Swedish Institute of Computer Science (SICS)
    - Hüsein Aysan, international MSc from MDH, with BSc from Istanbul Technical University, Turkey
    - Moris Behnam, international MSc from MDH, with MSc from University of Technology, Baghdad Iraq
    - Stefan Bygde, MSc and BSc from MDH
    - Andreas Hjertström, MSc and BSc from MDH
    - Yue Lu, MSc from University of Southern Denmark and BSc from China
    - Farhang Nemati, MSc from Uppsala and MSc from University of Tehran, Iran
    - Marcelo Santos, MSc from Chalmers and University of Santa Cruz, Ilheus-BA, Brazil
    - Séverine Sentilles, MSc from Univ. de Pau et des Pays de L'Adour, France
    - Aneta Vulgarakis, MSc from University "Ss. Cyril and Metodius" Skopje, Macedonia
- **Post-doctoral researchers**: The following post-doctoral researchers have been recruited or have joined the centre:
    - Radu Dobrin, PhD from MDH
    - Rikard Land, PhD from MdH
    - Thomas Nolte, PhD from MDH
    - Dag Nyström, PhD from MDH
    - Cristina Seceleanu, Post Doctoral Fellow, PhD from Åbo Akademi (FIN)
    - Insik Shin, Post Doctoral Fellow, PhD from University of Pennsylvania (US)
- **Professors**. Three chairs have been announced, with the following result:
    - Real-Time Systems, specializing in Automotive Software Systems:
        - Mikael Nolin, MDH, one of the co-applicants of the PROGRESS application and leader for the PROGRESS Platform cluster has been employed.
    - Real-Time Systems, specializing in Modelling and Verification:
        - Paul Pettersson from Uppsala University has been employed.
    - Dependable Software Engineering:

- Kristina Lundqvist from Massachussets Institute of Technology and
- Sasikumar Punnekkat from MDH has been employed.

Scientific focus and challenges

It is the scientific vision of PROGRESS to provide theory, methods, technology, and tools that enable cost efficient and predictable development of predictable embedded software.

Embedded computer systems have to meet a number of specific constraints and requirements related to performance, resource consumption, and dependability. By the reactive nature of their interactions with the environment, a majority of these systems also have stringent real-time requirements. Due to increasing software complexity and the long lives of embedded systems the life-cycle requirements on costs, time, and effort are becoming more and more stringent.

PROGRESS is focused on achieving predictability of properties that meet these requirements. The predictability will be achieved by modelling and by construction. Run-time predictability concerns aspects related to functional correctness, timing, performance, resource consumption, and dependability (in particular reliability and safety), whereas life-cycle aspects include costs and efforts required for design and maintenance. Life-cycle and run-time properties are intimately related, in that the employed life-cycle process determines the possibility to à priori analyse and predict the run-time behaviour, and that the employed run-time mechanisms and architecture to a large extent influence life-cycle costs and efforts.

Abstraction, composition, and scalability are indispensable aspects in managing future process and product complexity and in providing predictability. The central element of the PROGRESS approach is a model-based framework for Component-Based software Development (CBD) which embodies these aspects. The novelty (and the main challenge) is to apply these techniques (which are established in certain other domains) to the domain of embedded software.

The main innovation of PROGRESS is integration of component-based software development and reuse, with analysis, synthesis, and platform mechanisms, thereby providing predictability of key aspects of software and the development of software for embedded applications.

The following three main strategic scientific goals are identified for PROGRESS:

C. A model-based framework for predictable development of component-based predictable embedded SW.

P. Efficient and predictable mapping from the model-based framework to execution platforms, including appropriate platform mechanisms.

L. Efficient evolution and reuse of existing (legacy) systems, including integration of these in the model-based framework.

Related to these we identify a set of more specific scientific goals (challenges).

Challenges related to the model-based framework for CBD

Predictable component models and associated development tools

To address this challenge we develop:

C1 Generic and specific component models for providing predictability in building embedded systems using CBD

C2 Integration Development Platform for integrating different modelling, development and verification tools

CBD processes and practices, customizable and widely applied in industry
To address this challenge we develop:

C3 Predictable life-cycle processes for CBD

C4 Methods for seamless migration from existing life-cycle processes to CBD processes

Theories, methods, and tools for analysis and verification of component-based systems
To address this challenge we develop techniques for:

C5 Formal verification of functional and timing properties of component-based systems

C6 Test-case selection and generation for component-based SW

C7 Execution time analysis of component-based systems

C8 Dependability modelling and analysis

Challenges related to the execution platform

Efficient and predictable mapping from the model-based framework to execution platforms
To address this challenge we develop techniques for:

P1 Synthesis and configuration of component software and run-time infrastructure

Platform mechanisms providing predictable execution of component-based SW
To address this challenge we develop:

P2 Analysis and run-time structures for timing predictability of semi-independent subsystems

P3 Design time and run-time management of information in component-based SW

P4 Mechanisms for predictability and dependability assurance, including fault tolerant scheduling and techniques for error detection and fault containment.

Challenges related to evolution and reuse of legacy systems

Analysis and remodelling of existing systems
To address this challenge we develop:

L1 Theories, methods and tools for extracting analyzable models from legacy software, including probabilistic models

L2 Simulation based tools for analysis of models of legacy systems, including analysis of consequences of proposed changes to the code (impact analysis).

Integration of legacy software in embedded component-based systems
To address this challenge we:

L3 Develop legacy component models, and integrating these into the PROGRESS component model

L4 Extend the analysis methods and tools to handle legacy components

All research within PROGRESS targets the above challenges, and they are reflected in the organisation, as will be detailed below.

Research Projects

The following table lists all PROGRESS research projects currently being defined. We expect 2-3 additional projects to be defined by new senior staff joining PROGRESS in 2007. Details about the projects are provided in the presentation of the research group to which the project leader belongs.

Project Abbreviation	Cluster responsibility	Project Title	Primarily related item(s) above
PG-CBD-Model	CBD Ivica Crnkovic	Progress Component Models	C1
PG-CBD-CVer	CBD Paul Pettersson	Component Verification	C5
PG-CBD-StatA	CBD Björn Lisper	Static Timing Analysis of Component-Based Systems	C7
PG-CBD-IDE	CBD Ivica Crnkovic	Integrated Development Platform	C2
PG-Leg-Extract	Legacy Christer Norström	Model Extraction for Legacy Systems	L1
PG-Leg-Asis	Legacy Christer Norström	Analysis of Legacy System Models	L1, L2
PG-Leg-Comp	Legacy Christer Norström	Wrapping/Reusing Legacy Components	P2, L3
PG-Pla-SSI	Platform Thomas Nolte	Subsystem integration	P2
PG-Pla-INC	Platform Dag Nyström	Information centric software development	P3
PG-Pla-OSC	Platform Mikael Nolin	Optimization, Synthesis and Configuration	P1
PG-Dep-FRAMES	Dependability Radu Dobrin	Fault and Reliability Aware Methods for Efficient Scheduling	P4
PG-Dep-PEARLS	Dependability Sasi Punnekkat	Parameterized Evaluation of Attributes of Reliable Systems	C8
PG-Dep-ET	Dependability Sasi Punnekkat	Enabling Technologies for Dependability	P4
PG-CBD-Proc	CBD Ivica Crnkovic	Identification and specification of CB process	C3
PG-CBD-Trans	CBD Rikard Land	Tramsformation of processes	C4
PG-Demo-SAVE	Thomas Nolte	The SAVE demonstrator	C2, C5, P2, P3
PG-Demo-Evolution	Mikael Åkerholm	The CBD-evolution demonstrator	C1-C4,C6,C7 P1,P4
PG-Demo-Legacy	Johan Kraft	The Legacy demonstrator	C1,C2,C5,C8,P2 L1-L4

2.4 Software Engineering group

Focus

The group focuses on research related to software engineering in industrial settings. Complex products, projects and organizations are the research target and the directions include technologies and processes. In particular different aspects of component-based technologies are considered. The group has intensive cooperation with industry, international research centre, and with universities in Sweden. The group closely cooperates with the Embedded Systems Software Engineering group as well as with groups from SDL.

The group consists of one professor, one adjunct professor, five senior researchers (incl. post-docs) and 9 PhD students, five of them being industrial PhD students.

The major results of this research group in 2006 were:

- Ph.D Thesis – Rikard Land, Frank Lüders
- Organization of CBSE 2006 and QoSA 2006 at MDH, Västerås
- Organization of Euromicro Conference, Dubrovnik, Croatia, September 2006.
- Developing International SE Master program

In 2006 the following projects have been active:

- PROGRESS – Predictable development of Embedded Software Systems (The group had a lead role in 3 research directions of the newly funded PROGRESS centre and was involved in the following projects:
    - CBD Model - Progress Component Models
    - FRAMES - Fault and Reliability Aware Methods for Efficient Scheduling
    - PEARLS – Parameterized Evaluation of Attributes of Reliable Systems
    - ET – Enabling Technologies for Dependability
    - CBD Proc – Identification and specification of CB process
    - CBD Trans – Transformation of processes
- SAVE++ - Extension of SAVE project
- APICS - Process for Efficient and Effective Integration of Component Based Software
- PSI – Product Data Management and Software Data Management Interoperability
- FLEXCON - Flexible Embedded Control Systems
- Industrial IT
- ProPlat - Development and decisions processes
- SAVE/Autocomp (a common project from both groups)
- EU IST FP6 ARTIST2 Network of Excellence

Research projects

CBD Model - Progress Component Models

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

Project Leader	Ivica Crnkovic
Members	Hans Hansson (SDL)
	Frank Lüders
	Severine Sentilles
	Aneta Vulgarakis
	Marcelo Santos

	Björn Lisper (CSL)
Associated members	Kurt Wallnau,
	Pasqualina Potena

The objective of the ProModel project is to develop a generic component model suitable for development of real-time embedded systems. The generic model will have ability to instantiate different component models that will provide means for predictable development of embedded systems in a particular class of embedded systems domain.

The ProModel will make possible to use different analysis and composition theories of functional and non-functional properties and provide means for static and dynamic specification of components and component-based systems.

FRAMES - Fault and Reliability Aware Methods for Efficient Scheduling

Project Leaders:	Radu Dobrin
	Sasi Punnekkat
Project members:	Hüseyin Aysan
Associated member:	Damir Isovic

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

Real-time systems typically have to satisfy complex requirements mapped to the timing attributes of the tasks that are eventually guaranteed by the underlying scheduler. These systems consist of a mix of hard/soft tasks with varying criticalities as well as associated fault tolerance (FT) requirements. Hence scheduling decisions under fault assumptions has to reflect all these factors in addition to resource constraints. The FRAMES project will perform research on various methodologies for fault-tolerant scheduling of component based embedded systems.

PEARLS – Parameterized Evaluation of Attributes of Reliable Systems

Project Leaders:	Sasi Punnekkat
	Heinz Schmidt
Project members:	Radu Dobrin
	Hüseyin Aysan
Associated member:	Alexander Dimov (Sofia University)
	Pasqualina Potena
	Johan Fredriksson

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

Real-time systems typically have to satisfy complex requirements mapped to the timing attributes of the tasks that are eventually guaranteed by the underlying scheduler. These systems consist of a mix of hard/soft tasks with varying criticalities as well as associated fault tolerance (FT) requirements. Hence scheduling decisions under fault assumptions has to reflect all these factors in addition to resource constraints. The FRAMES project will perform research on various methodologies for fault-tolerant scheduling of component based embedded systems.

ET – Enabling Technologies for Dependability

Project Leaders:	Henrik Thane
	Sasi Punnekkat
Project members:	Sigrid Eldh
	Hüseyin Aysan
	Radu Dobrin
Associated member:	Ivica Crnkovic
	Hans Hansson
	Christer Norström
	Thomas Nolte

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

This project explores some interesting aspects relevant to verification, validation and predictable execution of CB embedded systems. Wrapping legacy code into dependable components, exploring suitability of testing strategies, code instrumentation for fast fault detection and error containment and ensuring FT properties of communications in distributed environments are currently identified sub-themes of this project.

CBD Proc – Identification and specification of CB process

Project Leaders:	Ivica Crnkovic
	Rikard Land
Project members:	Frank Lüders
	Alexandre Alvaro
	Iva Krasteva
	Zeljka Car
	Stig Larsson

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

The objective of this project is to develop a component-based development process and related it to different development and life-cycle standards. The aim is also to develop means for modeling and predicting efforts and time of activity performance in the processes.

CBD Trans – Transformation of processes

Project Leaders:	Ivica Crnkovic
	Rikard Land
Project members:	Frank Lüders

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

The objective is to study the process of implementing a CB process in an organization. Which are success factors and common mistakes during the transition process? The overall transition process will be described in a number of cases, with some in-depth studies of some particular activities.

SAVE ++

Project Leader:	Hans Hansson
Members from SE group:	Ivica Crnkovic
	Mikael Åkerholm
	Sasikumar Punnekkat

Funding:	SSF (PROGRESS)

Project description

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

The SE group members were active in successfully getting extended funding for the SAVE project, known as SAVE++. The main focus during the first 6 months has been on formulation of goals as well as requirements definition for development of a SAVE demonstrator project.

APICS - A Process for Efficient and Effective Integration of Component Based Software

Project Leader:	Ivica Crnkovic
Members:	Ivica Crnkovic
	Stig Larsson (Industrial Ph. Student)
	Fredrik Ekdahl (Industrial advisor)
Partners:	ABB
Funding:	ABB, SSF (SAVE-IT)

Project description

The project has started in Q2 2003. The research in Component Based Software Engineering has described requirements on individual components and the system aspects related to combination of components. However, the process for integrating components requires additional capabilities and characteristics to secure that the assembly of parts results in the expected product or system. These characteristics include both process oriented attributes such as review coverage and product oriented attributes such as performance. The goal of this project is to investigate and improve current practices in the integration of systems built on Component Based Software. The main research goal is to propose and evaluate integration processes for systems, with focus on real time systems.

PSI – Product Data Management and Software Configuration Management

Project Leader:	Ivica Crnkovic
Members:	Ivica Crnkovic
	Annita Persson Dahlqvist (Industrial Ph. Student)
Partners:	Ericsson
Funding:	Ericsson,
	KKS (SAVE-IT)

Project description

Product Data Management (PDM) is the discipline of controlling the evolution of a product design and all related product data during the full product life cycle, historically with the focus upon hardware product design. Software Configuration Management (SCM) is the discipline of controlling the evolution of a software product, with emphasis on the development phase. The PDM and SCM domains have evolved in parallel with none or little communication as the products were usually divided in software or hardware products. Today products are often complex systems consisting of hardware, software, and related documents, developed by several groups. This put high demands on support on several levels, both for the system level as well as for each group, especially during the development

phase. One important requirement is the possibility to integrate product information systems where PDM and SCM is part of this integration. However the knowledge of software management and its relation to hardware management is very low. The possibilities to integrate PDM and SCM are one of the key factors in product information management of today. The companies have serious problems using PDM and SCM together, since the overall development process is usually complex and not properly defined, a common knowledge of both domains is low, and the integration possibilities provided by PDM or SCM vendors are limited. The first goal of this project is to investigate the similarities and differences between SCM and PDM, to analyse the requirements for their usage and to analyse the development processes using both PDM and SCM. The investigation is based on theoretical reasoning, literature study, and case studies from different industrial domains. The second goal is to propose an integrated model where both PDM and SCM are used in a common process and where information from these systems is exchanged. The feasibility of that model is validated in industrial case studies.

FLEXCON - flexible controllers

Project Leader:	Karl-Erik Årzén, CLTH Program director,
	Ivica Crnkovic, local project leader
Members:	Ivica Crnkovic
	Johan Fredriksson
Partners:	LTH Lund University
	KTH - Royal Institute of Technology
	HIS - University of Skövde
Funding:	SSF

Project description

The key challenge of FLEXCON is how to provide flexibility and reliability in embedded control systems implemented with COTS component-based computing and communications technology. Research is performed on design and implementation techniques that support dynamic run-time flexibility with respect to, e.g., changes in workload and resource utilization patterns. The use of control-theoretical approaches for modeling, analysis, and design of embedded systems is a promising approach to control uncertainty and to provide flexibility, which will be investigated within FLEXCON. Other focal points are quality-of-service issues in control systems, and testing-based verification and monitoring of flexible embedded control systems. The main application area is adaptive industrial automation systems. An industrial robotics-based demonstrator will serve as the carrier of the project results.

Industrial IT

Project leader:	Ivica Crnkovic
Members:	Rikard Land (Ph.D. student)
	Kurt Wallnau (Industrial PhD student)
Partners:	ABB
	SEI/Carnegie Mellon University
	Lund University
	Monash University
	Eindhoven University
Funding:	The KK-foundation, ABB

Project description:

The architectural aspects (managing evolution of component-based systems), and semantic specification of components (contracts and component interfaces) are the main focus of the project. The project research work is also related to Software Configuration Management and Product Data Management. Several papers in this area have been published and the project members have been active in several international conferences and workshop.

Theses

Rikard Land, 'Software Systems In-House Integration: Observations and Guidelines concerning Architecture and Process', Ph.D Thesis, Mälardalen University Press

Software evolution is a crucial activity for software organizations. A specific type of software evolution is the integration of previously isolated systems. The need for integration is often a consequence of different organizational changes, including merging of previously separate organizations. One goal of software integration is to increase the value to users of several systems by combining their functionality; another is to reduce functionality overlap. If the systems are completely owned and controlled in-house, there is an additional advantage in rationalizing the use of internal resources by decreasing the amount of software with essentially the same purpose. Despite in-house integration being common, this topic has received little attention from researchers. This thesis contributes to an increasing understanding of the problems associated with in-house integration and provides guidelines to the more efficient utilization of the existing systems and the personnel. In the thesis, we combine two perspectives: software architecture and processes. The perspective of software architecture is used to show how compatibility analysis and development of integration alternatives can be performed rapidly at a high level of abstraction. The software process perspective has led to the identification of important characteristics and practices of the integration process. The guidelines provided in the thesis will help those performing future in-house integration to make well-founded decisions timely and efficiently. The contributions are based on several integration projects in industry, which have been studied systematically in order to collect, evaluate and generalize their experiences.

Frank Luders, 'An Evolutionary Approach to Software Components in Embedded Real-Time Systems', Ph.D Thesis, Mälardalen University Press

Component-based software engineering denotes the practice of building software from pre-existing smaller products, in particular when this is done using standardized software component models. The main expected benefits of this practice over traditional software engineering approaches are increased productivity and timeliness of development projects. While the use of software component models has become common for desktop and server-side software, this is not the case in the domain of embedded real-time systems, presumably due to the special requirements such systems have to meet with respect to predictable timing and limited use of resources. Much research exists that aims to define new component models for this domain, typically focusing on source code components, static system configuration, and relatively narrow application domains.

This dissertation explores the alternative approach of using components based on binary code, allowing dynamic configuration, and targeting a broader domain. A study of a general purpose component model shows that the model is compatible with real-time requirements, although putting some restrictions on its use may be necessary to ensure predictability. A case study demonstrates how the model has been beneficially used in an industrial control system. The dissertation furthermore proposes an approach for extending the component model with run-time services for embedded real-time systems. It presents a prototype tool for supporting such services, along with two empirical studies to evaluate the approach and the tool as well as the component model itself. One study shows that both the component model and the services provided by the tool result in very modest and predictable run-time overheads. The other study, evaluating the effects on productivity and quality of using the

approach in a software development project, did not produce quantitative evidence, but concludes that the approach is promising and identifies possible adjustments to it and opportunities for further studies.

Staff

Ivica Crnkovic is a professor of industrial software engineering at Mälardalen University where he is the administrative leader of the software engineering laboratory and the scientific leader of the industrial software engineering research. His research interests include component-based software engineering, software configuration management, software development environments and tools, as well as software engineering in general. Professor Crnkovic is the author of more than 80 refereed articles and papers on software engineering topics and a co-author and co-editor of two books: Building reliable component-based Systems, and Implementing and integrating Product Data Management And Software Configuration Management. He has co-organized several workshops and conferences related to software engineering (in particularly component-based software engineering) and participated in Program Committees of software configuration management symposia and workshops. From 1985 to 1998, Professor Crnkovic worked at ABB, Sweden, where he was responsible for software development environments and tools. He was a project leader and manager of a group developing software configuration management systems and other software development environment tools and methods for distributed development and maintenance of real-time systems. From 1980 to 1984, he worked for the Koncar company in Zagreb, Croatia. Professor Crnkovic received a M.Sc. in electrical engineering in 1979, a M.Sc. in theoretical physics in 1984, and a Ph.D. in computer science in 1991, all from the University of Zagreb, Croatia.

Hüseyin Aysan was enrolled as a Ph.D. student at Mälardalen University in 2006. He received his B.Sc. degree in Computer Engineering from Istanbul Technical University in 2004 and his M.Sc. degree in Robotics from Mälardalen University in 2006.

His main research focus is on dependable embedded systems built using component based development approach.

Mikael Åkerholm is an industrial PhD student employed at CC-systems. He received a master's degree in computer science and engineering from Mälardalen University in 2003, and continued with PhD studies at the same department directly. In 2005 he received his Licentiate exam. Mikael's research interests are component based software engineering, real-time, safety-critical, and embedded systems. He is participating in the SAVE project, which is a research project that tries to enable component based software engineering for safety critical vehicular systems.

Annita Persson Dahlqvist is a specialist in configuration management, software configuration management, and product data management at AB. She is the manager for the CM Managers group. She is also responsible for training, starting up new projects, process development, and supporting the organization regarding configuration management, and product data management issues. She earned her BSc in computer science from the University of Gothenburg, Sweden 1985 and in 2005 she received her licentiate exam from MDH. She has been working for Ericsson AB since 1985.

Radu Dobrin is a senior researcher. He received his PhD from Mälardalen University in October 2005. His research was performed in the area of flexible and predictable embedded real-time systems, and was partially founded by ARTES and the IST European project FIRST.

Currently, his research addresses dependability of real-time embedded systems built using component based development technology within the PROGRESS project at MDH.

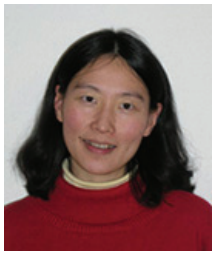
Daniel Flemström is a lecturer at Mälardalen University since June 2000 and since 2004 also a phd student. He received his Master Of Science from Mälardalen University, Sweden in 1995. He is teaching courses in programming languages, algorithms and data structures (C++/Java) and Component Based Technologies. Daniel is also giving courses in advanced Industrial IT component programming at the ABB University. His research interests include Component Based Software Engineering and Model Driven (Re) Engineering, Embedded Systems and Realtime applications.

Johan Fredriksson (Lic 2005, MSc. 2002, BSc. 2001) is a Ph.D. student and has been so since the beginning of 2003. Previous to commencing his graduate education, he was an undergraduate at the department during the years 1998-2002. Johan's research interests are middlewares in component technologies, real-time for safety-critical and embedded systems. He is participating in the SAVE project, which is a research project that tries to enable component based software engineering for safety critical vehicular systems.

Rikard Land With a MSc in Computer Science, Rikard has worked as software developer at Westinghouse 1998-2001. 2001 he enrolled as a PhD student at Mälardalen University, in the field of Software Engineering. His PhD thesis covered integration of in-house developed software systems and was defended in September 2006. He is currently working in undergraduate education, teaching courses in the field of Software Engineering. He is also a researcher in the Progress centre, focusing on life-cycle processes for embedded software systems.

Stig Larsson is an industrial Ph.D. student and is working as a scientist at ABB Corporate Research. His main research interest is software engineering. His experience includes management of company wide technology projects and management of development organizations with software and hardware development in several sites. He is responsible for product development processes in ABB. Stig Larsson received his MSc in Electrical Engineering from the Royal Institute of Technology, Stockholm, Sweden 1983.

Frank Lüders is a lecturer and researcher at Mälardalen University's Department of Computer Science and Electronics. He received a BSc in Electronics Engineering from the Vestfold College, Norway in 1993, a MSc in Electrical Engineering/Computer Systems from the Technical University of Denmark in 1997, and a PhD in Computer Science and Engineering from Mälardalen University in 2006. Frank worked with software development at ABB A/S in Norway until November 1999 and at ABB Automation Technologies AB in Sweden until 2003. His research focuses on software component models for embedded real-time systems and empirical evaluation of such models.



Hongyu Pei Breivold is an industrial PhD student working within Software Architecture and Process Group at Corporate Research, ABB AB in Västerås. She started working for ABB in 1994 and her experience includes participation of company-wide technology and software-intensive system development projects within different domains, such as software refactoring, participation in designing framework and software architecture for advanced robot design and optimization, development of efficient palletizing software in robotics area, participation in developing a generic manufacturing execution system (MES) software framework including software framework and generic business components that provide basic business functionality and are applicable to hot and cold flat mills, profile mills and other production control systems. She worked as a consultant under year 2001 to assist in micro thin client web support in ABB's Industrial IT control system and platform. Her main research interests include software architecture, software architecture analysis and evaluation, software evolution from architecture perspective.

Pasqualina Potena is a visiting researcher. She is a PhD student at Dipartimento di Scienze of Università degli Studi "G. D`Annunzio" (Chieti-Pescara, Italy). Her PhD advisors are the prof. Vittorio Cortellessa (Dipartimento di Informatica, Università degli Studi dell'Aquila, Italy) and the prof. Andrea Roli (Dipartimento di Scienze, Università degli Studi "G. D`Annunzio", Chieti-Pescara, Italy).

The research interests are concentrated in the composition of non-functional attributes in software systems.

Sasikumar Punnekkat is a Senior Lecturer at Department of Computer Engineering, leader of the Dependability cluster of PROGRESS and responsible for the MIMA-SE programs. He received Master Statistics (1982) and M. Tech Computer Science (honors) (1984) from the Indian Statistical Institute. He joined the Indian Space research Organization in 1984, and was involved in the design; development and testing of software for satellite launch vehicles. During 1993-97, he was recipient of the prestigious Commonwealth Scholarship and was awarded Doctor of Philosophy in Computer Science by the University of York, UK. Dr. Punnekkat was a post-doctoral research fellow (1999-2000) at Mälardalen University. He was a Senior Scientist at the Software Quality Assurance Division of Vikram Sarabhai Space Centre, India and was the Head of software test and Reliability Engineering during 2001-2004. Punnekkat has more than 30 research publications in international conferences and journals. His research interests span various aspects of real-time systems, fault-tolerant computing, software engineering, software reliability and testing.

Heinz Schmidt is an adjunct Professor from 2006. He was a Professor of Software Engineering at Monash University, Australia till end of 2006. He has over 20 years experience with component-based and object-oriented languages, systems and software in practice, research and training, notably around extra-functional properties of component software and their formal modeling and verification. Heinz has published over 120 refereed articles, and lectures in software engineering, programming languages and concurrent / distributed systems.

Before joining Monash University, Prof Schmidt conducted research at the German National Research Centre for Information Technology (GMD), the International Computer Science Institute at the University California, Berkeley, CSIRO Canberra and ANU CS. At GMD Heinz was one of the key researchers in the European ESPRIT project Graphical specification and formal implementation of non-sequential systems (GRASPIN), at ICSI he was a key researcher in the parallel Sather language and environment project. At CSIRO he established a software engineering research group and conducted industry-funded research in object-oriented systems. At Monash University he helped establish the Centre for Distributed Systems and Software Engineering, the Enterprise Distributed Computing Technology Centre (Melbourne), and the Monash Cluster Computing Network.

Cristina Seceleanu is a postdoctoral fellow. She received a MSc. in Electronics from Polytechnic University of Bucharest, Romania, in 1993, and a Ph.D. in Computer Science from Åbo Akademi University and Turku Centre for Computer Science, Åbo, Finland, in 2005. Her research focuses on developing formal models and verification techniques for reactive/embedded systems.

Séverine Sentilles is a PhD student at the Software Engineering Laboratory of the university of Mälardalen. She has been enrolled in the component-based development cluster of the PROGRESS centre since September 2006. Previously, she received her M.Sc. in "Technologies of the Internet" from the University of Pau and Pays de l'Adour (France) in 2006.

Her main research interest is focused on the modelisation of component-based systems and more precisely the specification of a compositional framework for predictable real-time embedded systems within the context of PROGRESS. She is also involved in the design of an Integrated Development Environment for the SAVE project which aims more particularly at the vehicular systems domain.

Anita Vulgarakis is a PhD student at the Software Engineering Laboratory of Mälardalen University since October 2006. She is part of the component-based development cluster of the PROGRESS centre. She graduated in July 2006 at the Faculty of Electrical Engineering, Skopje (Macedonia), with professional specialization in "Computer Science, Information Technology and Automation".

Her main research interest is component-based system modeling and specification of a compositional framework for predictable real-time embedded systems within the context of the PROGRESS centre. In addition to this, her research includes integration of formal requirements specifications into the component model.

Kurt Wallnau has 20 years of experience in software research and development. Mr. Wallnau currently leads the Predictable Assembly from Certifiable Components (PACC) exploratory research project at the Software Engineering Institute (SEI) at Carnegie-Mellon University, Pittsburgh, US. Prior to this work on PACC, Mr. Wallnau led work in the SEI COTS-Based Systems initiative. This work culminated in the Addison-Wesley book in the SEI Series, Building Systems from Commercial Components. At MDH he is working with his PhD thesis.

National and International research co-operation

The group cooperates with the following national partners (academic only, industrial partners are listed in Section 1.6):

- Uppsala University, IT Dept., on real-time and component-based technology, in projects ARTIST and SAVE.
- KTH, on embedded systems and component-based approach in projects SAVE and FLEXCON
- Linköping University, on embedded systems, component-based approach in project SAVE
- University of Skövde, in the FLEXCON project
- Lund University, Dept. of Computer Science, on Software Engineering and embedded systems, projects Industrial IT and FLEXCON

- Blekinge Institute of Technology, Department of Software Engineering and Computer Science, Software Engineering in Sweden initiative.

The following international co-operation has taken place during 2006:

Global Software Engineering European Master (GSEEM)

The group had taken a lead role in establishing GSEEM, which is a common Master Programme in Software Engineering organised by four Universities: Mälardalen University in Sweden, University of L'Aquila in Italy, Vrije Universiteit in Netherlands and Westminster University in United Kingdom. A GSEEM student will study at two universities and will have the chance to obtain a double degree. In addition to standard Master education in Software Engineering GSEEM provides with knowledge in global and distributed software development. It offers different specialisations (software architecting, real-time embedded systems engineering, web-based services and systems engineering) from experts and researchers in Software Engineering.

Cooperation with International Software Engineering Groups

The group has started or continued already established cooperation with the following international research and education centers:

- Software Engineering Institute (SEI) at Carnegie Mellon University, Pittsburgh, USA
- Monash University, Melbourne, Australia
- University of Zagreb, Croatia
- Technical University in Eindhoven, The Netherlands
- L'aqiula University, Italy
- Tufts University, Boston, US
- Sofia University, Department of Informatics and Mathematics
- University of Prague, Department of Informatics and Mathematics
- Karlsruhe University, Germany

The group has continued cooperation with SEI in the Component-based Software Engineering (CBSE) field, with focus on predictable assembly of certifiable components. The goal of this cooperation is to develop methods for efficient use of software components and from the known properties of components predict the behavior of the systems composed from these components. Predictability is of special interest for systems with specific requirements, in particular real-time, embedded and safety-critical systems.

In 2006 the activities related to this cooperation include:

- Kurt Wallnau, researcher at SEI has continued with his work on his PhD at IDE, with Ivica Crnkovic as advisor.
- SEI, University of Monash, Australia, Tufts University, US and MRTC organized a CBSE symposium at the ICSE conference in St Louis (CBSE 2005).

Monash University, Australia

The Software Engineering group has continued cooperation with Monash University. In addition to activities listed above, Prof. Heinz Schmidt visited MRTC several times discussing PROGRESS and other related projects. Prof. Heinz Schmidt is a member of the advisory board for the SAVE project.

Úniversity of Zagreb, Croatia

- Faculty of Electrical Engineering and Computing, University of Zagreb and the group has cooperation in undergraduate and graduate education. The course was held in

autumn 2006 as a common course (examinators prof. Mario Zagar, Zagreb, and Prof. Ivica Crnkovic, MDH). Ivica Crrnkovic bacme a visiting professor at Faculty of computing and Electrical Engineering.

Eindhoven University of Technology (TUE)

- Close cooperation with Mathematics and Computer science Department, in particular with Prof. Michel Chaudron. During 2006 we had a visiting master student Laurens Blanker from TU/e.

Sofia University, Sofia, Bulgaria

- Cooperation in research and education. During 2006, both Ivica Crnkovic and Sasi Punnekkat visited Sofia and gave lectures and Prof. Sylvia Illeva visited MDH.

L´aquila University, Italy

- Cooperation has been established between Prof Paola Inverardi and Prof. Ivica Crnkovic. The cooperation includes exchange of master and PhD students and organisation of ESEC/FSE conference (European software engineering conference/Foundation on software engineering conference). Also a PostDocs Massimo Tivoli from L'Aquila stayed six months at MDH.

University of Westminster, London, UK

- Cooperation in education under Erasmus Socrates. Dr. Ljerka Beus-Dukic visited MDH and gave seminars while Sasi Punnekkat visited Westminster and gave seminars to undergraduate students on benchmarking.

Thessaloniki University, Greece

- Initial cooperation in education and research has been started. Prof Ivica Crnkovic has held invited seminars, and Prof Panagiotis Katsaros visited MRTC.

Charles University, Prague

- Initial cooperation in education and research has been started. Prof Ivica Crnkovic has held invited seminars, and Prof Frantisek Plasil visited MRTC. There are plans that a postdoc from Charles Universuty stays at MRTC during 2007, 2008.

Services to the Scientific Community

The following is a list of the most important services to the scientific community by members of the group in 2006:

Ivica Crnkovic

- General Chair of EUROMICRO SEAA, held in Dubrovnik, September 2006
- Appointed as a co-chair of the Euromicro SEAA steering committee
- General Chair QoSA 2006 held at MDH, July 2006
- General Chair CBSE 2006 held at MDH, July 2006
- Appiojted as a General Chair for ESEC/FSE 2007
- PC Chair of Euromicro conference, CBSE track
- PC member for following conferences, symposia and workshops: FASE 2007, HICSS2007, FECSA2007, ICCBSS2007,SAVSBC2006, SEFT2006, WADS2006, WICSA2007
- Expert evaluator for several applications to different European Foundations

- Co-editor of a special issue of Elsevier's Journal of Systems and Software- Software Configuration Management
- Opponet and in the PHD grading committee:
- Robert Bialek, PhD Defense, Copenhagen, Danmark
- Richard Torkar, PhD Defense, BTH Ronneby

Sasi Punnekkat

- PC member for QoSA 2006
- Discussion leader for Licentiate thesis of Ruben Alexandersson, Chalmers University of Technology, Göteborg
- Session chair at QoSA 2006, ADCOM 2006

2.5 Embedded Systems Software Engineering group

Focus

The core to a successful system is its basic architecture. We are studying the many aspects of architectures, especially related to embedded systems and reliability, which includes specification of architectures, architecture analysis, component models, and essential components, methods and tools in embedded systems. We are both considering models and analysis for developing new systems and techniques to reintroduce analyzability into existing systems. In addition to this we have started several projects that are focused on efficiency in development. These projects are characterized by their close interaction and dependency on industrial collaboration to achieve valid results.

The basic approach is to formulate hypothesis and thereafter strengthen that hypothesis by extensive case studies, and finally prototype development.

In 2006 we have performed several case studies

The group focuses on:

- Reintroducing analysability into existing systems.
- Architectures, reuse, and component integration for automotive systems.
- Tailorable Embedded real-time databases.
- Component models and architectures for embedded systems in general and Vehicular Systems in particular.
- Efficiency in product development
- Business Oriented Concept Development of Electronic System Architecture and Platforms in Vehicles

The group consists of two professor, one senior lecturer, one researcher and 10 PhD students, 4 of them industrial PhD students.

Research projects

SAVE/ComponentModel

Project leader:	Kristian Sandström
Members:	Ivica Crnkovic
	Johan Fredriksson
	Mikael Åkerholm
Partners:	Save, Flexcon
Funding:	SSF

Project description:

Vehicles represents a class of embedded real-time systems where the requirements on safety, reliability, resource usage, and cost leaven all through development. The vehicular domain wants to practice Component based software development, which is a promising approach for efficient software development, enabling well defined software architectures as well as reuse. However, commercial component technologies are not used for those systems, they are simply to resource demanding, to complex and to unpredictable. The goal with the project is to define a component technology for resource constrained safety-critical embedded systems. The

approach is to use a mature run-time platform such as a commercial real-time operating system, and enable component based design through powerful compile time techniques.

Future plans:

We will continue the research on predictable component models for embedded real-time systems (rts) and theories for efficient mapping of component models on to run-time systems for embedded rts.

DRIVE – Distributed Real-time systems In Vehicles

Project leader:	Christer Norström, MDH
Members:	Joakim Fröberg, Industrial Ph.D-student at Volvo CE Components
	Kristian Sandström
Partners:	Volvo CEC
	Volvo Trucks
	Volvo Busses
Funding:	Volvo CEC
	KK-foundation

Project description:

On-board automotive electronic systems present a special problem formulation within in the domain of embedded systems in terms of reliability, cost, safety, and maintenance. At the same time, automotive industry faces challenges related to increasingly complex systems. This project aims at providing guidance for design of architecture, selection of technology and methods for developing automotive on-board electronics. Especially, architectural and technical solutions for integration of electronic components will be addressed by a series of studies in automotive industry.

We will study the engineering method to achieve project success in terms of quality and project plan when integrating electronic components in automotive electronic systems. The first objective of this research is to develop a model of how technical measures and integration method affects the qualities reliability and safety. The second objective of this research is to propose a framework for integration with leverage on safety and reliability qualities.

Results and achievements in 2006:

- Conference paper presented in Systems Engineering/Test and Evaluation Conference, Melbourne, 25-27 September 2006, Melbourne
- Conference paper presented in the 6th Conference on Software Engineering and Practice in Sweden, October, Umeå, Sweden
- A second case study on integration performed at Volvo Construction Equipment.
- A technical report compiled from the cases studies.
- A research plan with directions for study to complete PhD.
- A checklist with recommended practices for automotive mechatronics developed and validated in five industrial cases.

Future plans:

Thesiswith focus on issues of electronic component integration in vehicle systems to be completed during 2007. A study on safe design of electronics for vehicles will be completed and published. A method for decision making in design is to be published.

Extract

Project leaders:	Christer Norström
Members:	Johan Andersson
	Anders Wall
	Yue Lu
	Farhang Nemati
	Björn Lisper
	Peter Eriksson, ABB
	Magnus Larsson, ABB
	Erik Gyllenswärd, Bombardier Transportation
Partners:	ABB
	Bombardier Transportation
Funding	KKS
	ABB
	Bombardier Transportation

Project description:

When adding or changing code in a large software system, it is hard to predict all possible effects of the change due to the system complexity. The EXTRACT project aims to improve the maintainability of complex industrial software systems, by developing a method for automated model extraction. The extracted model describes the behavior of the software system with focus on timing and resource usage, properties important for the performance as well as reliability. These properties are very hard to analyze without adequate models of the software. Models of this type are not available in industry today as they are hard to construct and maintain manually and no tools exists for this purpose. By automating the extraction of such models, we enable model-based impact analysis with respect to the system performance and reliability. By using the impact analysis during the design phase of new features, potential problems can be avoided early. This makes maintenance more efficient and predictable.

Results and achievements in 2006:

- A new theory and tool for semiautomatic extraction of models has been developed.
- Three papers have been presented, of which one received a Best Paper Award.

Performance metrics in product development

Project leader:	Christer Norström, MDH
Members:	Stefan Johnsson, Industrial Ph.D- student at Level 21 Management AB
	Anders Wall
Partners:	Level 21 Management AB
Funding:	Level 21 Management AB
	KKS

Project description:

Traditionally when a firm wants to increase its performance the product development process has not been considered. Instead focus has been on other processes like manufacturing and as a result there are well established theories to evaluate the performance within manufacturing. Today the market is more competitive then ever and a well functioning product development process is required to be successful. The aim of this research project is to develop a framework

that makes it possible to reason about product development performance. In an abstract way the product development performance can be dived into three parts: efficiency; the ability to implement a requirement and solve issues, effectiveness; the ability to specify a product that agrees with customers need and productivity; the return of the invested resources in the R&D process. This performance framework will then be further developed into a metrics system that makes it possible to measure the performance of the product development.

This project is conducted in close cooperation with seven companies who all develop complex industrial systems within telecommunications, automotive and automation.

Results and achievements in 2006:

The project started in October 2006.

Future plans:

During 2007 a research study will be conducted together with the involved companies to learn how they measure performance today and investigate the possibilities to develop new metrics. The goal is to complete a Lic. Thesis in October 2008.

Business Oriented Concept Development of Electronic System Architecture and Platforms in Vehicles

Project leader:	Jakob Axelsson, MDH and Volvo Cars
Members:	Peter Wallin, MDH
	Christer Norström, MDH
	Ana Magazinovic, Chalmers
	Peter Öhman, Chalmers
Partners:	Volvo Cars
	Volvo Construction Equipment
	Volvo 3P
Funding:	Vinnova
	(Fordonsforskningsprogrammet)

Project description:

The project aim is to study and develop systematic methods for concept development of vehicle electronic architectures. Special focus is on the business relevance of decisions and handling of uncertain factors and risks. The objectives include a survey of today's methods as well as development of new methods and models that can serve as decision support in early phases, in particular when selecting architectures and developing software. A further goal is to contribute to the competence supply and knowledge distribution among the partners.

Results and achievements in 2006:

The project started in March 2006 when the Ph. D. students joined the universities. During the year, initial studies at the participating companies have taken place, resulting in an internal report comparing the businesses and technologies of these organizations. A state of the art report regarding architectural design of embedded systems has been written. Peter Wallin has studied the use of ATAM combined with AHP together with Joakim Fröberg and Jakob Axelsson. Jakob Axelsson has also done research on how to handle uncertainties in electronic architecture design and trade-offs.

Future plans:

During 2007, an extensive case study will take place to learn more about how the automotive industries work with architectural analysis and decisions. Interesting issues to investigate is what factors (both technical and non-technical) influence the architecture decisions, if there are different opinions on what constitutes an architecture and what use it has, and also regarding the interplay between the people directly and indirectly involved in architectural design. In addition to this case study, the work on AHP will continue and a if possible, a real architectural design project will be followed. Within the project, there will also be activities (mainly at Chalmers but with involvement from MDH) regarding cost and resource estimations in system development. The Ph. D. students will present there licentiate theses in 2008.

Methods for development of E/E-systemarchitectures in early phases

Project leader:	Jakob Axelsson, MDH and Volvo Cars
Members:	Håkan Gustavsson, MDH and Scania
	Christer Norström, MDH
Partners:	Scania
Funding:	Vinnova (VIC-T program)

Project description:

The E/E system in trucks are becoming increasingly more complex through the introduction of more electronics and software. This trend is expected to continue, and it poses requirements on the system architecture and methods for designing architectures. The projects aims at surveying challenges and methods for choosing architecture, and then develop new appropriate methods in close cooperation with industry. The methods should together ensure that both aspects of technology and business is considered in the early phases. Since the methods should be a special support in the early phases, uncertainty and risks should be treated by the methods.

Results and achievements in 2006:

The project started in March 2006 when the Ph. D. student joined the university. During the year, a state of the art report regarding architectural design of embedded systems has been written and extensive litterature surveys have been conducted. The project has focused, as a first step, on the valuation of flexibility in architectural design. For products where the unit cost is essential, provision for future expansions and modifications tend to be neglected since it is hard to evaluate.

Future plans:

In the fall of 2006, work was started on how to apply real options theory as a means of objectively evaluating flexibility in architectural design. The theory was studied in depth, and this work will continue during 2007 with focus on examinining how it can be applied to the design of truck electronic architectures. Realistic case studies will be done, and could include trade off analysis of, e.g., adding extra memory, processor power, I/O etc. In addition to this, a case study is planned on how to economically evaluate the limited resources of a distributed real-time system. Håkan Gustavsson will present his licentiate thesis in 2008.

Architectural modifications for lowering production cost

Project leader:	Christer Norström, MDH
Members:	Markus Lindgren, Industrial Ph.D.-student at ABB Force Measurement
	Anders Wall
Partners:	ABB Force Measurement, ABB Corporate Research
Funding:	ABB Force Measurement
	KKS

Project description:

Today much focus in product development projects is usually placed on minimizing development calendar time and resources. Such a focus can lead to technical decisions, which are beneficial in the short-term (for the project) but in the long-term lead to increased costs for the organization as a whole, e.g., due to poor quality software which require increased customer support and patches. A further complicating issue for complex industrial control systems is that it is usually required to adapt each sold system according to customer requirements, either via configuration of a standard system, or by developing additional functionality which is added to a standard system. In addition, these systems usually have a commissioning phase during which, e.g., the control system is tuned. Hence, technical decisions during product development can have unforeseen impact on a company's production costs.

A complex industrial control system's software architecture is a main driver in setting the possible levels for quality, functional content, and production cost for a product. Hence, by modifying the software architecture, and its components, we can affect quality, functional content, and cost and thereby possibly reduce company costs and increase customer satisfaction. This applies both during development of the initial release of the product as well as its following releases. A critical problem hence becomes how to define a product roadmap which minimizes internal costs and at the same time maximizes customer satisfaction.

The aim of the project is to develop a framework, presumable extending existing research in the area, which helps define a roadmap, including architectural modifications, resulting in lowered production costs while at the same time keeping customer satisfaction at an acceptable level.

Results and achievements in 2006:

A case study related to release planning has been conducted but not yet published.

Future plans:

Prepare a research plan with the goal of completing a PhD Thesis in 2008.

LegExtract – Model Extraction for Legacy Systems

Project leader:	Christer Norström, MDH
Members:	Anders Wall
	Johan Kraft,
	Farhang Nemati,
	Joel Huselius,
	Andreas Ermedahl,

	Sasikumar Punnekkat
	Hans Hansson
Funding:	SSF, Progress

Project description:

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

The LegacyExtract project will develop methods and tools for extracting models from an existing real-time system, typically a complex legacy system. The purpose is to allow for analyzing important system properties, like timing/performance and resource utilization.

Modeling legacy real-time systems includes both modeling of the static information from the source code, e.g. control-flow, message-passing, logics, as well as modeling of the legacy system's run-time behavior, i.e. the system's dynamic behavior. A typical example of a dynamic behavior is execution times. In this project we will work on both static-, and dynamic modeling.

Furthermore, the project aims at defining a method for establishing confidence in that a model actually is a valid model of a system. We can compare the predictions from a model with measurements of the real system, but the model is, by definition, an abstraction of the system, we cannot expect a perfect match of the measured and predicted behavior. We therefore need a weaker measure of similarity, which allows for tolerances to be specified.

LegAsis - Legacy Model Analysis

Project leader:	Christer Norström, MDH
Members:	Anders Wall
	Johan Kraft,
	Yue Lu,
	Jukka Mäki-Turja
	Thomas Nolte
Fundning:	SSF, Progress

Project description

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

Analysis based on simulations is not exhaustive, i.e. we can never be sure that the worst-case behavior of a model has actually been observed. In order to increase the confidence in the results from the analysis based on simulations we will investigate how to use an iterative simulation approach. By running many simulations randomly we expect to get a fairly good population of results from which we could pick, for instance, 5% top most "interesting" cases and guide the simulator in exploring those cases in more depth. An example of an interesting case could be the ones with the highest response time for a critical task.

The reason we have used a simulation based approach is that traditional methods for response-time analysis are based on a too simplified and restrictive task model. Hence, if a system is not strictly implemented according to the rules governed by the task models in the analyses, the system will not be analyzable. Typically, assuming a WCET for all instances of a task is not realistic since variations occur in real-life. However, it is interesting to investigate the possibility to increase the expressiveness of the task model for a response-time analysis in order to model execution times as distributions.

We should also investigate how to extend our framework for analysis of temporal behavior with analysis of dependability properties. A typical example of such a dependability property is safety. The model extraction solution developed in PG-LegExtract could most likely be adapted to extract models for analyzing safety properties, using e.g. a model checker.

Leg Comp - Composition of legacy systems

Project leader:	Christer Norström, MDH
Members:	Anders Wall
	Thomas Nolte
	Sasikumar Punnekkat
Fundning:	SSF, Progress

Project description

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

Reusing legacy real-time software in new system generations requires method for safe legacy integration, i.e. wrapping of the legacy software. Reasons for wrapping are, for example, componentization, the introduction of a new component technology, predictability requirements based on the assumptions made in the new system generation. Moreover, models of legacy systems may also be reused in a new system generation. Consequently, we need to investigate how to wrap legacy models and/or how to transform legacy models into models that are valid for the assumptions made in the new system.

Theses

No theses was completed.

Staff

Jakob Axelsson is adjunct professor in software and systems engineering. He studied Computer Science in Linköping, Sweden, and Lausanne, Switzerland. He received a M.Sc. from Linköping University in 1993, and a Ph.D. in 1997 for a thesis on hardware/software codesign of real-time systems. He has been working at ABB Corporate Research and ABB Power Generation (now Alstom) in Baden, Switzerland, Volvo Technological Development (now Volvo Technology) and Carlstedt Research & Technology in Göteborg, Sweden. He is currently with the Volvo Cars Corporation in Göteborg, where he is program manager for research and advanced engineering for electrical and electronic systems. He is also chairman of the boards of the ARTES and SAVE-IT national graduate schools in real-time and embedded systems, and has been president of the Swedish chapter of the International Council on Systems Engineering (INCOSE).

Christer Norström is professor in software and systems engineering and vice president for Mälardalen University. Previously, he was working as manager for future technology at ABB Automation Technology Products/ Robotics. He is also one of the founding members of the department. He has also worked as a consultant, in

particular for the automotive industry. Christer has given numerous courses on real-time system for industry both in Sweden and in Europe. His research interests are design of real-time systems, reliability and safety methods, software engineering, and architectures for real-time systems. Christer is very interested in technology transfer from academia to industry which he has manifested that through several successful transfers to the automotive industry. Christer is member of the board of the Västerås Technology park and Robotdalen. He is also chairman for the newly established spin-off company Zealcore Embedded Solution AB. Christer was previously department chairman at the Department of Computer Engineering, Mälardalen University. He received a Ph.D from Royal Institute of Technology (KTH), Stockholm in 1997, became Docent at KTH in 2001, and professor at Mälardalen University 2002. In year 2001 he was awarded best teacher at Mälardalen University.

Kristian Sandström is a Senior Lecturer in computer engineering. He received a Ph.D from the Royal Institute of Technology, Stockholm (2002). He has for many years given graduate, post-graduate, and industrial courses in several topics including; engineering of complex embedded systems, real-time systems, and distributed real-time systems. His research interest includes architecture, design, analysis, and implementation of embedded real-time systems with high demands on reliability. Furthermore, Kristian has worked as an embedded systems expert consultant for the industry during the last 8 years. He is one of the founders of the spin-off company ZealCore, where he works part time as a senior embedded systems expert responsible for company technology.

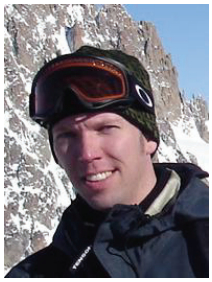
Anders Wall is a researcher at SEL He received his M.sc in computer science from Uppsala university in 1994, his Ph.Lic from Uppsala university in September 2000, and his Ph.D. from Mälardalen University in September 2003. Anders has three years of industrial experience from SW-development of industrial control systems at ABB. His research interest includes design of real-time systems, software architectures; component based software engineering for real-time systems and formal methods for real-time systems. He has given courses on software engineering, data communication, and project management at Mälardalen University.

Joakim Fröberg is an Industrial Ph.D. student employed Volvo Construction Equipment Components AB where he is working with development of electronic systems integration issues at the department of product development/electronics. Joakim is also a Ph.D. student at the Software engineering laboratory where he is working in the DRIVE project to study requirements and design of vehicle electronic architectures. He received his M.Sc. in Industrial Control System at Salford University 1996 and his licentiate degree at MDH 2004. His research interests include architectures of vehicle computer-based

systems, but also systems and requirements engineering related to engineering of vehicle electronics.

Johan Kraft (formerly Andersson) (M.Sc. 2002, Lic. 2005) is a Ph.D. student at SEL. Johan received a M.Sc. in Computer Engineering at Mälardalen University in 2002. During 2002-2003 he worked with embedded software development at ABB Robotics. During this time he enrolled at MDH/MRTC as an industrial PhD student, funded by ABB and ASTEC, the Vinnova competence center for advanced software technology. Johan presented his licentiate thesis in June 2005 and now continues his research with funding from KKS. Johan's primary research interest is (automated) extraction of analyzable models from complex real-time systems which enables impact analysis with respect to run-time properties, such as timing and resource usage.

Stefan Johnsson is an industrial Ph.D. student and is currently employed as a management consultant at Level 21 Management AB. He received his M.Sc in applied physics and electrical engineering from Linköping University 2003. Stefan has worked with the development and maintenance of control systems mainly for auxiliary converters at Bombardier for approximately four years. Since October 2006 he is on leave of absence from Bombardier to be an industrial Ph.D. student at MDH, where his research is focused on performance measures of product development in high technological industrial companies. The aim of the research is to develop a metrics system that measures the performance in the development process; this will be done through a research study together with seven high technological companies within telecommunication, automotive and automation industry.



Markus Lindgren is an industrial Ph.D. student and is working as system architect/developer at ABB Force Measurement. Markus received his BSc and MSc from Mälardalen University and his Licentiate from Uppsala University in 2000. Markus has worked as a consultant for approximately five years, both at companies in Sweden and Germany, mainly focusing on software design/architecture for embedded real-time system. In September 2005 Markus changed employer to ABB Force Measurement and started as an industrial Ph.D. student at MDH where his research is focused on software architectures for complex industrial control systems.

Farhang Nemati is a Ph.D. student at Software Engineering Lab (SEL) at Mälardalen Real-Time Research Centre (MRTC) at Mälardalen University. He received his Computer Engineering (Software Engineering) degree from University of Tehran, Iran in 1999. He worked as a software developer in industry for several years. Farhang received his M.Sc degree in Computer Science from Uppsala University in 2006. His research is funded by SSF. His main research interest is extraction models from complex embedded real-time legacy systems by combining static and dynamic analysis. Validation of the extracted models is also of his research interest.

Peter Wallin is a Ph.D. student and received his M.Sc in computer science from Mälardalen University 2006. His research is funded by VINNOVA and is done in cooperation with Chalmers, Volvo 3P, Volvo Cars Corporation and Volvo CE. The aim of the research is to find models to support decisions made during early stages in the development of electronic architectures for vehicles.

Håkan Gustavsson is an industrial Ph.D. Håkan has been working with vehicle electronic systems integration and architecture since 2002 at Scania CV AB in Södertälje. He is currently employed as an Industrial Ph.D. student within the electrical systems predevelopment section at Scania. He received his B.Sc. in Electrical Engineering at the Royal Institute of Technology 2002 after completing his studies with a final year at Fachhochschule Zentral Schweiz. His research area is systems engineering of vehicle electronics. Studying methods to analyze and improve the decisions made during the early phases of E/E-system development.

Yue Lu is a Ph.D. student at SEL. He received his M.Sc in Mechatronics engineering from the university of southern Denmark, 2005 June. During his M.Sc. studies, he was involved in the formal specification, verification & validation of embedded real-time system based on Component-based design by using model checking. After working in Sony & Ericsson BMC one year as a test developer, he started his new career in the Mälardalen University 2006 Oct. His research interest has recently centered on iterative simulation of control system based on timing analysis, and analytical analysis. It is wonderful to him that there will be some potential cooperative opportunities with other researchers from different institutions, with different nationalities within his research activities. Moreover, he also likes playing different roles in his short life, e.g. basketball player, Kitchener, Scenarist, singer etc.

2.6 Programming Languages Group

Focus

The programming languages group deals with research on different aspects of programming and specification languages. The focus of the group is the analysis and design of languages in real-time and embedded systems, but projects are also carried out in neighboring areas, like analysis of modeling languages. The group consists of one professor, two senior lecturers, one researcher, and nine Ph.D. students, whereof two are external. The group cooperates with SICS within the SICS-MDH collaboration, and one employee at the Västerås branch of SICS belongs to the group as external Ph.D. student. The group is also active in CUGS (the National Graduate School in Computer Science), with a member on the Steering committee and three Ph.D. students participating in the school during 2006. Finally, the group is also a core partner in the ARTIST2 Network of Excellence on embedded systems design.

Research projects

Worst-case execution time analysis (WCET)

Project leader:	Björn Lisper
Project members:	Björn Lisper, Andreas Ermedahl, Jan Gustafsson, Christer Sandberg, Stefan Bygde, Marcelo Santos
Partners:	AbsInt GmbH, Tidorum Ltd Volvo CE, CC-Systems AB, IAR Systems, Arcticus Systems
Funding:	KKS SSF (PROGRESS) MDH

Project description:

Worst-Case Execution Time (WCET) analysis finds an upper bound for the time needed to execute a program. Such WCET bounds are very important when designing and verifying real-time systems. Current industrial practice is to estimate these bounds from measurements, something often complicated and error-prone.

Static WCET analysis is an alternative method to determine the WCET of a program, relying on mathematical models of the software and hardware involved. To decide the WCET both the characteristics of the program code and the computer hardware must be considered. The WCET project focuses on the first problem, researching in methods to derive information on the possible execution paths of the analyzed program, e.g. iteration bounds of loops and dependencies between conditionals.

We also perform case studies on WCET analysis towards Swedish companies, using commercial state-of-the-art WCET analysis tools. The result of the case-studies is used to guide both continued research and commercial WCET tool development.

The WCET project is an active partner in the European ARTIST2 research network on timing analysis. The goal of the cluster is to combine the best components of existing European WCET analysis tools.

The WCET project was originally situated both at Uppsala University (in Uppsala, Sweden), C-Lab (in Paderborn, Germany) and MDH (in Västerås, Sweden) but has since summer 2003 moved fully to MDH.

Results and achievements for 2006:

A prototype tool called SWEET (SWedish Execution Time Tool) has been developed, in a modular fashion supporting different phases of WCET analysis. The current research focus is on flow analysis methods.

Our research group has always been present at the international WCET workshop. In 2003, Jan Gustafsson was the organizing chairman of this workshop. In 2004 and 2005, Andreas Ermedahl was a PC member of the WCET workshop, in 2006, Björn Lisper was, and in 2007 Christer Sandberg will be.

StatA – Static Timing Analysis of Component-Based Systems

Project leader:	Björn Lisper
Members:	Stefan Bygde, Marcelo Santos, Andreas Ermedahl, Jan Gustafsson, Christer Sandberg
Funding:	SSF, Progress

Project description:

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS. The objectives of this project are to develop methods for static timing analysis of component-based embedded systems with real-time demands. Methods may be developed for both hard and soft real-time systems, and they should be able to deal with highly reusable, parameterized components. The methods will be adapted to the generic component model developed in PG-CBDModel, but they will not necessarily be restricted to this model.

High Level Languages for Hard and Embedded Real-Time Systems

Project leader:	Björn Lisper
Members:	Jan Carlson
Funding:	Internal, CUGS

Project Description:

The long-term goal of this project is to develop adequate languages for the specification, modelling, and programming of hard real-time systems, in particular in embedded systems. This research is motivated by the need for efficient and safe design of these systems, and we believe that currently used languages, like C, do not provide adequate support for all aspects of the design process.

Real-time and embedded systems are often reactive in nature, meaning that execution is driven by external events to which the system should respond with appropriate actions. Such events can be simple, but many systems are supposed to react to sophisticated situations involving a number of simple events occurring in accordance with some pattern. A systematic approach to handle this type of systems is to separate the mechanism of event pattern detection from the definition of appropriate responses. The event detection mechanism can for example be based on event algebra, i.e., expressions that correspond to the event patterns of interest are built from simple events and operators from the algebra.

We have developed novel event algebra with two important characteristics: It complies with intuitive algebraic laws and the detection can be correctly performed with limited resources in terms of memory and time. The future work includes formulating schedulability analyses and scheduling algorithms for tasks triggered by event algebra expressions, in particular for the case when these tasks exist together with time triggered tasks with hard deadlines.

Results and achievements in 2006:

A new detection algorithm was developed by which any event expression can be detected with bounded memory. A journal paper describing the algebra semantics, the new detection algorithm and a proof that the two are consistent, was submitted to "Science of Computer Programming".

Future plans:

A PhD (Jan Carlson) is planned May. 2007.

Parallel Execution of PLEX Programs

Project leader:	Björn Lisper
Members:	Jan Gustafsson
	Johan Lindhult
	Janet Wennersten
	(Ericsson AB),
	Ole Köller (Ericsson AB)
Funding:	Ericsson
	Vinnova (ASTEC)

Project Description:

In any system with shared data and concurrent activities, there is a need to guarantee exclusive access to the shared data. If parallel processing, and synchronization, wasn't an issue at the time of designing the system, non-preemptive execution on single-processor architecture, automatically guarantees exclusive access to the shared data. While legacy software systems, developed and maintained over many years, contains large amounts of sequential software (executed on single-processor architectures), there is a development towards different forms of parallel hardware. The problem arises when the single processor

architecture is to be replaced by a multi-processor ditto; the independent parts may now access and update the same data concurrently. A naive solution would be to re-implement the system, but since a legacy software system may contain several million lines of code, this solution is infeasible. A more reasonable solution would be criteria that ensure correct parallel execution. To ensure the correctness of such criteria, the formal semantics of the language in question need to be considered.

Results and achievements in 2006:

So far, the project has specified the formal semantics for PLEX; both for the current sequential implementation, as well as for a restricted parallel implementation that executes on shared-memory architecture. We have also performed a manual inspection of some existing PLEX code in order to investigate the actual frequency of some possible problems that may occur when the software is executed in parallel.

Future plans:

- A licentiate thesis based on the results achieved so far is planned for the spring of 2007.
- Design and implementation of a program analysis that safely decides when a program must yield the same result regardless of the implementation (sequential or parallel).
- The project is expected to run until the autumn of 2008, resulting in a PhD degree.

X-product
interactive artistic expression for an extensive material

Project leader:	Rikard Lindell
Members:	Rikard Lindell, Agneta Pauli
Funding:	MDH - NT faculty board branch of art

Project description:

The X-produkt project explores the process of artistic expression for an interactive installation. We have based the work on Agneta Pauli's artwork, and Rikard Lindell's music, and interactive animations. Agneta made thousands (3500) drawing all with the motive theme of an X in a period of 1992 to 1997. These drawings are rich expressive but folds under a manner; black ink on white paper. The idea is that users - here exhibition visitors - explore a database of animations and music which content tagged with affective qualities. The visitors communicate with the work through gestures; the gestures are then recognized by the system into different affections. We use the Senseboard™ device - a bluetooth based device with detects hand motions - as input device. Our aim with this project is for the visitors to be more immerging into work, more active as watcher, and listener. We also wanted to explore the crossing of art and affective computing

Results and achievements in 2006:

Creation of music content.
Assessment, Sorting and Collecting of 2000 drawings.
Development of the interactive artwork; gesture recognitions system, interacive music system, interacive animation system.
Paper: Assessment, Sorting and Collecting of a Thousand Drawings - som accepterades till The First International Symposium on Culture, Creativity and Interaction Design

(CCID2006) of The 20th BCS HCI Group conference in co-operation with ACM. London, UK. 11-15 September 2006

Global Constraints in Constraint Programming and Local Search

Project leader:	Björn Lisper
Members:	Per Kreuger (SICS/Kista) Björn Lisper (MDH) Marcus Bohlin (SICS/Västerås)
Partners:	SICS
Funding:	SICS, internal

Project Description:

The aim of this project is to increase the competence in constraint programming (CP) at MDH and in Västerås, in order to make this powerful optimization technique more easily available for the local industry. This will be achieved in three ways: by research education of the SICS staff in Västerås, by conducting research within CP, and by running industrial projects where CP is applied to real problems. The research conducted will focus on: local search methods and how they can be integrated within the CP framework, static and dynamic global constraints.

3D Graphics Simulation

Project leader:	Björn Lisper
Members:	Thomas Larsson Tomas Akenine-Möller (Lund)
Partners:	Lund University
Funding:	Internal

Project description:

In this project, the focus is on developing new algorithms and optimization techniques for computer graphics and virtual reality. Currently, we are addressing the problem of doing fast and accurate collision detection between detailed geometric bodies that are commonly used in different kinds of graphics simulations. In particular, we address the problem of dealing with collision among deforming bodies that change their overall shape in every simulation time step.

Results and achievements in 2006:
A novel generalized collision detection algorithm for highly dynamic objects was published in the journal Computers & Graphics.

New faster algorithms for faster intersection tests between fundamental geometric primitives have been developed. The achieved results will be published in two reserach papers. Recently, a paper was published in the journal Computers and Graphics, and another paper on faster intersection tests has been accepted for publication in the journal of graphics tools.

Future plans:

We plan to generalise our collision detection methods to a broader set of body types. We also plan to work on the collision detection problem arising in specific real-time simulation

applications. In virtual surgery, for example, the instruments need to interact with soft tissues and organs in a realistic way.

PICO - Philosophy of Information and Computing

Project leader:	Gordana Dodig-Crnkovic
Members:	Gordana Dodig-Crnkovic
	Björn Lisper
	Jan Gustafsson
	Lars-Göran Johansson (UU)
Funding:	Internal
	KK-foundation

Project description:

Philosophy of Information and Computing brings together scientific, philosophical and ethic perspectives on information and computation subject matters. The field is under development internationally within CAP (Computing and Philosophy) project. By bringing together contemporary ideas, PICO provides an introduction to a fundamental area of research that is rapidly growing. Year 2005 we made a contribution to the research area by organising E-CAP 2005, European Computing and Philosophy Conference. In the year 2006 the proceedings of the conference were published in tripleC journal, http://triplec.uti.at/articles.php.
The book, Gordana Dodig-Crnkovic: Investigations into Information Semantics and Ethics of Computing, PhD Thesis, Mälardalen University Press, September 2006, was published.
The book Dodig-Crnkovic G. and Stuart S., eds. Computation, Information, Cognition – The Nexus and The Liminal; Cambridge Scholars Publishing, Cambridge is forthcoming in 2007.

Results and achievements in 2006:

2006 The proceedings of the E-CAP conference published in tripleC journal, http://triplec.uti.at/articles.php.
Gordana Dodig-Crnkovic, Investigations into Information Semantics and Ethics of Computing, PhD Thesis, Mälardalen University Press, September 2006..

Future plans:

A Book: 'Computation, Information, Cognition – The Nexus and The Liminal'.
G Dodig-Crnkovic, Susan Stuart eds.,
to be published by Cambridge Scholars Press 2007.

Theses

One PhD thesis was presented by the Programming Languages group in 2006:

Gordana Dodig-Crnkovic. Investigations into Information Semantics and Ethics of Computing,

This thesis consists of two parts which are the result of studies in two areas of Philosophy of Computing (PC) and Philosophy of Information (PI) regarding the production of meaning (semantics) and the value system with applications (ethics).

The first part develops a unified dual-aspect theory of information and computation, in which information is characterized as structure, and computation is the information dynamics. This enables naturalization of epistemology, based on interactive information representation and

communication. In the study of systems modeling, meaning, truth and agency are discussed within the framework of the PI/PC unification.

The second part of the thesis addresses the necessity of ethical judgment in rational agency illustrated by the problem of information privacy and surveillance in the networked society. The value grounds and socio-technological solutions for securing trustworthiness of computing are analyzed. Privacy issues clearly show the need for computing professionals to contribute to understanding of the technological mechanisms of Information and Communication Technology.

The main original contribution of this thesis is the unified dual-aspect theory of computation/information. Semantics of information is seen as a part of the data-information-knowledge structuring, in which complex structures are self-organized by the computational processing of information. Within the unified model, complexity is a result of computational processes on informational structures. The thesis argues for the necessity of computing beyond the Turing-Church limit, motivated by natural computation, and wider by pancomputationalism and paninformationalism, seen as two complementary views of the same physical reality. Moreover, it follows that pancomputationalism does not depend on the assumption that the physical world on some basic level is digital. Contrary to many believes it is entirely compatible with dual (analogue/digital) quantum-mechanical computing.

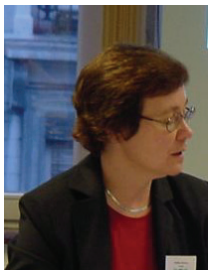
Staff

Björn Lisper is professor in Computer Engineering at Mälardalen University since 1999, where he is responsible for the Computer Science research. He received his MSc (Engineering Physics) 1980, and Doctor of Technology (Computer Science) 1987, both from KTH, Sweden, where he also was appointed "docent" in Computer Systems (1991). He is a member of the board of the Vinnova-supported CNS competence centre at SICS, and of the steering group of the National Research School in Computer Science (CUGS). His current research interests are in programming language issues, embedded and real-time systems: program analysis and language design. He is also still interested in functional programming, and parallel computing.

Jan Gustafsson is Senior Lecturer in Computer Science at Mälardalen University since 1985. He s one of the founders of the departement, its educational programmes and its research. He has been the head of the department for a number of years. He worked at ABB Västerås, Sweden 1975 - 1985 with development of real-time industrial control systems. He received a B.Sc. in Mathematics, Physics, Astronomy and Computer Science at Uppsala University, 1974, a Licentiate degree in Machine Elements (Computer Controlled Mechanics) at KTH, Stockholm, Sweden, 1994, and in 2000 he graduated at Uppsala University. Since 2005 he is Docent at Mälardalen University. His current research concerns flow analysis of real-time programs in WCET (Worst-Case Execution Time) analysis.

Gordana Dodig-Crnkovic is a Senior Lecturer in Computer Science. She holds PhD degrees in Physics and in Computer Science. Her field of research is theory of science, computing and philosophy, theory of computation and ethics. She is also teaching those subjects at undergraduate and graduate level.

Dr. Andreas Ermedahl is a senior researcher at CSL. His main research focus is on Worst-Case Execution Time (WCET) analysis, and he is internationally well known for his work within this area. Other research interests include power consumption analysis, wait- and lock-free algorithms and real-time communication networks. Dr. Ermedahl is also the coordinator of the industrial graduate school SAVE-IT. Dr. Ermedahl received his Ph.D. degree in Computer Systems from Uppsala University, Sweden in 2003. He is currently working in the WCET project at CSL.



Christina Björkman is Lecturer and she holds a PhD on Gender issues in Computer Science Education from Blekinge Institute of Technology (2005). She received a MSc degree in Engineering Physics from the Royal Institute of Technology in 1983. She has been lecturer in Computer Systems at Uppsala university since 1985, where she in 2001 was involved in developing a new engineering programme. Christina Björkman's research concerns gender issues within computer science. She has been project leader for several projects in the area and is currently a member of the network "Gender, Learning and Information Technology", funded by the Knowledge Foundation's network LearnIT, from which she currently has funding for a research project on gender and knowledge in computer science.

Christer Sandberg is a Lecturer and PhD student at CSL. He received a Bachelor of Science at Mälardalen University 1994. He teaches mainly Programming, Algorithms and Data Structures and Compiler Theory. He is doing research within the WCET project.

Thomas Larsson is a Lecturer and Ph.D. student at the Department of Computer Science and Electronics at Mälardalen University. Currently, his research interests are real-time computer graphics algorithms, spatial data structures, intersection test methods, real-time rendering, and virtual reality. He recieved a bachelor and master degree in 1996 and 1999, respectively, in computer engineering. His Licentiate of Philosophy thesis in computer science was completed in 2003. Currently, he works as a lecturer and he also continues to work on his Ph. D. thesis.

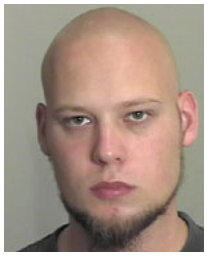
Rikard Lindell is a Lecturer and Ph.D. student at the Department of Computer Engineering at Mälardalen University. Rikard's main interests are within interaction design and exploring and developing new and alternative interaction techniques for digital artefacts. Rikard is especially keen on finding alternatives to the current paradigm of windows, icon, menus and pointing devices (WIMP). He holds a licentiate degree in computer science since 2004.

Jan Carlson is a Ph.D. student. He received his M.Sc. degree in Computer Science from Linköping University, Sweden (2000), and his licentiate in 2004. His research interests include programming language design, functional and logic programming languages, and formal methods.

Marcus Bohlin is a Ph.D. student employed by SICS. He received his licentiate degree in 2004. His area of research is local search methods in constraint programming.

Johan Lindhult (former Erikson) is a PhD student at CSL. He received his M.Sc. degree in Computer Science from Mälardalen University in Västerås, Sweden (2002). His research is mainly focused at analysis of programming languages. Current activities deal with parallelization of software for Ericssons AXE-system.

Marcelo Santos is a Ph.D. student at CSL since October 2006. He received his B.Sc. in Computer Science at Universidade Federal de Uberlandia (Brazil) and a M.Sc at Universidade Federal do Rio Grande do Sul (Brazil) and at Chalmers University of Technology (Sweden). Before starting the Ph.D. he was teaching at the Computer Science Department at the Universidade Estadual de Santa Cruz (Ilheus-Brazil).



Stefan Bygde is a PhD at CSL since August 2006. He received his M.sc degree in Computer Science at Mälardalen University, Västerås, Sweden (2006). His research interests include WCET analysis and program analysis in general.

National and International research co-operation

The Programming Languages group co-operates with the following national academic partners:

- Uppsala University on Philosophy of Computing and Information,
- Lund University on Computer Graphics,
- SICS on constraint programming, and human-machine interaction, and

- Linköping University within the National Graduate School in Computer Science (CUGS).

The following international co-operation has taken place during 2005:

- The WCET group has participated in the Compilers and Timing Analysis cluster within the ARTIST2 EU Network of Excellence.

Services to the Community

The following is a list of the most important services to the scientific community by members of the research group in 2006:

Björn Lisper:

- was on the program committees of the International Conference on Engineering of Reconfigurable Systems and Algorithms 2006, and of the 6th International Workshop on Worst Case Execution Time Analysis,
- was on the grading committees of Vilhelm Dahllöf, Daniel Karlsson, and Peter Aronsson, IDA/LiU, and Phuong Hoai Ha, Chalmers.
- became a member of the newly formed IFIP WG 10.5 on Embedded Systems,
- was a member of the steering group of CUGS (National Graduate School in Computer Science) seated in Linköping, and
- reviewed a number of papers for conferences and journals.

Jan Gustafsson:

- was member of the PC committees of ISORC 2006 (The IEEE International Symposium on Object-oriented Real-time distributed Computing), and SRDS-25 (The 25th IEEE Symposium on Reliable Distributed Systems),
- was member of the Steering Group for the International Workshop on Worst Case Execution Time Analysis, and
- arranged the "WCET Tool Challenge" 2006, an international evaluation of WCET tools.

Andreas Ermedahl:

- was on the program committees of the LCTES 2006 (Languages, Compilers, and Tools for Embedded Systems) and the Embedded World 2006 conferences, and
- Served as coordinator for the SAVE-IT research school.

Gordana Dodig-Crnkovic:

- Was on the Steering committee of the European Computing and Philosophy Conference,
- Was opponent for Carina Andersons Lic at IDP, MDH,
- Was session chair at the E-CAP and i-C&P Conference on Computers & Philosophy,
- Reviewed a proposed book, as well as a number of conference papers, and
- Took part in the initiative of constituting an international institute for Information Science

Interactions with society

Björn Lisper is a member to the scientific advisory board of the journal Teknik & Vetenskap.

Andreas Ermedahl and **Jan Gustafsson** (with Jakob Engblom, Virtutech) wrote and published two popular science papers on their research: Tidsanalys av programvara - Del 1, grunderna för WCET analys. *Elektronik i Norden* 12/2006, and Del 2, tillämpningar och WCET-verktyg, *Elektronik i Norden* 13/2006.

Gordana Dodig-Crnkovic has given an interview in Sörmlands radio and Eskilstuna-Kuriren about her research, and has given a lecture about her research, and the philosophy of computing, for Västerås kulturråd.

2.7 Real-Time Systems Design

Focus

The mission of the RTS Design group is to provide engineers with scientific methods and tools for designing safety-critical real-time systems. In analogue with the scientifically well founded methods and tools for mechanical construction. RTS Design develops methods for constructing safety-critical real-time systems, ultimately capable of guaranteeing their multitude of requirements to be fulfilled.

RTS Design is currently focusing on:

- Design and specification methods for real-time systems. Especially models and high level analysis of embedded real-time systems with respect to both functional (like temporal, reliability and safety) and non-functional attributes (like maintainability and testability).
- Resource handling and scheduling, with an emphasis on assessing timing requirements.
- Predictable run-time systems, i.e., run-time systems amenable to analysis of functional and temporal correctness.
- Verification, including formal verification of system models as well as testing methodologies, both considering functional and timing aspects.
- Communication predictability, including analysis and methodologies for predictable communication services.

The majority of RTS Design's activities are performed in close co-operation with industry and/or with an intention to actually produce results that in the short or medium term are beneficial for industry.

Members and Partners

Group leaders:	Hans Hansson/Mikael Nolin
Members:	Moris Behnam
	Markus Bohlin
	Sigrid Eldh
	Paul Pettersson
	Andreas Hjertström
	Joel Huselius
	Kaj Häninen
	Thomas Nolte
	Jukka Mäki-Turja
	Dag Nyström
	Insik Shin
Partners:	CC-Systems (Jörgen Hansson)
	Arcticus Systems (Kurt-Lennart Lundbäck)
	Volvo Technology (Henrik Lönn)
	Volvo Cars (Jakob Axelsson)
	Volvo Construction Equipment (Nils-Erik Bånkestad)
	LiU/RTSLAB (Simin Nadjm-Tehrani)
	KTH/DAMEK (Martin Törngren)
	UU/UppAal (Paul Pettersson/Wang Yi)

U. of Catania (Lucia Lo Bello)
U. o Cantabria (M. Gonzales Harbour)
Massachutets Institute of Technology (K. Lundqvist)
U. o the Balearic Islands (J. Proenza)

Details of our projects are given below:

Research projects

OSC – Optimization, Synthesis and Configuration

Project leader:	Mikael Nolin, MDH
Members:	Jukka Mäki-Turja, MDH
	Markus Bohlin, SICS & MDH
Partners:	MultEx, PROGRESS, SAVE
Funding:	SAVE-IT, SSF (PROGRESS)

Project description:

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

The objective of the PG-Pla-OSC is to derive techniques for generation of resource efficient and and predictable run-time structures for the execution of components and assemblies. The techniques will use optimization techniques to find suitable configurations (e.g. priority assignments for tasks and allocation of components to tasks). The techniques will use code synthesis to generate efficient run-time structures according to the configurations selected.

In order to perform optimization, synthesis and configuration, analysis of properties of possible configurations is needed. While striving to reuse existing analysis techniques, some novel techniques will be developed when existing analysis is lacking (or existing analysis is not suitable for Progress-systems).

Results and achievements in 2006:

This project was started within PROGRESS during 2006. The most significant result was a paper in cooperation with MultEx-project on analysis of stack-memory usage, presented at RTSS in December.

MultEx

Project leader:	Mikael Nolin, MDH
Members:	Jukka Mäki-Turja, MDH
	Kaj Hänninen, MDH & Arcticus Systems
Partners:	Arcticus Systems,
	Volvo Construction Equipment,
	CC Systems
Funding:	SAVE-IT/KKS, KKS

Project description:

In this project we will study how the software development process for embedded control systems can be made more efficient. More efficient, both with respect to development time, achieved software quality and hardware utilisation. Specifically, we will use novel theories that allow predictable integration of multiple execution paradigms within a computer system. We will study the impact this new ability has on how software-component models are

designed and how the development process can be modified to allow efficient implementation of execution paradigm independent components. We will also investigate how such a modified development process can be supported by software engineering tools.

Results and achievements in 2006:

In september 2006, Kaj Hänninen presented his licentiate thesis "Introducing a Memory Efficient Execution Model in a Tool-Suite for Real-Time Systems". The thesis was reviewed by Dr. Ola Redell from Enea Systems.

Jukka Mäki-Turja spendt 6 weeks at Univ. d. Cantabria, visiting the group headed by Prof. M. Gonzalez-Harbour. The work will result in a series of publications, currently being finalized.

Mikael Nolin spendt 3 weeks at Massachutets Institute of Technology (MA, USA), visiting the Dr. Kristina Lundqvist's Embedded Systems Lab at the dept. of Aero and Astronautics.

In cooperation with students from PROGRESS, Markus Bohlin and Jan Carlsson, we presented a novel method to determine stack-memory utilization for the kind of systems studied in MultEx. The method was published in Rio de Janeiro at the Real-Time Systems Symposium (RTSS).

Subsystem Integration (SSI)

Project leader:	Thomas Nolte, MDH
Members:	Moris Behnam, MDH
	Insik Shin, MDH
	Mikael Nolin, MDH
Partners:	PROGRESS
	SAVE project
Funding:	SSF (PROGRESS), MDH

Project description:

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS. The main objectives of this project are providing a predictable resource efficient subsystem integration framework for PROGRESS. Subsystems are characterized by real-time, legacy and dependability features and requirements. This project currently focuses on the following problems:

- predicting the timing behavior of subsystems when integrated forming hierarchical real-time scheduling
- providing efficient resource sharing schemes for subsystem integration

Issues dealt with include:

- real-time scheduling
- real-time schedulability analysis
- resource sharing

Results and achievements in 2006:

The project has successfully started, recruiting one Ph.D. student (Moris Behnam) and one postdoc (Insik Shin). In the latter part of 2006 one initial paper has been published dealing with hierarchical scheduling of subsystems with real-time requirements, in the presence of shared resources:

Real-Time Subsystem Integration in the Presence of Shared Resources, Moris Behnam, Insik Shin, Thomas Nolte, Mikael Nolin, Proceedings of the Work-In-Progress (WIP) session of the 27th IEEE Real-Time Systems Symposium (RTSS'06), Rio de Janeiro, Brazil, December, 2006.

INCENSE

Project leader:	Dag Nyström, MDH
Members:	Mikael Nolin, MDH
	Andreas Hjertström, MDH
Funding:	SSF (PROGRESS), MDH

Project description:

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

The current trend in real-time system is an ever growing complexity. One of the key factors that constitute this complexity is the amount of data and data flow in a system. The starting point and the belief of this project is that adopting an information centric-view, rather than using existing ad hoc approaches for information handling, when developing and maintaining these systems is a way of alleviating this complexity. The work in this project includes developing an information-centric approach to data management for development and maintenance of component-based embedded real-time systems. The aim of the project is to use a real-time database management system (RTDBMS) to manage data in the development and maintenance of real-time systems, i.e., data flow between components is modeled by a systematic database management concept. The RTDBMS will be placed in a component-based development setting where data management constitutes one view, the information-centric view, of the system. This allows data management to become naturally introduced into the design and architecture of control-systems.

Results and achievements in 2006:

Completion of a master´s thesis by two master´s students. The thesis acts as a background and starting-point of the project.

SAVE demonstrator

Project leader:	Thomas Nolte, MDH
	Dag Nyström, MDH
Members:	Ivica Crnkovic, MDH
	Hans Hansson, MDH
	Moris Behnam, MDH
	Andreas Hjertström, MDH
	Severine Sentilles, MDH
	Mikael Åkerholm, MDH
	Anders Pettersson, MDH
Partners:	LiU/RTSLAB (Simin Nadjim-Tehrani)
	KTH/DAMEK (Martin Törngren)
	UU/UppAal (Paul Pettersson/Wang Yi)
Funding:	SSF (SAVE, PROGRESS), MDH

Project description:

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

The objective of the SAVE demonstrator project is to integrate the results of the SAVE/SAVE++ project. In the SAVE/SAVE++ project, research is performed at 4 Swedish universities, and the demonstrator aims at integrating these research results. The SAVE/SAVE++ project aims at providing methods and techniques for component-based software engineering of safety-critical vehicular systems.

Results and achievements in 2006:

- Initial work on merging the previous results from SAVE and constructing a common view on the SAVE IDE
- Initial contacts with the industrial partners regarding demonstrators, hardware and application has been taken.

CVer - Component Verification

Project leader:	Paul Pettersson
Members:	Cristina Seceleanu
	Aneta Vulgarakis
	John Håkansson, UU
Funding:	SSF (SAVE, PROGRESS), MDH

Project description:

This is one of the projects with the SSF (and MDH) supported research centre PROGRESS.

The objective of this project is to develop techniques for the analysis of dynamic behaviors of real-time embedded systems designs described in the Progress component model. The ultimate goal is to develop a tool that supports analysis by model-checking of the Progress component model. Three activates needed to reach this goal are identified: a formal semantics of the Progress component model; an analysis techniques by model-checking tailored for component models with timing; and a tool for model-checking functional and timing properties of the component model. In addition, the developed technique and tool will be applied in an industrial evaluation.

HEAVE

Project leader:	Mikael Nolin, MDH
Members:	Anders Möller, MDH, CC-Systems,
	Joakim Fröberg, MDH, Volvo Construction Equipment
Partners:	CC-Systems
	Volvo Construction Equipment
	SAVE project
Funding:	KK-Foundation (KKS)
	CC-Systems
	Volvo Construction Equipment

Project description:

The project Component Technology for Heavy Vehicles (HEAVE) is a three year project where MDH will cooperate with Volvo Construction Equipment (Eskilstuna) and CC-Systems (Uppsala/Västerås) in order to enable the use of modern Component Based Software Engineering (CBSE) techniques within the industrial segment of heavy vehicles. The project

leader, Mikael Nolin, will together with industrial PhD-students from Volvo and CC-Systems investigate the current practices and needs with respect to CBSE within the industrial segment. The next step will be to identify a suitable existing CBSE technique and if necessary propose modifications or additions to that technique. A demonstrator project using the (possibly modified) CBSE technique will be used to asses the usefulness of the technique. In HEAVE we will not only consider technical merits of any proposed CBSE technique. We will also consider how well the technique can be integrated into the development process and the possibility to gradually migrate into the proposed technique.

Results and achievements in 2006:

This project was successfully completed in January 2006. The project ended with submission of a journal article. The article is currently being updated according to reviews received.

Theses

In 2006 RTS Design staff presented the following theses:

Thomas Nolte *Share-Driven Scheduling of Embedded Networks*, , Ph D Thesis, Mälardalen University Press, May, 2006

Kaj Hänninen *Introducing a Memory Efficient Execution Model in a Tool-Suite for Real-Time Systems*, , Licentiate Thesis, MRTC, September, 2006

Below, these theses are presented in more detail.

PhD Thesis

Thomas Nolte, Share-Driven Scheduling of Embedded Networks

Date: May 5

Opponent: Luís Almeida, University of Aveiro, Portugal

Committee: Cecilia Ekelin, Anton Cervin, Neeraj Suri

Main Supervisor: Hans Hansson

Assistant Supervisors: Christer Norström, Sasikumar Punnekkat

Abstract:

Many products are built from more or less independently developed subsystems. For instance, a car consists of subsystems for transmission, braking, suspension, etc. These subsystems are frequently controlled by an embedded computer system. In the automotive industry, as well as in other application domains, there is currently a trend from an approach where subsystems have dedicated computer hardware and other resources (a federated approach) to an approach where subsystems share hardware and other resources (an integrated approach). This is motivated by a strong pressure to reduce product cost, at the same time as an increasing number of subsystems are being introduced.

When integrating subsystems, it is desirable that guarantees valid before integration are also valid after integration, since this would eliminate the need for costly reverifications. The computer network is a resource that is typically shared among all subsystems. Hence, a central issue when integrating subsystems is to provide an efficient scheduling of message transmissions on the network. There are essentially three families of schedulers that can be used: priority-driven schedulers that assign priorities to messages, time-driven schedulers that

assign specific time-slots for transmission of specific messages, and share-driven schedulers that assign shares of the available network capacity to groups of messages.

This thesis presents a framework for share-driven scheduling, to be implemented and used in embedded networks, with the aim to facilitate subsystem integration by reducing the risk of interference between subsystems. The framework is applied in the automotive domain.

The initial parts of the thesis give an overview of systems, subsystems and network technologies found and used in the automotive domain. Then, the share-driven scheduling framework is presented, analytically investigated and proven, as well as evaluated in a simulation study. Finally it is shown how the framework is to be configured and used in the context of subsystem integration. The results show that the framework allows for flexible and efficient scheduling of messages with real-time constraints, facilitating integration of subsystems from a network point of view.

Licentiate Thesis

Kaj Hänninen, Introducing a Memory Efficient Execution Model in a Tool-Suite for Real-Time Systems

Date: September 22

Opponent: Dr. Ola Redell, Enea Systems.

Examiner: Prof. Hans Hansson, MRTC

Main Supervisor: Mikael Nolin

Assistant supervisor: Jukka Mäki-Turja,

Abstract:

This thesis shows how development of embedded real-time systems can be made more efficient by introduction of a memory efficient execution model in a commercial development suite. To identify the need of additional support for execution models in development tools, the thesis investigate by a series of interviews, the common requirements in development of industrial embedded real-time systems. The results indicate that there exists functionality in industrial systems that could be more efficiently implemented in other execution models than the currently supported ones. The thesis then presents how use of multiple execution models (hybrid scheduling) can reduce processor utilization in real-world applications. Furthermore, the thesis presents an integration of a memory efficient execution model in an industrially used real-time operating system. In addition, the thesis describes an efficient technique to analyze memory consumptions of functionality executing under the introduced execution model. Embedded computers play an important role in peoples everyday life. Nowadays, we can find computers in product such as microwave ovens, washing machines, DVD players, cellular phones and cars, to mention a few examples. For example, a modern car may have more than 70 embedded control units handling functionality such as airbags, anti-lock braking, traction control etc. In addition, there is a clear trend indicating that the amount of computer controlled functionality in products will continue to increase. Many of today's embedded systems are resource constrained and the software for them is developed for a few execution models. Even though researchers have proposed a large number of different execution models for embedded real-time systems, in practice however, only a few of the proposed execution models are supported in industrial development tools. This implies that

developers often force fit functionality to be executed under these models, resulting in poor resource utilization and increasing complexity in software.

Staff

Hans Hansson is professor in Computer Engineering, specialising in real-time systems, at Mälardalen University since 1997. He is director of research at IDE, heads the MRTC and the PROGRESS strategic research centre, co-ordinates the national research initiative SAVE and the industrial graduate school SAVE-IT. He received an MSc (Engineering Physics), a Licentiate degree (Computer Science), a BA (Business Administration), and a Doctor of Technology degree (Computer Science) from Uppsala University, Sweden, in 1981, 1984, 1984 and 1992, respectively. He was appointed "docent" in Computer Systems at Uppsala University 1998. Hans was programme director for the national real-time systems research initiative ARTES 1998-2004, and was visiting professor at Uppsala University 1999-2004 and at University of the Balearic Islands in 2005. Before joining MDH, Hans was department chairman at the Department of Computer Systems, Uppsala University, and researcher and scientific advisor at the Swedish Institute of Computer Science in Stockholm, Sweden. His current research interests include real-time system design, scheduling theory, distributed real-time systems, and real-time communications networks. He is co-founder of ZealCore Embedded Solutions AB.

Mikael Nolin is a professor at SDL. He is responsible for the projects HEAVE and MultEx, as well as a cluster leader for the strategic centre PROGRESS. Mikael joined Mälardalen University in February 2002 after having worked at Melody Interactive Solutions with development of software for embedded information servers. Mikael received his PhD and MSc from Uppsala University in 2000 and 1995 respectively. His research is mainly in the areas of software architecture, component based software engineering, and tools for software synthesis and configuration. He is focusing mainly on software for the vehicular domain. Mikael is sharing his time between research at MRTC and industrial work as a software expert at CC Systems.

Paul Pettersson has joined as a professor in real-time systems at the Department of Computer Science and Electronics in October 2006. He received from Uppsala University a M.Sc. in Computer Science in 1993 and a Ph.D. in Computer Systems in 1999 for his thesis on modeling andanalys is of real-time systems. After a Post Doc period as researcher at the center of Basic Research in Computer Science at Aalborg University in

Denmark, he worked as a Senior Lecturer at the Department of Information Technology at Uppsala University from 2000. He was appointed Associated Professor ("Docent") in Computer Science at Uppsala University in 2006. Paul has worked as director of studies and program director of the national network for real-time research and graduate education ARTES since 2003 and 2005, respectively. He has also been director of studies at the industrial graduate school SAVE-IT since 2004. Before joining MDH, Paul was leader of the Testing of Reactive Systems group at the Department of Information Technology at Uppsala University. His current research interests include component based design, analysis, and testing of embedded and real-time systems. He is co-founder of the tools UPPAAL (for model-checking of timed systems), TIMES (for schedulability analysis of real-time systems), and Cover (for model-based testing of timed systems), and of the company UPPAAL International AB.

Thomas Nolte is the leader of the Systems Design Laboratory at Mälardalen Real-Time Research Centre (MRTC), located at the Department of Computer Science and Electronics at Mälardalen University, where he is working as a researcher in the Real-Time Systems Design group, active in the PROGRESS Centre for Predictable Embedded Software Systems and the SAVE++ project, both supported by the Swedish Foundation for Strategic Research (SSF). Thomas research interests include scheduling of real-time systems, distributed embedded real-time systems, especially communication issues, and automotive and vehicular systems.

Thomas Nolte received his B.Eng., M.Sc., Licentiate, and Ph.D. degree in computer engineering from the Department of Computer Science and Electronics at Mälardalen University, Sweden, 2001, 2002, 2003, and 2006 respectively. During first half of 2002, Thomas was a visiting researcher at the at the Department of Electrical and Computer Engineering, University of California, Irvine (UCI), USA, and during autumn 2004, as well as between February and August 2006, he was a visiting researcher at the Department of Computer Engineering and Telecommunications, University of Catania, Italy.

At Mälardalen University, Thomas has been the Ph.D. student representative (doktorandombud) of all Ph.D. students at Mälardalen University July 2003 to June 2005. Also, during the same period, he was the chairman of the Ph.D. student council (ordförande i doktorandrådet) at Mälardalen University. Moreover, he was the M.Sc./B.Sc. Thesis Coordinator at the Department of Computer Science and Electronics between October 2002 and June 2006.

Dag Nyström works part-time as a researcher at SDL. He received his Ph.D in Computer Science at Mälardalen University in 2005. His research focus on real-time databases and data management of embedded real-time systems. Dags acts as a de-facto supervisor in the INCENSE project. Furthermore, Dag works part time in his own spin-off company commercializing his research in industry.

Jukka Mäki-Turja is Senior Lecturer. He received a Bachelor of Science in Applied Computer Engineering from Mälardalen University, Sweden (1993) a Philosophiae Licentiate in Computer Science from Linköping University, Sweden (1997), and a PhD in Computer Engineering from Mälardalen University (2005). His research interests are design of real-time systems, distributed real-time systems, scheduling theory, and analysis of real-time systems.

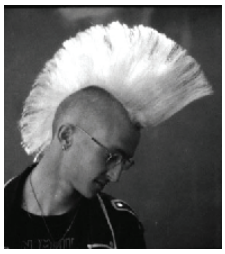
Insik Shin is a post-doc research fellow at SDL. He received a Ph.D. in Computer & Information Science from the University of Pennsylvania, USA, in 2006. He also received an M.S. from Stanford University, USA, and a B.S. from Korea University, Korea, both in Computer Science. His research interests include real-time systems, embedded systems, and wireless communications.

Kaj Hänninen is an industrial Ph.D student employed by Articus Systems. He received a MSc in computer engineering in 2003, and a licentiate degree in 2006 from Mälardalen University. His research focus on software engineering of embedded real-time control systems using multiple execution models.

Moris Behnam is Ph.D. student in Computer Engineering at MälardalenUniversity. He is participating in Progress project, where he is workingwith Real Time Subsystems Integration. He received his M.Sc. in computer and control engineering at the University of Technology in Iraq and another M.Sc. in Real Time System at Mälardalen University, Sweden. Moris research interests are real time system, real time hierarchicalscheduling, distributed real time systems and real time control systems.

Andreas Hjertström received a MSc in computer engineering in 2006 from Mälardalen University. He works as a Ph.D. student at SDL with a research focus on information management of embedded real-time control. Andreas is a member of the Incense project.

Sigrid Eldh is an industrial Ph.D. student at SDL, and working as a Verification Expert within Ericsson AB. Her interest is efficient verification and testing of software, but also process improvement and testing techniques.
She is one of the founders of SAST (Swedish Association of Software Testing), founder of ASTA (Australian Software Testing Association), chair of the Swedish Board for Software Testing, handling testing standards and certification of testers, a member of the BCS ISEB examination panel and board, and also a founding member of ISTQB, International Software Testing Qualification board.



Joel Huselius (MSc 2001, Tekn. Lic. 2003) has been a Ph.D. student at Mälardalen University since the summer of 2001, part of this time has been spent in collaboration with the Swedish Institute of Computer Science. His work has so far resulted in a collection of conference papers and a Licentiate Thesis named "Preparing for Replay" – which he successfully defended in November 2003, acting opponent was Prof. Peter Fritzson of LiU, Sweden. Current research interests include debugging of real-time systems and mechanical model generation of real-time systems.

National and International research co-operation

The following is a partial list of national and international research co-operation by RTS-Design staff in 2006:

Hans Hansson

- is co-ordinating the SAVE consortium doing research on Component Techniques for Safety-Critical Vehicular Systems. Additional partners in the consortium are RTSLAB Linköping Univ., Damek KTH, and the UppAal group Uppsala Univ.
- is co-ordinating the industrial graduate school SAVE-IT, which includes co-operation with LiU, KTH, and UU.

Mikael Nolin

- Visited Embedded Systems Laboritory at Massachusetts institute of technology (MA, USA) for 4 weeks in May.
- Arranged a research visit for Jukka Mäki-Turja to Univ. d. Cantabria for 6 weeks in May/June.

Thomas Nolte

- Visited the Department of Computer Engineering and Telecommunications, University of Catania, Italy, between the last of January to the beginning of August 2006.

RTS Design has concrete co-operations with the following national and international researchers and groups:

- Martin Törngren: DAMEK group at KTH, Stockholm, Sweden
- Paul Pettersson, Wang Yi: The UppAaal-group at Computer systems, Uppsala University, Sweden

- Simin Nadj-Tehrani: RTSLAB at IDA, Linköping University
- Guillermo Rodriguez-Navas and Julian Proenza Arenas at the Universitat de les Illes Balears
- Lucia Lo Bello at the University of Catania
- Heinz Schmidt at Monash University
- Michael Gonzalez-Harbour at University of Cantabria
- Kristina Lundqvist at Massachusetts Institute of Technology

Virtually all members of RTS Design have been active in the ARTES/SNART national research networks, including participation in the ARTES postgraduate student conference and summer school.

Services to the Scientific Community

The following is a list of the most important services to the scientific community by members of RTS Design in 2006:

Hans Hansson

- is associate editor of Kluwer's Journal of Real-Time Systems and IEEE Transaction on Industrial Informatics
- is on the reference group for the embedded systems research programme CERES at Halmstad University
- is member of the Swedish Research Council (VR) Comp Science Eval Committee
- is member of the ARTES reference group
- was on the grading committee at the PhD dissertation of Martin Karlsson, UU.
- is scientific evaluator of the EU 6th Framework Integrated Project DECOS.
- was on the international advisory committee for IES'2006 – IEEE Symposium on Industrial Embedded Systems
- was/is on the programme committee for: EMSOFT 2006; ETFA'06 Track on Industrial Communication Systems; ETFA07 Track on Real-Time and (Networked) Embedded Systems; FeT 2007 - 8th IFAC International Conference on Fieldbus Systems and their Applications; The 9th IEEE International Symposium on Object-oriented Real-time distributed Computing - ISORC'06; RTSS satellite Workshop on Models and Analysis Methods for Automotive Systems; The Real-Time and Embedded Computing Systems and Applications Conference RTCS'06; 25th IEEE Symposium on Reliable Distributed Systems 2006.
- was external evaluator for the appointment of a Senior Lecturer at KTH
- was editor and coordinator of the production of a book summarizing the achievements of the ARTES national research programme 1997-2006.
- was organisor of the Swedish Embedded Systems Meeting, March 13, 2006
- was organisor of a workshop in Västerås with the IPP-HURRAY group from Porto and MRTC, May 9, 2006
- gave an opening address at CBSE'07
- gave a lecture at Skövde University on the wiriting and evaluation of research applications
- gave an invited lecture on real-time networking at Åbo akademi /TUCS in Turku, Finland
- was mentor within a programme organised by "Gender Forum" at MDH
- was "afternoon guest" at Radio Västmanland

- was judge in an international "open-source for embedded systems software"-competition

Mikael Nolin

- served at the programme committee of Real-time and Embedded Computing Systems and Applications Conference (RTCSA), August 2006.
- acted as reviewer for (e.g.) The Computer Journal (British Computer Society), Journal of Systems and Software (Elsevier).

Thomas Nolte

- served at the programme committee of the "work-in-progress" session at the 12th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS'06).
- served at the programme committee of of the "real-time and (networked) embedded systems" track at the 11th IEEE International Conference on Emerging Technologies and Factory Automation (EFTA'06).
- served as session chair of T02S2 "wireless networks II" and T03S4 "application systems" at the 11th IEEE International Conference on Emerging Technologies and Factory Automation (EFTA'06).
- acted as reviewer for, e.g., RTAS'06, ECRTS'06, EMSOFT'06, RTCSA'06, ETFA'06, WFCS'06, INCOM'06, IECON'06, Real-Time Systems journal (Springer), IEEE Transactions on Computers, IEEE Transactions on Industrial Informatics.

2.8 Monitoring and Testing group

Group leader:	Henrik Thane
Members:	Anders Pettersson
	Daniel Sundmark
	Mathias Ekman
	Hans Hansson (associated)
Partners:	ABB Robotics
	Bombardier Transportation
	ENEA Real-Time AB
	Zealcore Embedded Solutions AB
	Ericsson
	University of Skövde

Description

The goals of this research group are to develop methods for decreasing the ever accelerating cost for corrective software maintenance. In the industry today the largest part of the lifecycle cost for a typical computer based product is spent on corrective maintenance, i.e., testing and debugging. According to a recent study by NIST up to 80% of the life cycle cost for software is spent on testing and debugging. The increasing complexity of software, along with a decreasing average product development time, has increased the costs of errors.

The software used in industrial automation systems, vehicular control systems, medical devices, telecommunication, as well as in military and space applications have a high degree of software complexity. This complexity is typically caused by the usage of multiple embedded computers, millions of lines of program code, several concurrently interacting programs (multi-tasking) and dependence on an external context in real-time. A known fact is that bugs often are introduced early in the design but not detected until much later in the product lifecycle, typically during system integration and early customer acceptance tests (as illustrated in Figure1, graph C and D). For embedded real-time software this fact makes the situation really difficult since most failures that are detected during integration and early deployment tests are extremely difficult to reproduce, due to a large degree of interaction between software, hardware and the environment. This makes debugging of embedded concurrent systems costly, since repetitive reproductions of the failure is necessary in order to track down the bug. What makes matters worse is the fact that the actual act of observation may change the behaviour of the system, especially if the observation is performed using some software other than the application code (causing a probe-effect).

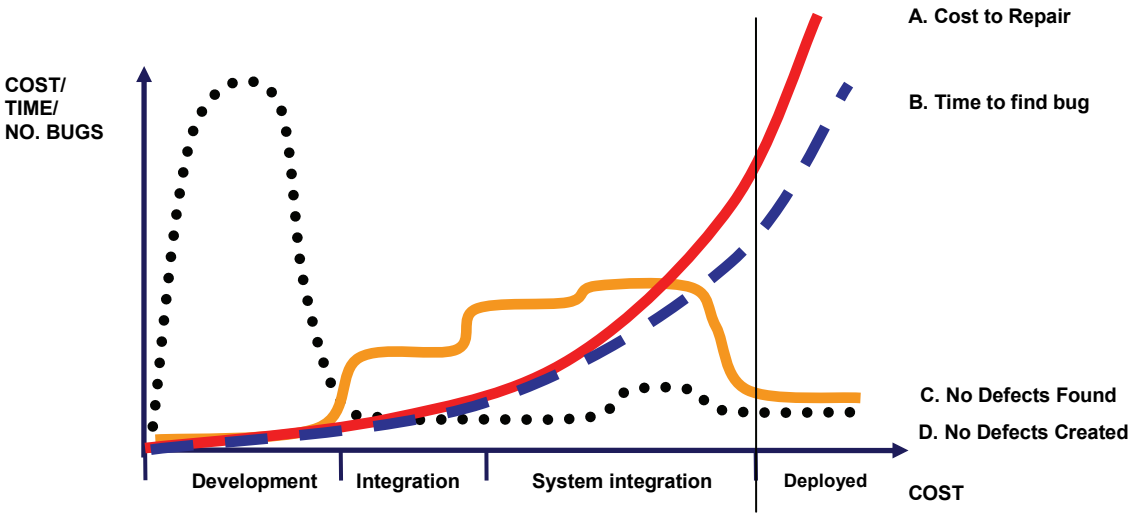


Figure 1. Graph *D*, shows the number of bugs introduced per lifecycle phase. Graph *C*, shows the number of bugs found per phase. That is, bugs are often introduced early but found late. Graph *B*, shows the relative time it takes to find one bug. More complex bugs are only found during later stages of software/hardware/environment interaction in combination with significant subsystem integration. Graph *A*, shows the cost per bug. The later a bug is found the more expensive it is, due to possible system redesign and the time spent to find it.

As Figure 1 (graph D) illustrates, the largest part of a software project is spent on corrective maintenance in the system integration, and the deployment phases; essentially 70% of the resources spent on testing and debugging is spent there. The industry is today dealing with corrective maintenance in the later phases using brute force, in terms of manpower. Consequently, the competitive edge becomes, in the long run, the cost for labour.

The availability of methods and tools dealing with testing and debugging in the later lifecycle phases are next to non existent in both academia and industry. Most existing methods deal with the development phase and the early integration phase, and usually assume that the product is designed from scratch. Most new products are however, evolved from code inherited from previous products. It is not uncommon that the legacy comprises the effort of 100s or 1000s of man-years. Consequently, current methods and tools are not appropriate, since the systems are not developed from scratch.

Results and achievements in 2006:

During 2006 a number of publications were published and presented

Research project

LESS BUGS

Project leader:	Henrik Thane
Members:	Daniel Sundmark
	Anders Pettersson
	Mathias Ekman
Partners:	Bombardier Transportation
	Zealcore Embedded Solutions AB
Funding:	KKS
	Bombardier Transportation
	Internal

Project description:

In this project we propose research on improvement of the debugging and testing processes for deployed complex industrial systems as well as for systems with large legacies of program code. In previous projects we have successfully developed techniques for improving the debugging and testing process for complex embedded systems. Some of the results have even resulted in a spin-off company. We will elaborate and expand on that work and add real industrial constraints. Constraints such as:

- System dependencies on external environments in real-time
- Large amount of legacy software
- Highly standardized development environments with standard compilers, debuggers, and operating systems
- Low tolerance to performance degradation for diagnostic purposes. That is, diagnostic systems can only add 2-5% to the system load and should consume a minimum amount of memory.

Essentially, we want to find answers to the following questions:

- How to improve the diagnostic means in complex systems based on standard components, standard development environments, and standard operating systems, where a large legacy needs to be taken into account? That is, how to introduce diagnostic systems for testing and debugging in existing or new target systems with minimal performance degradation and without having to redesign the system.
- How can we decrease the time and money spent on debugging of complex software systems using tools and methods rather than brute force (people and money) as applied in the industry today? This work would entail an extension of our previously successful work on using black-box recorders and deterministic replay methods for reproducing complex failures during debugging of real-time software. Specifically, we would evolve the results from small embedded real-time systems to larger more complex industrial software systems running on standard operating systems like Microsoft Windows NT/2000/XP/Pocket PC or Linux.
- How to make use of the deterministic replay method in order to accelerate testing in complex industrial systems in later life cycle phases? This would essentially involve the usage of deterministic replay technology for regression testing and forced testing coverage, which otherwise is extremely hard to achieve using existing technologies. This would significantly expand on our previous work on testing.

Staff

Henrik Thane is an Associate Professor/Docent at SDL. Henrik has both an industrial and academic background. He received a Ph.D. from the Royal Institute of Technology in Stockholm (2000) and has worked as a programmer and consultant in the real-time systems area for several years. In addition to research he has during the last ten years worked as an expert consultant for the industry and given numerous industrial courses on design and verification of software in safety-critical computer based systems. Henrik's research interests are design and verification of safety-critical systems, monitoring, debugging and testing of (distributed) real-time systems, as well as real-

time operating systems, and scheduling.

Henrik was until is also the CEO and President of ZealCore Embedded Solutions AB, a company focused on bringing software based debugging for field/production applications to the industry.

Mathias Ekman is an industrial Ph.D student employed by Bombardier Transportation AB. He received his MSc in Computer Science at MDH during 2003. Mathias is working at Bombardier with development of safety critical real-time systems with focus on operating systems.
His research interests are monitoring, testing and debugging of distributed safety-critical real time systems.

Anders Pettersson is a Ph.D. Student at Department of Computer Science and Electronic (IDE) at Mälardalens University (MDH). Anders started his undergraduate studies in 1996, at MDH, and received his Master of Science in Computer Engineering, in August 2000. After receiving his MSc Anders become a Ph.D. student at MDH, doing research in the Tatoo Project at Mälardalens Real-Time Research Center (MRTC). In October 2003 Anders received his Licentiate degree. His licentiate thesis focused on testing and analysis for testing of multi-tasking real-time system. Anders main contribution in the thesis is an extension of a method for analysis of real-time systems. During 2004 Anders become a member of the LessBugs project and left the Tatoo project. The research focus for Anders in the LessBugs project is regression testing of multi-tasking real-time systems and analysis of such systems. Anders is a student member of IEEE and member of Swedish Software Testing Board (SSTB).

Daniel Sundmark is a Ph.D. student. He received his MSc in Information Technology from Uppsala University in 2002. Daniel's current research interests include real-time system monitoring, testing and debugging, an area in which he in March 2004 presented his licentiate thesis. He also has about a year of industrial experience of software engineering in this field. Daniel is an elected member of the faculty board for natural sciences and engineering. Furthermore, Daniel is elected doktorandombud for Mälardalen University.

National and International research co-operation

The following is a partial list of national and international research co-operation by the MTD staff in 2006:

- Discussions with and invitations to various research groups, including Uppsala (Dr. Paul Pettersson), Philadelphia (Prof. Insup Lee), and Ghent (Dr. Michiel Ronsse).
- Henrik was invited to be the Discussin Leader/Opponent to Anders Hessels Licentiacte thesis defense, at Uppsala University.

Interactions with society

The members of MTD are interacting with society in several ways, in 2006 including

- Cooperation with Wentsrömska Gymnasiet (upper secondary school) resulting in introduction for students in upper secondary school into studies and research at a university. This by supervising and leading the students last year projects.
- Anders Pettersson is a member of Swedish Software Testing Board. This has the benefits of making a lot of contacts in Swedish software industry as well as being involved in discussions of existing problems in the software industry regarding testing, monitoring and debugging. In addition to the project's partners, the other member of SSTB broaden the project members' view of industrial problems in the field.

2.9 Adaptive Real-Time Systems group

The original Predictable and Flexible Real-Time systems research group dissolved in 2006. The group leader Gerhard Fohler moved to University of Kaiserslautern in Germany, and some other group members, Radu Dobrin and Thomas Lenvall, left MDH after successful PhD degree. Damir Isovic became new group leader of the remaining members. The name of the group has been changed to Adaptive Real-Time Systems. We are currently putting efforts in expanding the group.

Group leader:	Damir Isovic
Members:	Larisa Rizvanovic
	Pengpeng Ni
Partners:	University of Kaiserslautern, Germany
	Ardendo, Sweden
	Universitat Politecnica de Catalunya, Barcelona, Spain
	Faculty of Electrical Engineering, Bosnia
	Philips Research, the Netherlands
	TU Eindhoven, the Netherlands
	ABB Research, Sweden

Focus

Over the past years, the domain of real-time systems has evolved from mainly dealing with closed embedded systems with crucial deadlines, to support open environments where independently developed applications share common resources, usually with varying resource needs over time. In this context, it is important that the applications can adapt their execution to changing environment while keeping the system performance at a desired level, i.e., we need adaptive real-time systems that can support coexistence of activities with diverse properties and demands in the system.

We are doing research on flexible scheduling methods and resource reservation mechanisms that are suitable for adaptive real-time systems. We are aiming at developing scheduling techniques that can enforce timing constraints with a certain degree of flexibility, providing desired trade-offs between predictable performance and efficient resource usage. Our research identifies appropriate levels of predictability, extends algorithms and architectures to combine static and dynamic components, and enables designers to combine predictability and flexibility in adaptive real-time systems.

In addition to these core areas, we have been extending our real-time reseach to be applied on novel multicore platforms. Multiple processing cores enable multiple threads to run simultaneously on a single processor. Conventional real-time schedulers that are designed for single-core processors will not effectively use available processing power of multi-core architectures. This calls for novel scheduling approaches that will exploit true parallelism, which is the main focus of this activity.

Research projects

BETSY - BEing on Time Saves EnergY – EU IST Project

Project leader:	Gerhard Fohler
Members:	Damir Isovic

Partners:	IMEC, Belgium University of Cyprus, Cyprus C-LAB, Germany Universität Stuttgart, Germany Industrial System Institute, Greece Philips Research, Netherlands Technische Universiteit Eindhoven, Netherlands CSEM, Suisse
Funding:	EU, MDH

The aim of the BETSY project is to have multimedia streams on wireless hand-held devices seamlessly adapted to fluctuating network conditions and available terminal resources while reducing the energy consumption of the stream processing. This way the user can enjoy true multimedia experiences with freedom of movement in a networked home or at any hot-spot.

To achieve this, we need to be able to make trade-offs between the use and consumption of network and terminal resources, such as bandwidth use, CPU consumption, memory needed and power consumption by the terminal, while guaranteeing end-to-end timeliness - required for streaming data. The results of the BETSY project will make this possible.

(Managed from University of Kaiserslautern in 2006)

Real-time Architecture for Networked Multimedia Streaming systems

Project leaders:	Damir Isovic (coosupervise with Gerhard Fohler)
Members:	Larisa Rizvanovic
Funding:	MDH

(Mälardalen University's personal grant for a graduate student)

In a few years' time, most home entertainment devices, such as TV sets and VCRs, will be fully digital, demanding computing methods to match strict temporal demands of audio and visual perception. Consequently, the concept of ``one cable - one box'' will be replaced with pictures and videos available where and when demanded in-home as part of ambient intelligence in the living space. Similarly, video transmission and communication over mobile phone is already starting to become commonplace.

Key challenges to be addressed include specification of stream and resource characteristics, high demands on processing and timely delivery of multimedia streams, wireless communication between devices and transmission of streams, and architectures for the integration of numbers of devices from various manufactures with diverse demands and capabilities. This project is planned to work on real-time architectures for networked multimedia streaming systems.

The project in this area faces challenges on a theoretical level, as new algorithms have to be developed which can match the varying multimedia streams with the varying network and CPU resources, with experimental aspects, as many parameters and trade-offs for the algorithms have to come from experiments and cannot be "calculated", all the way to implementation work, developing and implementing new architectures for system capable of handle such networked streaming issues.

User friendly H.264 for Realtime Editing

Project leader:	Damir Isovic (coosupervised with Gerhard Fohler)
Members:	Pengpeng Ni, Ardendo
Funding:	KKS, Ardendo, MDH

(Industrial PhD with Ardendo)

The research project is aimed to support effective and quick browsing of multimedia content over network through full Video Cassette Recording (VCR) functionality.

The set of full VCR functionality includes several play-back operations, such as forward, backward, step-forward, step-backward, fast-forward, fast-backward and random access. Among them, the backward, fast-forward/backward and random access are the trick operations which can put very high demands on network bandwidth and CPU computation capacity, due to the inter prediction technique used widely in video coding standards such as MPEG4.

The scope of this project is to analyze video encoding and file format parameters in order to produce MPEG4 compliant (or with minor extensions) video streams that enables good performance and smooth VCR functionality in applications such as Video-On-Demand system and video editing program.

FLEXCON - Flexible Embedded Control Systems – SSF

Project leader:	Gerhard Fohler
Members:	Damir Isovic
Partners:	Lund Institute of Technology - Department of Computer Science DAMEK - Royal Institute of Technology DRTS Group - University of Skövde ABB Robotics ABB Automation Product
Funding:	SSF, MDH

(Successfully closed in 2006)

The key challenge of FLEXCON is how to provide flexibility and reliability in embedded control systems implemented with COTS component-based computing and communications technology. Research will be performed on design and implementation techniques that support dynamic run-time flexibility with respect to, e.g., changes in workload and resource utilization patterns. The use of control-theoretical approaches for modeling, analysis, and design of embedded systems is a promising approach to control uncertainty and to provide flexibility, which will be investigated within FLEXCON. Other focal points are quality-of-service (QoS) issues in control systems, and testing-based verification and monitoring of flexible embedded control systems. The main application area is adaptive industrial automation systems.

ARTIST – Advanced Real-time Systems, EU Network of Excellence, FP5

In actionline three: Adaptive Real-Time Systems for Quality of Service (QoS) Management.

Soft real-time approaches and technology for telecommunications, large open systems and networks Teams with expertise in real-time operating systems and middleware.

Partners: http://www.artist-embedded.org/Overview/

Theses

None in 2006.

Staff

Damir Isovic, PhD, lecturer and researcher; since feb 2007 director of undergraduate studies at IDE. He received his MSc in Computer Engineering and a Diploma of Higher Education in Natural Science Mathematics and Astronomy from MDH in 1998 and 1999, respectively. His research interests include real-time systems and scheduling theory, with a specific emphasis on combining flexibility and reliability in construction of schedules. Damir is also evolved in the development and the maintenance of the internal web pages of Department of Computer Science at MDH. In November 2004 he presented his PhD thesis "Scheduling for Media Processing in Resource Constrained Real-Time Systems".

Larisa Rizvanovic is a Ph.D. student at SDL. She received an MSc in Computer Engineering from Mälardalen University in 2001. She has started with her graduated studies in 2004, when she was awarded a personal grant from the Faculty Board (MDH), "Meriteringsprogram för Kvinnor". Before that, she was working as research engineer at SDL. Her research interests are real-time architectures for networked multimedia streaming systems.

Ni Pengpeng is an industrial Ph.D student at SDL. She received her M.Sc in Computer Technology from Mälardalen University in 2003. Then she works at Ardendo AB as software engineer. Pengpeng's research is currently focusing on providing VCR functionality to MPEG4 compliant video streaming. The other interests are video transcoding and transmission, media assets management, and multimedia content retrieve.

National and International research co-operation

The group members participated in the following international activities:

- Damir Isovic and Gerhard Fohler were partners in EU IST project BETSY – Being on time saves energy, EU IST Project, partners including Philips Research, IMEC
- Damir gave a guest lecture at University of Kaiserslautern, Germany, June 2006

The group has concrete co-operations with the following national and international research groups and companies:

- University of Kaiserslautern, Germany
- Universitat Politecnica de Catalunya, Barcelona, Spain
- Faculty of Electrical Engineering, Bosnia

- Philips Research, The Netherlands
- TU Eindhoven, The Netherlands
- ABB Research
- Ardendo, Sweden

Services to the Community

Damir Isovic

- was involved in organization of two international conferences
- acted as reviewer for IEEE Transactions on Computing Journal
- acted as reviewer for several international conferences
- acted as research contact for ARTIST Noe at MDH
- was interviewed by a newspaper
- was heavily involved in undergraduate education

2.10 Scalable Architecture for Real-time Applications (SARA) group

The group is currently focusing on

- Computer architectures,
- Innovative architectures for system-on-chip designs,
- Evaluating the effect of moving traditional software functions into hardware,
- Using and taking part in the development of latest technology and methods for hardware design,

The research is performed in close co-operation with industry and undergraduate education

Within the framework of SARA several subprojects are defined. The common denominator for these projects is the hardware accelerator for real-time operating systems (RTU)

The research has been succesfull and the activites is minimzed and perhaps it will be continuing with a new project.

Group leader:	Lennart Lindh (5%)
Group members:	Lennart Lindh
	Susanna Nordström (industrial PhD, Prevas AB)
	Stefan Sjöholm (studie break)
	Andreas Löfgren
Partners:	Georgia Institute of Technology, USA
	Altera
	KTH
	Prevas AB (Västerås, www/prevas.se/)

Area description

The project is based on a previous project sponsored by the KK-foundation, industry and the university. The project originated from a design of a hardware accelerator for real-time operating systems (the Real-Time Unit – RTU) for single and multiprocessor systems. In recent years the research group has worked with hardware design methodology and successful industrial projects. The main motivation for the research project is to develop flexible and scalable parallel platforms for complex real-time systems

The approach is defined by the following design goals:

Predictability: The software and hardware should be partly predictable. In a complex system, often 80-90 % of the tasks have soft deadlines (non-critical) and 10 % have hard deadlines (critical tasks).

Observability and controllability: The verification requires 50-75% of the total development time. Easy debugging and performance monitoring is also an important goal to reduce the development time.

Low Hardware and Software Overhead (simplifications): The non-productive software and hardware should be minimised. Simple solutions are important aspects when the design decisions are taken. The base system and the hardware platform should be as simple and small as possible.

Component oriented design: Component design is one important goal for decreasing the development time. The system should easily handle components, i.e. software or hardware

components. The design paradigm will rest on an object-based software/hardware design and a priority inheritance based communication protocol.

The SARA system architecture

The SARA system architecture includes a design paradigm and a verification environment. The system is based on an application, a base system and a hardware platform. The application is designed with an object-based approach, and the objects are divided into three classes; shared, server and base object. The base system is a collection of communication/synchronisation systems for the application, verification/analyse system and resource/time handling. The base system is implemented in a hardware platform, but there also exists corresponding software classes.

RTU - a class in the base system

To improve the performance of a real time control system, the processor clock frequency can be increased. Sometimes this is not sufficient and so a co-processor can be used instead. The co-processor (RTU) is a special purpose hardware performing real time operating system functions. Different real time operating system functions have successfully been implemented into hardware the last 10 years. The scheduling algorithm of the RTU is priority based, and supports preemptive and non-preemptive schemes. The scheduler algorithm of the RTU can also balance the load among the processors in the system.

Universities that are testing research results from the group:

- Pedro Guerra, Universidad Politecnica de Madrid, Madrid, Spanien (Started 2005)
- Atanas Desev, PhD student, University of Food Technologies, Bulgaria (Started 2005)
- Patrick Stakem, Professor, Loyola College, Baltimore, USA (Started 2005)
- Insop Song, Andrew Morton research group, University of Waterloo, Canada (startade 2006)

Workshops

The group organized one industrial/academic workshop in Stockholm FPGAworld (fpgaworld.com). The workshop provides a link between the research group and industry in Sweden. The research groups are addressing many similar problems, but with different backgrounds and approaches. The workshop intended to provide a forum where the researchers and industry can interact. Results can be better reviewing, education, corporation, writing papers etc.

Research projects

Replace software by hardware

Project members: Stefan Sjöholm (Break 2006)
Lennart Lindh (supervisor)

Project description

The research is how and when software (uP) should be replaced by hardware (FPGA).

Several case studies will be presented. The goal of the case studies is to show how an uP can be replaced by an FPGA in different IO-board applications, to not only improve performance, but also to reduce cost, time to market and other important constraints. In the case studies the FPGA design will include a behavioural controller. The behavioural controller is a design technique to be used when replacing uP with FPGA. The behavioural controller(s) is designed

in VHDL at RT-level to handle all scheduling, allocation and different forms of pipelining in the FPGA. This method has the potential to result in a very small (cost efficiency) FPGA but still with high performance.

UDP/IP/Ethernet communication in FPGAs

Project members: Andreas Löfgren
Hans Hansson (supervisor)

Research Summary

UDP/IP communication in FPGAs

The goal with the research is to investigate the Ethernet communication area and describe the benefits/disadvantages of designing a customized UDP/IP communication core in HW (FPGA).

Three case-studies with different levels of parallelism is presented: A "minimal" small core suitable for simple point-to-point communication, an "advanced" core that manages larger Ethernet frames, higher speed (1Gbit/s) and a TCP channel. The "medium" representation is a trade-off between the "minimal" and "advanced" solution.

Configurable Hardware Support for Real-Time Operating Systems

Project members: Susanna Nordström
Denny Åberg (supervisor)
Lars Asplund (supervisor)

Research Summary

The licentiate thesis task will focus on configurable hardware support for real-time operating system (RTOS) accelerators for system-on-chip (SoC) in single processor systems in field programmable gatearrays (FPGAs). Today's software based RTOS has the ability to be configured for optimal resource usage in order to decrease memory footprint, an important matter when RTOS is used in resource restricted embedded environments such as SoC and FPGA designs. When RTOS hardware support is used, not only memory footprint is motivation for configuration for optimization; the number of logic elements used in the FPGA has to be considered as well. The thesis work will present the modifications of the hardware support for increased configurability. After licentiate degree, focus will be on heterogeneous multiprocessor systems.

Results and achievements in 2006

a. Susanna Nordström, Presentation at Prevas AB, 2006.
b. Susanna Nordström, Presentation, 3rd annual FPGAworld Conference, 16 November 2006.

Staff

Lennart Lindh. Lennart Lindh is dividing his time between Mälardalens University and the industry (about 50/50). His main focuses are implementation of complex functions in hardware, Real-Time operating systems and flexible multiprocessor systems. He is today active PC member in some academic/industrial workshops/conferences, responsible for master program, education in his field etc.

Stefan Sjöholm is industrial Ph.D. student. His research is targeted at industrial hardware design methods, and their suitability for VHDL. The research is conducted in corporation with ABB Automation Systems and RFHC RealFast hardware Consulting AB, Västerås, where the case studies are performed.

Susanna Nordström is an industrial Ph D student of the Industrial Research School since April 2004. Her research interest is hardware support for real-time operating systems in order to enhance system performance and predictability. The research is conducted in corporation with RealFast Intellectual Property, Västerås. The company has a new paradigm for real-time operating system implementations.

Andreas Löfgren is industrial Ph.D. student. His research is targeted at hardware based UDP protocols. The research is conducted in corporation with RFHC RealFast hardware Consulting AB, Västerås.

National and International research co-operation

The project has a very active co-operation with Professor Vincent Mooney from the School of Electrical and Computer Engineering at Georgia Institute of Technology, Atlanta. The co-operation is aimed at real-time kernels and system-on-chip.

Universities that are testing/using research results from the group:

- Pedro Guerra, Universidad Politecnica de Madrid, Madrid, Spanien (Started 2005)
- Atanas Desev, PhD student, University of Food Technologies, Bulgaria (Started 2005)
- Patrick Stakem, Professor, Loyola College, Baltimore, USA (Started 2005)

At the national level, we have established collaboration with the Electronic Design Department at KTH.

Services to the Community

Lennart Lindh organised academic and industrial workshops in Stockholm (FPGAworld.com) together with Vincent Mooney from Georgia institute of Technology, USA and David Källberg, Uppsala.

Interactions with society

Lennart Lindh gave a number of tutorials on FPGA-circuits in embedded systems for industry and at conferences.

Several companies have been established as a result of the research in the SARA group (see http://www.realfast.se and www.prevas.se for more information).

Also, several articles have been published in the popular press about our work on real-time operating system kernels and hardware design.

3 Intelligent Sensor Systems (ISS)

Intelligent Sensor System (ISS) is a research profile at the Department of Computer Science and Electronics at Mälardalen University. Within the ISS profile the research is truly multidisciplinary and the competence areas are:

- Sensors and biomedical engineering, with research focusing on wearable sensor systems using wireless technologies (also including sensor networks) and microwave imaging.
- Predictable communication, focusing on predictable communication performance in wireless networks, and on architectures for communication in sensor networks.
- Robotics, focusing on SoC-implementation stereovision with real time performance.
- Artificial intelligence, enables "intelligent" data interpretation and decision support of sensor data for both experts and less experienced persons in areas that have been to complex for traditional methods.

The research is applied, focusing towards mobile, intelligent sensor systems leading to increased safety and effectiveness within industry, care, healthcare and sports medicine.

Developing intelligent sensor systems demands knowledge of, and contact with a number of research disciplines, including automatic control, computer science, computer and software engineering, electrical engineering and artificial intelligence.

The ISS research is covering various aspects of all these areas, and – what is more important – attempts to bridge gaps between disciplines to provide novel and effective solutions to real problems. One of the cornerstones of ISS is its good contact with industry and industrial co-operation. Almost all our projects and activities include industrial partners. To further develop our interactions with industry we are establishing more longterm bilateral co-operations with some of our main industrial partners.

Within Intelligent Sensor system, research is performed in the areas biomedical engineering, artificial intelligence, robotics, computer communication and electronic circuit design. The research is applied, focusing towards mobile, intelligent sensor systems leading to increased safety and effectivity within industry, care, healthcare and sports medicine.

The formation ISS has its origin from several years collaboration in research and thesis work between the research groups at research level, research education level as well as undergraduate education.

The research plan for ISS is based on a three-pronged vision:

- To provide state-of-the-art competence for industry and health care.
- To advance basic and applied research in relevant areas.
- Education for engineers and researchers.

The advancements of these are mutually supportive, in that insights gained in one will guide the advancement in the others.

On a more technical level the guiding vision is to

provide engineers with substantially better tools and methods for the development of intelligent sensor systems and applications.

Intelligent Sensor Systems

Intelligent Sensor Systems are systems with the ability to sense features of their environment, as physiological parameters in human beings or the conditions of an industrial machine. The sensors can communicate with their surroundings and through build-in intelligence, sensor information can be interpreted e.g. by the means of case based reasoning, providing decision support.

Intelligent sensor systems are embedded in a multitude of applications and products, in areas such as multimedia, telecommunications, robotics, process control, flexible manufacturing, avionics, vehicular systems, air-traffic control, nuclear power plants, and medical equipment and defense applications. For instance, an autonomous vehicle will have an embedded computer-based control system that has to respond in time to avoid collisions.

Developing intelligent sensor systems demands knowledge of and contacts with a number of research disciplines, including automatic control, computer science, computer and software engineering, and electrical engineering. The ISS research is covering various aspects of all these areas, and – what is more important – attempts to bridge gaps between disciplines to provide solid engineering solutions to real problems.

ISS is organised in the following interrelated and mutually supportive sub-programmes:

- The MSc programmes in Computer Science and System technology and Robotics which are research oriented MSc programmes, integrated with the ISS researc h.
- Research projects, including application oriented industrial and health care co-operation projects, as well as more traditional research projects.
- Research infrastructure, including regular meetings and seminars, participation in national and international research networks, as well as a mobility programme (including the invitation of PostDocs, and support for international research visits).

3.1 Industrial co-operation

One of the cornerstones of ISS is the many close industrial co-operations. Almost all our projects and activities include industrial partners.

We have concrete co-operations with the following companies/organisations:

- ABB
- AbMedica
- AI Labs
- Activio
- Arbexa
- Avesta Steel Mill
- Bombardier Transportation
- Calesco Foil AB, Kolbäck
- Comosys
- Ericsson
- Elektronikmekanik AB
- Euroling AB
- Flodafors Lego
- FOI
- Funkai Intelligent Solutions
- Hök Instruments
- IFP Research AB
- Kanmed
- Lectus sängar AB
- Medicus
- Mälarhälsan AB, Köping
- Huntleigh Healthcare
- MinST
- Monark Exercise AB
- Motion Control
- Ortivus
- PBM StressMedicine AB
- Philips Research, The Netherlands
- SCEMM
- Schwartzer GMBH
- Screenlab AB
- SenseBoard Technologies AB
- SensorNor
- SKF
- Svensk Bilprovning
- teknIQ
- Tieto Enator
- Tritech
- TuTech Innovations
- Volvo (Construction Equipment)
- Yes Travel

The co-operation with industry comes in many forms, including:

- Joint projects, with or without support from external funding agencies
- ISS staff performing case-studies in industry
- MSc thesis projects
- Industrial graduate students
- Industrial PhD-students
- Industrial engineers and researchers participating in ISS projects
- Industry providing equipment and software
- Direct monetary support (donations)
- Guest lectures and field trips
- Spin-off companies

To further develop our interactions with industry we are establishing more long-term bilateral co-operations with some of our main industrial partners.

Currently we have strategic long-term co-operations with several companies: Hök Instruments AB, Arbexa, PBMStressmedicine AB, ABB Robitcs, Volvo and Activio. Essential for the success of these types of co-operations, are long term goals and mutual benefits for both partners, as well as persons maintaining the portfolio. We believe that this way of working together is a model for the future.

3.2 Research groups and scientific achievements

Within the laboratories, the actual research is performed by research groups that have extensive internal and external co-operation. The following is a list and brief presentation of the current research groups at ISS, including leadership, senior researchers, and sources of funding. Also, for each group some of the main scientific achievements in 2006 are listed. Details about projects, activities and achievements are provided in the following lab-specific chapters. Here the focus is on providing representative illustrations of the scientific progress in the different research groups.

The Intelligent Systems group

Headed by Docent Peter Funk; Researchers Dr. Ning Xion, Dr. Gordana Dodig Crnkovic, MSc. Mobyhen Ahmed; Research coordinator BSc. Therese Jagestig Bjurquist, PhD students; Lic. Erik Olsson, MSc. Shahina Begum. (and 3 associated PhD students at IDP) in 2006. The groups research targets applications of artificial intelligence methods and techniques in industrial and medical domains; funding from SSF and KKS.

Scientific achievements 2006:

- Methods, techniques and a research prototype that in interaction with clinician learns to automatically classify time series from sensor readings from patients. Tests by experts for decision support are ongoing. Has resulted in a number of journal papers and conference papers. Results are also valuable in the medical area.
- New case-based classification method using wavelets that is able to classify time series of data from sensors (sound, current etc.) and make reliable fault diagnosis based on experience. Ongoing implementation of research results into a product at ABB.
- An intelligent experience reuse framework is under design and implementation using a range of AI methods and techniques with the goal to help specialist, e.g engineers and clinicians but also public in the taks of experience reuse for differt areas.

Communication Performance Predictability and Analysis group

headed by Prof. Mats Björkman; Researcher Dr. Bob Melander, Dr. Svante Ekelin; 5 graduate students; focusing on communication for small embedded devices, and traffic measurement and analysis; funding from VR, Vinnova, KKS, CUGS, and MDH.

Scientific achievements 2006:

- Development of algorithms for resource-efficient routing in sensor networks.
- Continued work on the characterization of network flow sizes and their impact on network performance.
- Measurements in wireless networks, where characteristics are fundamentally different from wired networks.
- The available bandwidth measurement method BART was further evaluated in testbed and Internet scenarios.
- The TOPP model for describing available bandwidth estimation was further extended in order to explain measurement results obtained in wireless networks

Sensors and Mechatronics

headed by Dr. Maria Lindén; Dr Mikael Ekström; Professor Ylva Bäcklund; Dr Mia Folke, Dr Javier Garcia Castano; Senior Lecturer Dr. Mannan Mridha, Dr. Denny Åberg; Researcher Prof. Lars Asplund, 1 research engineer; 10 PhD students; two of them Industrial PhD student (2 leaving the group during 2006); focusing on wearable multisensor systems also including artificial intelligence, microwave sensors and imaging and robotics. The wireless communication enables free mobility and several of our projects are basen on the Bluetooth™ technology. 3 PhD and one licentiate during 2006. Funding from Vinnova, KKS, EU, Mål 2, Länstyrelsen, Robotdalen and MDH.

Scientific achievements 2006:

- Development of algorithms for automatic hand over of Bluetooth.
- Continued work on the characterization and routing of BT-protocols.
- A light-weight, wireless ECG-surveilliance system for continous registration.
- Development of a probe enabling blood flow measurements at different tissue depths, based on the PPG (photo pletysmograph) and laser Doppler principle respectively.
- Continued work on the novel way to measure CO_2 in expired air through a resonant sensor.
- The microwave project is a novel proof of principle project, for imaging the human body and here a close collaboration with a France research group (Superlec) has been established.
- Implementation of colour conversions and algorithms for finding corners in a videostream based on 1 MGate FPGA.
- Design of new FPGA system using 8 million gates.
- Development of a new principle to estimate the lactate threshold through correlation to the CO_2-level. An application for patent for the principle has been submitted.
- Three PhD thesis Krister Landernäs, Ali Fard and Javier Garcia Castano.
- One Lic thesis Annika Jonsson.

3.3 The Intelligent Systems Group

Focus

Headed by Docent Peter Funk; Researchers Dr. Ning Xion, Dr. Gordana Dodig Crnkovic, MSc. Mobyhen Ahmed; Research coordinator BSc. Therese Jagestig Bjurquist, PhD students; Lic. Erik Olsson, MSc. Shahina Begum. (and 3 associated PhD students at IDP) in 2006. The groups' research targets applications of artificial intelligence methods and techniques in industrial and medical domains; funding from SSF and KKS.

The main interest of the group is research in artificial intelligence and its applications. The group is in particularly interested in methods and techniques such as Case-Based Reasoning, Intelligent Agents, Genetic Algorithms, Intelligent Human Computer Interaction, Sensor and Information Fusion and Knowledge Representations. The intelligent system group has succeeded in attracting funding for a number of large research projects, from foundations like SSF and KKS, and industry such as ABB, Volvo, and SKF. The AI group has also initiated a number of successful multidisciplinary research projects with IDP and ISt. Projects the AI group plays a major role in is ExAct (24 MSEK) and the following Factory-in-a-box project (41 MSEK, ExAct was a prerequisite for applying, Chalmers Tekniska Högskola, Högskolan i Jönköping, Linköpings Tekniska Högskola), Butler (SICS, Bombardier, Outocumpu, Avesta Steel Mill) shows that the intelligent systems group has an important role at MDH and the department and also is a key research group bridging and contributing to multidisciplinary research projects between departments at MDH and with other universities and university colleges. The group is also internationally recognised for its application-oriented AI and learning systems research.

Main results and achievements in 2006:

- ExAct project funding by SSF Proviking. Participating companies ABB, Volvo, and SKF. A number of licentiate thesis and publications. This SSF ProViking project was also a prerequisite for the Factory in a Box project. The project budget during 4 years is 24.5 MSEK. Peter Funk is the main project leader.
- Participation in "Factory in a Box" granted 41 MSEK during 4 year (application together with a Chalmers University of Technology, Linköping University and Jönköping University). Mats Jackson at Mälardalen University is main applicant and main project leader, Peter Funk is project leader for Intelligent Systems and Knowledge Reuse.
- The group was avarded funding from EU-mål 2 and Västmanlands länssytelse for the project EKEN, experience reuse between SME companies in Västmanland.
- Successful application to the Swedish Knowledge Foundation, KKS, "Intelligent sensor systems for medical applications" granted 3,9 MSEK cash funding during 3 year (application together with Ylva Bäcklund who is the main applicant). One female PhD student is employed in the project.
- Peter Funk was elected as president for the Swedish aritificial intelligence society.
- Collaboration with spin-off company AI Labs, 5 former AI students commercialising research ideas based on research projects in the AI group.

IPOS, Intelligent sensor systems for medical applications

Project leader:	Mia Folke and Peter Funk (IDE)
Members:	Shahina Begum (Ph.D. student)
	Mobyen Ahmed (research engineer)
	Peter Funk (supervisor)
	Bo von Schéele (supervisor)
	Ning Xiong, Ph.D.
	Johnny Holmberg, Ph.D
Partners:	PBM StressMedicine AB
Funding:	KK-foundation
	PBM StressMedicine AB
	Activio
	Hök Instrument AB
	Mälardalen University

Project description:

The IPOS project addresses automated and semi automated sensor readings in clinical and sports applications used for diagnosis, prevention and rehabilitation. Sensor readings in medical context are becoming increasingly important. Classical sensor classification methods are not always sufficient for reliable diagnosis, prognosis and treatments (the case in stress diagnosis, our main target application). Techniques from artificial intelligence are used in a decision support context both for experts, clinicians and patients.

Results and achievements in 2006:

A number of Masters Thesis projects, numerous publications and participation at international events (conferences, workshops).

ExAct, Intelligent Systems and Artificial Intelligence for industrial applications

Project leader:	Peter Funk. Docent, IDE
Members:	Mats Jackson, professor IDP
	Ning Xiong, Ph.D
	Johnny Holmberg, Ph.D
	Markus Bengtsson, PhD stud MDH, IDP
	Milun Milic, PhD stud, ABB Automation, IDP
	Erik Olsson, PhD stud, ABB Automation, IDE
	Sofi Elfving, PhD stud, MDH, IDP
	Anette Brannemo, PhD stud, Volvo CEC, IDP
	Anna Andersson, PhD stud, Volvo CEC, IDP
	Mikael Hedelind (M.Sc. ABB)
Partners:	ABB automation,
	Volvo, SKF,
	Underhållsföretagen
Funding:	ABB automation,
	Volvo, SKF,
	Underhållsföretagen

SSF ProVIking
teknIQ

Project Description

The ExAct project is coordinated by Peter Funk (CSL), with additional partners from MDH/IDP (Mats Jackson), Hercules Dalianis (KTH, Nada) and Paul Johannesson (DSV, Stockholm University). The goal of ExAct is three fold: firstly to create a flexible, intelligent, proactive, collaborative experience sharing framework for industry, secondly collecting and structuring experience (both human experience and automatically recorded experience by manufacturing equipment) and thirdly initiating competence cluster and experience sharing among users. ExAct includes a number of global companies (ABB Robotics, Volvo, SKF and SCEMM, universities (3) and one trade organisations with more than 70 companies. These partners have committed to finance 15.5 MSEK. SSF ProViking is funding 9 MSEK during 3 years.

Results and achievements in 2006:

The project has also produced a number of publications and participated in a number of international conferences and workshops. Active participation in ProViking Factory in a Box Project (prof. Mats Jackson main project leader) and 41 MSEK was granted (the single largest individual project run at Mälardalen University) and the project including 4 universities. The project is closely coordinated with the ExAct project making Mälardalen one of the most important centers of research with high relevance for production industry.

EKEN

Project leader:	Peter Funk (IDE)
Project coordinator:	Therese Jagestig Bjurquist
Members:	Shahina Begum (Ph.D. student)
	Mobyen Ahmed (research engineer)
	Ning Xiong, Ph.D.
	Dave Bernal Gil, M.Sc
	Erik Olsson PhD student
Funding:	Länsstyrelsen Västmanland
	EU Mål 2 Norra, Regionala fonden
	Mälardalen University

Project description:

We live in a society where knowledge management is a basic condition for the business world. The problem for many companies or industries today, is the lack of *efficient knowledge and experience* reuse. The goal of the project is to offer the participating companies methods and tools for efficient knowledge and experience management. ***Case-Based Reasoning (CBR)*** and ***Artificial Intelligence (AI)*** techniques will be used in this project to get a high efficiency. One of the benefits is also the opportunity and facility to identify people with similar tasks and problems at different companies and share their experience.

Results and achievements in 2006:

During 2006 we have developed generic methods and two prototypes for experience sharing, one for sensor signals and one for textual experience reuse. Also algorithms for knowledge

discovery are under development and parts of the result have been presented at international conferences and workshops. A case study on what is available and some initial discussions with industry for their need has been performed.

English Butler

The English Butler consortium is coordinated by Björn Levin (SICS), with additional partners from MDH/ISt (Erik Dahlqvist), and CSL (Peter Funk). The objective is to provide industrial plants with autonomous self-surveillance. The "English butler" is a system that monitors the process using the abundance of sensors and control devices built into modern process industries, detects deviations, and when possible takes corrective actions without operator intervention. The system will keep the operator informed and provide explanations.

Genetic Algorithm Theory

Project leader:	Jacek Malec, Lund University
Members:	Roger Jonsson (Ph.D. student)
	Björn Lisper (local advisor)
	Peter Funk (local advisor)
Funding:	Internal

Project description:

Genetic algorithms are gaining an increasing amount of interest in many domains. Even though good results are often achieved, the theoretical framework is still young. Theoretical research today is using a Markov chain as a model for genetic algorithms. The main drawback with this model is that is only able to model very small problems.

Our research concerns the Markov chain model of the Simple Genetic Algorithm, where we aim at both simplifying the model so that it is useful for larger problems, and using it to find expressive features and correlate them to design choices. The design is today made by trial and error.

Plans and achievements:

A Licentiate thesis and a conference paper are planned for 2007.

Staff

Peter Funk is Senior Lecturer (docent) at Mälardalen University since January 1999 and leader the of the department's AI/Intelligent Systems group. He received his Ph.D. from the University of Edinburgh, Department of Artificial Intelligence (AI) for his research in knowledge based systems. Docent since 2002. He has been involved in industrial research at Ericsson for 9 year in the area of applied AI methods and techniques. He is the first who received the Wallenberg grant for scientific research three times. Winner of Mälardalen University's innovation competition, Idetävling >2002<. His research focuses on AI methods and techniques for industrial applications, and medical applications, intelligent human computer interaction and internet applications, to enable intelligent systems and functionality. His research and research projects have attracted more than 36 MSEK

funding since he started his employment at Mälardalen University 7 years ago.

Ning Xiong is a researcher at CSL. He holds a Ph.D. from University of Kaiserslautern, previously employed at Royal Institute of Technology (KTH) and the Swedish Defense Research Agency (FOI). Main research interest are: Case-based reasoning, feature selection and machine learning; Computational intelligence techniques (e.g. fuzzy logic, neural networks and genetic algorithms) and their applications to process modeling and classification; Multi-sensor data fusion and time-series processing in relation with industrial CBR Systems. He works in the ExAct project, teaches and is supervising PhD students.

Gordana Dodig-Crnkovic is Senior Lecturer. She graduated 1979 in physics, received 1983 a M.Sc. and 1988 a Ph.D. in Theoretical Nuclear Physics, at the University of Zagreb. She is teaching Research Methodology for Computer Science and Engineering, Scientific Method in Computer Science, Professional Ethics in Science and Engineering, Formal languages, automata and theory of computation, and a National Course in Philosophy of Computer Science. Her research is in the area of Philosophy of Computation and Information, where she is also co-ordinating the national PI-network.

Baran Çürüklü is a PhD since 2005 and is currently doing a Post Doc abroad. He received his Master of Science in Applied Computer Engineering from Mälardalen University, Sweden (1998), and his licentiate in 2003. His research focuses on application of artificial intelligence for vision using methods such as computational neuroscience.

Rikard Lindell is a Lecturer and Ph.D. student at the Department of Computer Engineering at Mälardalen University. Rikard's main interests are within interaction design and exploring and developing new and alternative interaction techniques for digital artefacts. Rikard is especially keen on finding alternatives to the current paradigm of windows, icon, menus and pointing devices (WIMP). He holds a licentiate degree in computer science since 2004.

Mobyen Ahmed, M.Sc. is a research engine in artificial intelligence in the ExAct and IPOS project. Her research interests are artificial intelligence methods and techniques for industrial and medical applications.

Shahina Begum is a departmental Ph.D. student in artificial intelligence in the IPOS project. Her research interests are artificial intelligence methods and techniques for medical applications.

Erik Olsson is a departmental Ph.D. student in artificial intelligence in the EXACT project. His research interests are artificial intelligence methods and techniques for industrial applications, mainly fault diagnosis of industrial machines.

Roger Jonsson is Lecturer and Ph.D. student at CSL. He received a Bachelor of Science in Applied Computer Engineering from Mälardalen University, Sweden (1995). His research interests is the theory of evolutionary algorithms

Therese Jagestig Bjurquist is project coordinator

National and International research co-operation

Peter Funk was external examiner for one Ph.D thesis at Trinity College, Ireland and external examiner for one Ph.D thesis at Dublin University College, Ireland.

Services to the Community

Peter Funk:

- was elected to the president of the Swedish Artificial Intelligence Society, SAIS, and (deputy board member).
- Guest Editor together with Lambert Spannenburhg of Special Issue of Journal Journal of Intelligent & Fuzzy Systems, Elsevier.
- Review for Applied Artificial Intelligence Journal.
- Review for Special Issue of the Computational Intelligence Journal (case-based reasoning in health care), 2006. ISI Journal Citation Reports® Ranking: 2004: 18/78
- was external examiner for one Ph.D thesis at KTH.
- In Program Committee of ICDM 2006, the 6th Industrial Conference on Data Mining, Leipzig, Germany, July 14-15 2006 (paper Submission 22 January 2006).
- In Program Committee of ECCBR 2006, 8th European Conference on Case-Based Reasoning, Turkey, 4th-7th September 2006

- In Program Committee of KES'2006, International Conference on Knowledge-Based Intelligent Information & Engineering Systems

Ning Xiong:

- was in the PC for ECCBR 2004 (7th European Conference on Case-Based Reasoning).
- was reviewer for IEEE Transactions on Systems, Man, and Cybernetics journal.
- was in the program committee of SAIS-SSLS 2005.
- reviewed a number of papers for conferences and workshop.

Interactions with society

Peter Funk is president of the Swedish Artificial Intelligence Society leading to much interaction both national and international with public and academia. He has been interviewed about his research and research projects at Mälardalen University a number of times, resulting in articles in national and regional press (Nyteknik, VLT, SR P4 et.al.). He appeared on Radio Västmanland P4 broadcasting, together with Mats Jackson, about a new research project improving the competitiveness of Swedish production industry.

3.4 Communication Performance Predictability and Analysis group

headed by Prof. Mats Björkman; Researcher Dr. Bob Melander, Dr. Svante Ekelin; 5 graduate students; 1 licentiate and 2 PhDs planned for 2007; focusing on communication for small embedded devices, and traffic measurement and analysis; funding from VR, Vinnova, KKS, CUGS, and MDH.

Scientific achievements 2006:

- Development of algorithms for resource-efficient routing in sensor networks.
- Continued work on the characterization of network flow sizes and their impact on network performance.
- Measurements in wireless networks, where characteristics are fundamentally different from wired networks.
- The available bandwidth measurement method BART was further evaluated in testbed and Internet scenarios.
- The TOPP model for describing available bandwidth estimation was further extended in order to explain measurement results obtained in wireless networks.

Focus

Performance, predictability and analysis are important issues in the development of communicating real-time systems, soft real-time as well as hard real-time. For hard real-time systems, predictability and analyzability are properties of crucial importance. Communication designed for such systems must thus be predictable on all levels. Of special interest is how communication for small embedded systems can be designed and implemented with predictability and analyzability as primary requirements, while still maintaining performance. For systems with soft real-time requirements, a number of important issues have gained interest recently. Using the Internet as a data transport medium is one such issue. Although the Internet was originally designed to give best-effort service only, the performance of the Internet is indeed analyzable and predictable, although only statistically. In order to achieve such predictability, suitable models of Internet traffic must be developed. Traffic analysis and traffic modelling are therefore two important research issues on the path towards predictability of cross-Internet traffic performance. An issue of importance is the usage and performance of small nodes in massive systems, sometimes called sensor networks. Small nodes with limited resources, connected in massive networks, pose important research questions regarding connectivity, routing and resource utilization.

Research projects

COMSED - Communication for Small Embedded Devices

Project leader:	Mats Björkman
Members:	Jonas Neander
	Adam Dunkels
Partners:	SICS
Funding:	CUGS,
	SICS
	Internal

Project description:

Communication for small embedded devices pose several challenging problems, two of these are addressed in this project. One problem is how to minimize the resource consumption of the communication subsystem in such small embedded devices, while still maintaining performance and predictability.

This includes the study of how to minimize code sizes and memory usage, as well as how to design protocols for communication in a network of such systems so that the protocols themselves minimize resource utilization in the network, while still achieving good and predictable performance. The other problem that is studied is how to use existing infrastructure as base stations to offload small embedded, wireless and energy constraint devices. This project studies how to prolong the lifetime, reduce delay time and guarantee of QoS of small embedded devices in application areas like fabrics and hospitals. We do this by centralize distributed energy consuming activities like routing, topology changes and mobility to a non energy constraint base station.

Achievements:

During 2006, one licentiate thesis was defended by Jonas Neander. Delay Tolerant Networks and their applicability in sensor networks have been studied, as well as the adaptation of real-time scheduling techniques to hierarchical sensor networks. Resource-efficient routing, taking spatial location into account, has been studied.

Future plans:

During 2007, the techniques for addressing and power management will be addressed. Asymmetrical protocols for lower radio power consumption will be investigated further. One licentiate thesis is planned.

Traffic Measurement and Analysis

Project leader:	Mats Björkman
Members:	Henrik Abrahamsson
Partners:	SICS
Funding:	VINNOVA
	SICS
	Internal

Project description:

This project concerns traffic measurements and analysis in computer networks. The main focus is on methods and methodology for measurements and analysis, but tools for measurement are also a part of the project. Traffic measurement and analysis is important in today's and future networks. More powerful methods are however needed. Traffic characterization is an important first step towards development of more precise and powerful models for analysis or synthesis of traffic. Problems studied in this project include: models for generation of synthetic traffic, aggregated traffic and flow stability, and dynamic measurements for routing and load balancing.

Achievements:

Traffic characterization methods have been investigated and evaluated; bi-modal as well as multi-modal models have been studied and applied to real traffic traces. The issues of

aggregated traffic and flow stability have been further studied, together with the applicability of traffic characterization in traffic analysis.

Future plans:

During 2007, the applicability of traffic characterization for traffic engineering purposes will be the main focus.

EvaluNet - Network Performance Evaluation

Project leader:	Mats Björkman
Members:	Andreas Johnsson
	Bob Melander
	Svante Ekelin
Partners:	SICS
	Ericsson Research
Funding	VINNOVA
	Ericsson Research
	SICS
	Internal

Project description:

EvaluNet is focused towards tools and methods for traffic characteristic estimation. A number of issues are addressed in the project. One issue concerns the combination of active and passive measurements in order to obtain faster and more accurate estimations. Another issue concerns the sharing of measurement results between clients having parts of a path in common. This could be done in order to reach more accurate estimations with less injected traffic. A third issue is how to perform network tomography from a set of peer-to-peer measurements, i.e. to obtain a multidimensional estimation of the network topology and characteristics from a set of point-to-point measurements. A fourth issue is how to use advanced filtering in the estimation process.

Achievements:

BART was further developed. BART is an end-to-end available bandwidth measurement method that uses filtering in the estimation process. BART was further evaluated in testbed as well as in Internet scenarios. Different parameter settings and their impact on the estimates were studied.

Future plans:

The funding from VINNOVA ended at 2006-06-30. The activities will continue in cooperation with SICS and Ericsson Research.

EvaluNet II

Project leader:	Mats Björkman
Members:	Ewa Hansen
	Andreas Johnsson
	Bob Melander
Partners:	Gatorhole AB
	Ericsson Research
Funding	KKS
	Ericsson Research

Gatorhole AB
Internal

Project description:

EvaluNet II is an enlargement and continuation of the ongoing EvaluNet project, and industry partners are Ericsson Research and Gatorhole AB. The research questions addressed are an extension to those of the EvaluNet project, the focus of EvaluNet II is on the development of network bandwidth measurement tools for use by network operators as well as end consumers.

EvaluNet II leverage on the results from the VINNOVA funded EvaluNet project, especially the algorithms for bandwidth measurement and prediction developed there

Achievements:

Studies of the use of advanced filtering in the estimation process. An advanced tool for network bandwidth measurements has been developed and evaluated. A study on how the filtering is affected by wireless networks has also been studied.

Future plans:

The EvaluNet II project ended in 2006-12-31. The activities will be continued in cooperation with Ericsson Research and SICS.

Thesis

In 2006, COMPASS staff presented the following thesis:

- Using Existing Infrastructure as Support for Wireless Sensor Networks

Below, this thesis is presented in more detail.

Licentiate Thesis

Jonas Neander, Using Existing Infrastructure as Support for Wireless Sensor Networks

Date: June 20

Opponent: Dr. Björn Knutsson

Examiner: Prof. Hans Hansson

Supervisors: Prof. Mats Björkman, Dr. Mikael Nolin & Dr. Jukka Mäki-Turja

Abstract: Recent advancements in electronic design, such as low-power circuits, energy efficient wireless communication, and improved energy supply, has enabled the vision of wireless sensor networks to become a reality. Wireless sensor networks typically consist of hundreds up to thousands of collaborating low-cost, battery-driven and wireless sensor nodes with scarce resources. The wireless sensor nodes are typical small physical entities, and usually small as a matchbox but can in extreme cases be no larger than a cubic millimeter.

In this thesis we present an architecture called AROS that uses existing infrastructure to aid in the management of wireless sensor networks. As an example, the existing infrastructure could be situated in hospitals or industrial buildings. The existing infrastructure can aid in prolonging the lifetime of the wireless sensor network by having “unlimited” energy, long range radio capacity, and high-speed computers. We enable prolonged lifetime by centralizing some of the energy consuming administrative functionality of wireless sensor networks.

We show, by simulations, that the AROS architecture is able to prolong the lifetime of the sensor nodes. AROS is compared to a well known cluster based architecture, LEACH. The comparisons show that AROS with static configuration performs at least as well as LEACH in small wireless sensor networks in the size 100x100m, and up to 97 % better in long distance wireless sensor networks in the size of 400x400m. We show that AROS still has got 88 % of its sensor nodes alive when LEACHs' network demises.

In our simulations we have also studied how dynamic network clustering in AROS, using a TDMA scheduler and non-mobile wireless sensor nodes, affects the amount of data received by a base station. We show that AROS is better than LEACH-C in collecting data to the base station with the same total amount of energy for long distance networks and that AROS performs as well or better than LEACH-C in small wireless sensor networks.

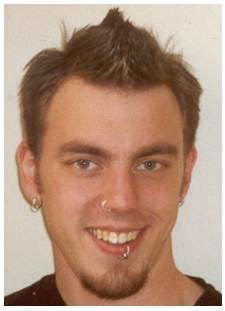
Staff

Mats Björkman is Professor in Computer Communication at Mälardalen University, appointed in 2001. He received his Ph.D. in Computer Systems (Datorteknik) from Uppsala University in 1993, the thesis title was Architectures for High Performance Communication. Mats then held a post-doctoral research position at University of Arizona, working in the X-kernel research group. In 1995 he returned to Uppsala University as a senior lecturer in computer communication. His research interest includes communication performance analysis and predictability, small embedded systems, wireless communication and system-wide performance and predictability issues.

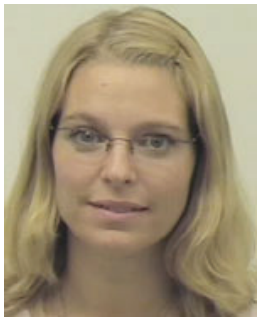
Svante Ekelin was born in Stockholm in 1958. In 1982 he earned the degree of civilingenjör in Engineering Physics at KTH in Stockholm. Svante earned his PhD in Theoretical Physics at KTH, and spent one year as CNRS postdoctoral fellow with the Laboratoire de Physique Théorique in Bordeaux in 1987. After 11 years as associate professor of Mathematics at KTH, he joined Ericsson in 1999, where he is presently a senior researcher at the department of IP Networks within Ericsson Research.

Bob Melander is a part-time research scientist at SDL where he works in the computer communications research group. He received an MSc (Engineering Physics) and a PhD (Computer Science) from Uppsala University in 1997 and 2003, respectively. Bob is also affiliated with Ericsson Research where he is member of the department of Broadband Access Networks. His research interests include network performance measurements and analysis, network/traffic modeling and simulation, mobile/wireless computing, and economics of computer networking.

Henrik Abrahamsson is a researcher at the Swedish Institute of Computer Science (SICS) and a PhD student at SDL. He has a MSc from Uppsala University and has been working at SICS since 1999. His research interests include Internet traffic engineering, traffic analysis and routing.



Adam Dunkels is a researcher at the Swedish Institute of Computer Science (SICS) since 2000 and a PhD student at SDL since 2002. He published his MSc thesis in 2000 after three years of undergraduate studies at Luleå University of Technology. His current research interests include lightweight communication support and Internet connectivity for tiny embedded devices and sensor networks, overlay and network architectures, and security for small networked devices.



Ewa Hansen is a Ph.D. student at SDL. Prior to this position, she has been an undergraduate student at the department of computer engineering since 2001. Her current research interests are communication support for small embedded devices. Energy saving protocols for sensor networks is her priority interest. She is a student member of ACM.

Andreas Johnsson is Ph.D. student at SDL. His current research interests are measurement and analysis of available bandwidth, as well as other end-to-end characteristics, in best effort networks. He received a M.Sc. in Computer Science from Uppsala University in 2002.

Jonas Neander is a CUGS Ph.D. student at SDL. His current research interests are communication support for small embedded devices. He is currently working within the sensor networks field where one important issue is to decrease the energy consumption in the network.

Prior to this position, he has been an undergraduate student at the department of computer engineering since 1998. He is a Student Member of IEEE and ACM.

National and International research co-operation

The following is a partial list of national and international research co-operation by Compass staff in 2006:

Mats Björkman

- is coordinator and leader of the EvaluNet and EvaluNet II joint research effort, involving MDH, SICS, Ericsson Research, TeliaSonera, Gatorhole AB, Netintact AB and Stiftelsen för internetinfrastruktur.
- is member of the steering group of the SSF program Winternet.
- is senior member of the CUGS national graduate school.
- is supervisor to two PhD students at the Swedish Institute of Computer Science (SICS).

Services to the Community

Mats Björkman

- was on the grading committee at two PhD dissertations.
- was "opponent" at one licentiate presentations.
- is scientific advisor for a media technology educational program, Blekinge Tekniska Högskola.
- was reviewer for several conferences and workshops.

3.5 Sensors and Mechatronics

Focus

The research within the group Sensors and mechatronics focuses towards wearable sensor systems using wireless technologies, microwave imaging and vision within robotics.

The wireless, wearable sensor systems have been based on Bluetooth and Zigbee as a communication standard so far, but the same principle can be used in other standards as w-lan and RFID. Also, multisensor systems facilitate a more holistic view over the health status, not measuring a single parameter at a time. For example, we have systems combining ECG with the heart sound and blood flow (PPG) (collaboration with the Linköping group). Further, sensor systems with integrated intelligence are more appropriate. E.g. a system used in stress medicine measures heart rate, breathing rate, carbon dioxide level, oxygen saturation and skin conductivity, interprets the data and provides a feedback to the "patient" (collaboration with the Intelligent Systems Group). Decision support systems and knowledge discovery enables this. Through build-in intelligence, sensor information can be better utilised. In telemedicine applications, only a limited amount of data will have to be transmitted, saving energy, which is important if battery situations. Another area is the newly started field within microwaves for medical imaging as well as a novel way to measure CO_2 in expired air through a resonant sensor.
The microwave project is a novel proof of principle project, for imaging the human body and here a close collaboration with a French research group (Supélec) has been established.

Vision technology is one of the more challenging sensors for a robot. Like the human senses, seeing can solve so many localization and recognition tasks much better than other techniques. The availability of modern camera sensors to reasonable prices, together with the development of high performance solutions for System on Chip are the fundamentals for the research in the robotics area. The research is focused on high speed camera systems based on System on Chip technology. Algorithms that normally take 1-2 seconds on a high speed computer have been adapted to our platform, giving results from two cameras at a speed of 25 frames/s.

These fields/contributions, are all fairly new but very promising, and with a great potential and a good chance for Swedish industry to become competitive.

Research projects

Prevention of pressure sores, development of a new blood flow sensor

Project leader:	Maria Lindén
Members:	Annika Jonsson
	Ylva Bäcklund
Partners:	Linköping University:
	Margareta Lindgren (LiU)
	Anna-Christina Ek (LiU)
	Lars-Åke Malmqvist(LiU)
Funding:	VR
	Faculty

Sparbanksstiftelsen Nya

Project description

The project aims at developing a sensor system to help in the assessment of pressure sore mattresses and in the understanding of aetiology of pressure sores.

Sensor systems integrated in textile

Project leader:	Peter Hult (LiU)
Members:	Maria Lindén,
	Linda Rattfäldt (LiU)
Partners:	Linköping University
	School of textiles at the University Collage in Borås
	County Council of Sörmland
	City of Katrineholm
	Flodafors Lego
Funding:	Vinnova
	Regionförbundet

Project description

This project is cooperation between Mälardalen University, the school of textiles at the University Collage in Borås and Linköping University. By replacing the traditional electrodes and wires with conducting textiles, surveillance systems can be made more comfortable to wear. This opens opportunities to new areas: patient care at home, athletes and occupational groups that are exposed to dangers i.e. firefighters.

Parts of this project are performed in close collaboration with County Council of Sörmland and the City of Katrineholm in order to develop systems for home health care together with the users. To commersialise the prototypes, a company, Flodafors Lego, is included in the project.

Wireless ad-hoc sensor network with Bluetooth™

Project leader:	Mikael Ekström
Members:	Javier Garcia Castaño
	Martin Ekström
	Marcus Blom
	Maria Lindén
Funding:	EU

Project description

The aim of the project is to develop reliable automatic wireless distributed (without central server) and centralized (Ethernet based) networks for mobile sensors, a “smart wireless node” which will operate in a distributed architecture.

The first approach has been based on Bluetooth™ enabled biomedical sensors but it could be applied to other wireless technologies and in different industry fields.

This network will allow the use of wireless sensors in hospitals and homecare providing communications for mobile patients and cable replacement applications. This network contents several mobile wireless nodes, which could have sensoring and/or routing

capabilities. A distributed Bluetooth-network has been established, enabling handovers as a Bluetooth-unit moves over distance larger than the range of one Bluetooth™-unit.

Intelligent systems for diagnostics and treatment within stress medicine

Project leader:	Mia Folke
Members:	Peter Funk
	Ylva Bäcklund
	Shaina Begum
	Martin Ekström
Partners:	Stressmedicin AB
	Hök Instrument AB
	Activio AB
Funding:	KK

Project description

The project develops methods and systems for diagnosis and treatment of stress. Multisensors are used within the project in combination with computerized models for decision support (case based reasoning, artificial intelligence). Thereby it becomes possible to get a reliable diagnose from a clinician who not is an expert within the field. Further the patient gets an opportunity to observe the effects of the treatment.

Development of sensors and AI-system for individually optimized physical training for athletes

Project leader:	Mia Folke
Members:	Peter Funk
	Ylva Bäcklund
	Shaina Begum
	Martin Ekström
Partners:	Stressmedicine AB
	Hök Instrument AB
	Activio AB
Funding:	KK

Project description

A carbon dioxide sensor is developed within the project. By measuring the carbon dioxide and pulse, individual training profiles are made for athletes at all levels. The profiles can be optimized with the help of computerized models for decision support (artificial intelligence).

Alternative input and control devices for disabled

Project leader:	Maria Lindén
Members:	Christer Gerdtman
	Ylva Bäcklund
Partners:	ElektronikMekanik AB
	Bertil Pettersson
Funding:	KK

Project description

The project deals with alternative, wireless input and control devices for disabled. To develop such a unit, knowledge about the needs, possibilities and limits of the disabled is required. The system also consists of advanced technology in electronics, computer science and wireless technologies. There are strong demands on the system for intuitive use and user friendliness. The system must also be possibly for individual adaptation.

In a first prototype, a gyro based computer mouse has been developed. The mouse is module based and has many functions that enable a disabled person to control a computer. It also allows the person to work efficient on the computer. The functions have been developed together with disabled persons. It operates by sensing the rotation of a body part and advantages are the high sensitivity of the mouse and that it is easy to install and use, thanks the USB «plug&play» functionality.

Competence center – Multisensors for better health

Project leader:	Maria Lindén
Members:	Mikael Ekström
	Marcus Blom
	Mia Folke
	Martin Ekström
Partners:	Mälarhälsan AB, Köping (Arboga, Kungsör)
	Calesco Foil AB, Kolbäck
	Västerås Stad
	Lanstinget i Västmanland
Funding:	EU Objective 2

Project description

The aims of the project are to:

- form a network between clinics, manufacturers, developers and researchers to strengthen the competences in biomedical engineering and sensor technology.
- develop and spread new technologies for preventive health care, health care and home care to companies and actors belonging to the objective 2 region in order to strengthen their competitiveness and profitability. Secondarily, the profitability in other fields will grow from the better health and reduced sick leave.

Within the project, wearable, flexible multisensor-systems for measurements of physiological parameters as heart activity and breathing will be developed and used in preventive health care and home health care.

The regional industry and society will benefit from the development of new technology by an increased competence and competitiveness. Further, new products and manufacturing of products might occur, as well as up-starts of new companies.

Robotics for SMEs, vision project

Project leader:	Lars Asplund
Members:	Jörgen Lidholm
	Fredrik Ekstrand
Funding:	Robotdalen

Project description
In robotics there are two important areas, and one is sensor systems, that are the basis for a robots capability of recognizing the external world, and the other is artificial intelligence, i.e. given that the robot has an understanding of its surrounding world, what are the actions the robot should perform.
The sensor systems can be compared with our human senses, and one of the most important senses we have for understanding the world around is, is our eyes, and the corresponding for a robot is a vision system.
In the project Robotics for SMEs, funded by Robotdalen, the vision project is one project out of four. The ultimate goal is to make industrial robots more useful for small and medium sized enterprises. By putting the robot on a fully autonomous platform the robot can go from one working place to another without human interaction. This then require that the platform can navigate in an industry without any special rebuilding efforts.
The research project in the Robotics group is focused on vision system based on reconfigurable electronics. i.e. FPGAs. The current status is that one single FPGA can simultaneous handle four cameras, and from these four cameras in real time extract required information for both positioning the robot platform and possible the hand of the robotarm - the gripper.

On Design of Wide Tuning Range RF VCO´s for Multi-standard Tranceivers

Project leader:	Denny Åberg
Members:	Ali Fard
Partners:	Denmark Technical University
Funding:	MDH

Project description:

Today, we see an increase in multi-standard wireless communication devices, e.g. a cell phone with GSM and Bluetooth transceivers. The cost per multi-standard device is in principal linear with the number of RF standards it follows since one transceiver is needed per standard. A multi-standard transceiver could therefore dramatically reduce the cost and increase the functionality for RF communication devices.

The Voltage Controlled Oscillator (VCO) is a vital RF building block. The VCO is generally very power consuming and occupies a large chip area. For this reason a single VCO is preferred per task in a multi-standard transceiver, instead of parallel design.

This project focus on the design of wide tuning range RF VCO´s with low power and low phase noise suited for 2 to 6 GHz transceivers realized in low voltage CMOS technologies.

The project was finalized with the dissertation of Ali Fard in January 2006.

Microwaves in biomedical engineering

Project leader:	Denny Åberg
Members:	Tommy Gunnarsson
	Magnus Otterskog
	Nikola Petrovic
Partners:	Arbexa, Supélec University
Funding:	KKS

EU Objective 2

Project description:

Microwaves are non-ionizing and hence less interfering with biological tissues than x-rays. For this reason microwave imaging in biomedicine is a potential method for mass-screening (mammography). At the same time, microwave sensing is a modality with higher dynamic signal response compared to x-rays, which is a further reason to investigate microwave imaging as a modality for biomedical applications.

This project investigates how microwave imaging can be applied for this reason, focusing on measurement techniques and inverse algorithm development.

Competence center in Microwaves. The microwave project has led to sufficient insights of microwaves as measurement modality to form a competence center for microwaves, aiming at spreading new techniques to small and medium sized companies in the area. The goal of the project is to demonstrate cut-scan (tomografic) vision of biological material using microwaves. A proof of principle microwave tomography which demonstrates noninvasive, non-destructable cut-scan vision of decimeter thick objects. This project is funded by the EU, as part of the Objective 2, Länsstyrelsens project for business growth in the Mål 2 region. See www.mal2norra.nu for details.

Industrial co-operation

Flodafors Lego: To commersialise the research prototypes developed in the project *Sensor systems integrated in textile.*

Stressmedicine AB, Hök Instrument AB, Activio AB: To commersialise the research ideas and knowledge developed in the projects *Development of sensors and AI-system for individually optimized physical training for athletes* and *Intelligent systems for diagnostics and treatment within stress medicine respectively.*

Arbexa: To facilitate quantitative permittivity measurements in organic bodies. This is the first step to use microwaves in medical scanning.

Theses

Ali Fard, Analysis and design of Low-Phase-Noise Integrated Voltage-Controlled Oscillators for Wide-Band RF Front-Ends PhD Thesis, Jan.

The explosive development of wireless communication services creates a demand for more flexible and cost-effective communication systems that offer higher data rates. The obvious trend towards small-size and ultra low power systems, in combination with the ever increasing number of applications integrated in a single portable device, tightens the design constraints at hardware and software level. The integration of current mobile systems with the third generation systems exemplifies and emphasizes the need of monolithic multi-band transceivers. A long term goal is a software defined radio, where several communication standards and applications are embedded and reconfigured by software. This motivates the need for highly flexible and reconfigurable analog radio frequency (RF) circuits that can be fully integrated in standard low-cost complementary metal-oxide-semiconductor (CMOS) technologies.

In this thesis, the Voltage-Controlled Oscillator (VCO), one of the main challenging RF circuits within a transceiver, is investigated for today's and future communication systems. The contributions from this work may be divided into two parts. The first part exploits the possibility and design related issues of wide-band reconfigurable integrated VCOs in CMOS technologies. Aspects such as frequency tuning, power dissipation and phase noise performance are studied and design oriented techniques for wide-band circuit solutions are proposed. For demonstration of these investigations several fully functional wide-band multi-GHz VCOs are implemented and characterized in a 0.18μm CMOS technology.

The second part of the thesis concerns theoretical analysis of phase noise in VCOs. Due to the complex process of conversion from component noise to phase noise, computer aided methods or advanced circuit simulators are usually used for evaluation and prediction of phase noise. As a consequence, the fundamental properties of different noise sources and their impact on phase noise in commonly adopted VCO topologies have so far not been completely described. This in turn makes the optimization process of integrated VCOs a very complex task. To aid the design and to provide a deeper understanding of the phase noise mechanism, a new approach based on a linear time-variant model is proposed in this work. The theory allows for derivation of analytic expressions for phase noise, thereby, providing excellent insight on how to minimize and optimize phase noise in oscillators as a function of circuit related parameters. Moreover, it enables a fair performance comparison of different oscillator topologies in order to ascertain which structure is most suitable depending on the application of interest. The proposed method is verified with very good agreement against both advanced circuit simulations and measurements in CMOS and bipolar technologies. As a final contribution, using the knowledge gained from the theoretical analysis, a fully integrated 0.35μm CMOS VCO with superior phase noise performance and power dissipation is demonstrated.

Krister Landernäs Implementation of digital-serial LDI/LDD allpass filters, PhD Thesis, Sept

In this thesis, digit-serial implementation of recursive digital filters is considered. The theories presented can be applied to any recursive digital filter, and in this thesis we study the lossless discrete integrator (LDI) allpass filter. A brief introduction regarding suppression of limit cycles at finite wordlength conditions is given, and an extended stability region, where the second-order LDI allpass filter is free from quantization limit cycles, is presented.

The realization of digit-serial processing elements, i.e., digit-serial adders and multipliers, is studied. A new digit-serial hybrid adder (DSHA) is presented. The adder can be pipelined to the bit level with a short arithmetic critical path, which makes it well suited when implementing high-throughput recursive digital filters.

Two digit-serial multipliers which can be pipelined to the bit level are considered. It is concluded that a digit-serial/parallelmultiplier based on shift-accumulation(DSAAM) is a good candidate when implementing recursive digital systems, mainly due to low latency. Furthermore, our study shows that low latency will lead to higher throughput and lower power consumption.

Scheduling of recursive digit-serial algorithms is studied. It is concluded that implementation issues such as latency and arithmetic critical path are usually required before scheduling considerations can be made. Cyclic scheduling using digit-serial arithmetics is also considered. It is shown that digit-serial cyclic scheduling is very attractive for high-throughput implementations.

Javier Garcia Castano, Algorithms and Protocols Enhancing Mobility Support for Wireless Sensor Networks Based on Bluetooth and Zigbee, PhD Thesis, Sept.

Mobile communication systems are experiencing a huge growth. While traditional communication paradigms deal with fixed networks, mobility raises a new set of questions, techniques, and solutions. This work focuses on wireless sensor networks (WSNs) where each node is a mobile device. The main objectives of this thesis have been to develop algorithms and protocols enabling WSNs with a special interest in overcoming mobility support limitations of standards such as Bluetooth and Zigbee. The contributions of this work may be divided in four major parts related to mobility support. The first part describes the implementation of local positioning services in Bluetooth since local positioning is not supported in Bluetooth v1.1. The obtained results are used in later implemented handover algorithms in terms of deciding when to perform the handover. Moreover local positioning information may be used in further developed routing protocols. The second part deals with handover as a solution to overcome the getting out of range problem. Algorithms for handover have been implemented enabling mobility in Bluetooth infrastructure networks. The principal achievement in this part is the significant reduction of handover latency since sensor cost and quality of service are directly affected by this parameter. The third part solves the routing problems originated with handovers. The main contribution of this part is the impact of the Bluetooth scatternet formation and routing protocols, for multi-hop data transmissions, in the system quality of service. The final part is a comparison between Bluetooth and Zigbee in terms of mobility support. The main outcome of this comparison resides on the conclusions, which can be used as a technology election guide.

The main scientific contribution relies on the implementation of a mobile WSN with Bluetooth v1.1 inside the scope of the"Multi Monitoring Medical Chip (M3C) for Homecare Applications" European Union project (Sixth Framework Program (FP6) Reference: 508291) offering multi-hop routing support and improvements in handover latencies with aid of local positioning services.

Annika Jonsson, Pressure sore etiology - highlighted with optical measurements of the blood flow, Lic Thesis, May.

In line with the quality awareness of good prevention of pressure sores and in treatment of those sores already developed, evaluation of antidecubitus mattresses plays an important role. However, there are shortages in the evaluations performed today, since often interface pressure is the only parameter regarded. Since ischaemia in the tissue is the primary cause of pressure sore, the focus in this thesis is on blood flow measurements in tissue exposed external loading. To study the tissue blood flow would give a better and more direct indication on the mattress effectiveness in minimizing the negative effects on the tissue viability.

The results presented in this thesis reveal that the superficial blood flow in areas prone to pressure sore development is affected by increased skin temperature and external loading of the tissue. Both the effects from pressure and shear stress have been studied.

Measurements of the tissue blood flow are interesting to relate to the two theories about at which tissue layer the pressure sores start to develop. To achieved more knowledge about the pressure sore etiology and also be able to non-invasively measure the tissue blood flow for evaluations of antidecubitus mattresses an optical sensor has been developed. The sensor combines the two optical methods, laser Doppler flowmetry and photoplethysmography. With the design of the sensor, measurements of the superficial skin blood flow and the deeper blood flow, even the muscle blood flow, can be performed. Measurement depths of 2 mm, 8 mm, and 20 mm into the tissue is assumed.

Preliminary result from measurements performed with the optical sensor in four test subjects, revealed great individual differences in blood flow, but also different response to the same external loading at different measurement depths, in the same individual. This new optical sensor is likely to be of great value in future studies of pressure sore etiology and in future evaluations of antidecubitus mattresses.

Staff

Maria Lindén the director of ISS and sub-dean of the Faculty Board for Natural Science and Engineering at Mälardalen University. She is working as a senior lecturer at Mälardalen University since 1999. She received a PhD from Linköping University in Biomedical Engineering with the title “High resolution laser Doppler Imaging”. Her current research interest includes sensor development with the focus on wearable, wireless sensor systems.

Mikael Ekström is a senior lecturer at MDH since 2000 and adjunct senior lecturer at School of Computer and Information Science, Edith Cowan University, Australia since 2005. Head of the research group Sensors and Biomedical engineering.

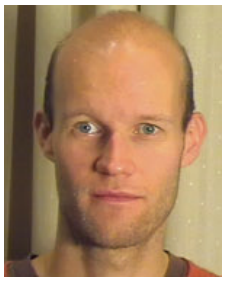
Ylva Bäcklund Since December 1999, she has been appointed as a professor in Electronics at the former department of Electronics at Mälardalen University (MDH). After the merge with the dept of Computer Science she is now the head of the Dept. of Computer Science and Electronics. Since she joined MDH her first task was to build up research and research education in Electronics. Areas of particular interest are sensors for wireless patient monitoring in hospital and home health care, and microwave technology for biomedical engineering. The research has attracted funding from Vinnova and from the Knowledge foundation for the research projects ”Wireless Patient Monitoring Systems”, "Microwave technology for Biomedical Engineering", "Intelligent sensor systems for diagnosis, treatment and health care", and from the EU 6th

framework programme in a CRAFT project entitled ”Multi-monitoring medical chip for homecare applications”. Ylva has been the chairman of a working committee for the Swedish research council, (2002-2003) and is a member of the board for”Innovationsbron” (2003 – present). Before joining MDH, Ylva was research leader of the Micro System Technology group at the Electronics department, Uppsala University. She received her Master of Science (Engineering Physics), Licentiate degree (Electronics), PhD (Doctor of Technology in Electronics) and "Docent" (Associate Professor in Electronics) from Uppsala University in 1986, 1990, 1992, 1996 respectively.

Mia Folke took her PhD at MDH in September 2005 and is now working as a research assitstent. Her research interests are sensor development for sports medicine.

Javier Garcia Castaño is a lecturer at MDH. He received his PhD from MDH in 2006. He received his MSc in Telecommunication from department of Electronics at University of Alcala de Henares, Madrid. His research interests are wireless ad-hoc network.

Denny Åberg is a senior lecturer at Mälardalen University and holds a PhD from KTH. Current research interests are microwave imaging.



Magnus Otterskog holds a PhD from Örebro University and is working as a researcher at MDH with microvawe imaging.

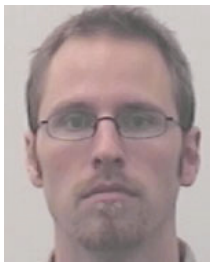
Nikola Petrovic ia a PhD-student at MDH. His research interests are microvawe imaging.

Tommy Gunnarsson is a PhD-student at MDH. His research interests are microvawe imaging. Tommy is working with a research group in Paris, Supélec

Christer Gerdtman is an industrial PhD-student at MDH. His research interests' concerns alternative input devices to computers for disabled persons. He received his MSc in Electrotechniques from Lund University.

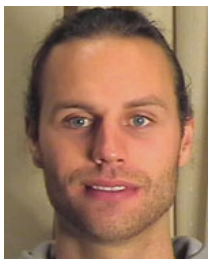
Annika Jonsson is a PhD-student at MDH and presented her lic in May 2006. Her research interests are development of a new blood flow sensor for the prevention of pressure sores.

Lars Asplund is professor in computer systems at Mälardalen University since 2001, and from 2002 lab-leader at CAL. He received a Ph.D. in Physics at Uppsala University in 1977. In the last twenty years his research has been in real-time systems, distributed systems, learning systems, and most recently in safety critical systems. He has written nine textbooks. His current research interests are safety critical systems, system on chip and Robotics.



Fredrik Ekstrand is a research engineer at ISS. His current research interests are special purpose vision systems and robotics. He is currently working on a hardware platform for the ChipVision project. Prior to this position, he has been the chief hardware developer for the Senseboard Virtual Keyboard. He has a B.Sc. in Electrical Engineering from Uppsala University.

Jörgen Lidholm is a Ph.D. student at ISS. His current research interests are special purpos vision systems and robotics.
He is currently working on stereo vision based simultaneous localization and mapping for robots. He received a M.Sc. in Computer Engineering from Mälardalen University in 2007.



Martin Ekström is a PhD-student at ISS and focuses on biomedical wearable, wireless sensor network systems such as Bluetooth enabled ECG. Currently working with self-organizing and power efficient wireless sensor networks for physical monitoring. He received a M.Sc. in Electronics from MDH in 2006.

Marcus Blom is a PhD-student at ISS. His research interest is in within wireless sensor network systems and he is currently working on modeling the power consumption for these kinds of systems.

He took his degree of Master of Science in Electrical Engineering from Lunds University.

National and International research co-operation

- Delft University, Richard Goossens (Maria Lindén, Mette Holmgren)
- Prof. Ivo Fredolin, Tallin University of Technology (Maria Lindén)
- Juan Carlos Garcia Garcia, Universidad de Alcala de Henares, Spain (Mikael Ekström)
- Prof. Robert Pruers, Katolieke Universtät, Lueven, Belgium (Mikael Ekström, Ylva Bäcklund)
- A/Prof Wojciech Kuczborski, School of Computer and Information System, Edith Cowan
- Department of Biomedical Engineering, Linköpings University, Prof. Per Ask, Lars-Göran Lindberg och Peter Hult m fl. (Maria Lindén)
- Linköping Universitety Hospital, IMV, Prof. Anna-Christina Ek, Margareta Lindgren. (Maria Lindén)
- CeMID^{Care}: City of Katrineholm: Kristina Ekstrand, Jan Nilsson, County: Maj Rom, Industry network: Roger Andersson, Industry: Flodafors Lego, Screenlab AB m fl) (Maria Lindén)
- School of Textile, Borås, Lena Berglin (research"intelligent textils"). (Maria Lindén)
- Network for knowledge establishment of wireless sensor systems in hospitals and home environment. The project has been financed by SSF and coordinated from Linköping (Lars-Göran Lindberg, Peter Hult) and Västerås (Maria Lindén) and have around ten more national members.
- Örebro University, Prof Carina Johansson, Institutionen för Technology. (Maria Lindén, Ylva Bäcklund, Mikael Ekström)
- Västerås hospital, MT manager Torbjörn Alm, klin fys ing Andrew Walker (Maria Lindén)
- Örebro Universitety hospital, manager Hans-Olof Carlsén, MT manager Nils-Erik Pettersson. (Maria Lindén)
- Bosöns Elitidrottscenter, Lennart Gullstrand (Mia Folke); common research study.
- Flygmedicinskt centrum, Katarina Samuelsson (Mia Folke).

Services to the Community

Ylva Bäcklund:

- was on the grading committee for 4 PhD disseratations during 2006.
- is member of the board for the ”Teknikbrostiftelsen”, (the organisation is now named ”Innovationsbron Uppsala”. 2003 – present.
- was member of steering committe for ”Gender Forum” in Västerås, 2003-2006
- is referee/reviewer for International Journal IOPP (Institute of Physics Publishing Ltd, London).

Maria Lindén

- is a member of board of the Swedish Society of Medical Engeneering and Physics since 1999, 2004-2005 as President and from 2006 as Scientific Secretary.
- acted as a referee for the journal Medical and Biological Engineering and Computing (MBEC).
- was a member of the scientific program committee and session chair of NBC on Biomedical engineering, 2005 in Umeå and also acted as a referee.
- is the sub-dean of the Faculty Board of Mälardalen University for Natural Science and Engineering at Mälardalen University.

Lars Asplund

- has taking an active part in the creation of Robotdalen (www.robotdalen.org), which is an initiative to make Mälardalen internationally very strong in academic research and industrial development in the robotics area. The initiative involves two academic institutions MDH and Örebro University, major companies such as Volvo CE, ABB Robotics, Atlas Copco, SMT Tricept, and official representatives from the regions Örebro, Eskilstuna, Västerås, Västmanland, and Södermanland.

Interactions with society

The Sensors and Mechatronics group has been an active force in the establishment of the network *Academic ageing*, there the City of Västerås, the county council of Västmanland and several other departments of MDH are members. One of the aims is to develop technologies to help elderly and impaired persons to stay longer at home with a remained independency and life quality.

The Sensors and Mechatronics group also takes an active role in the ”CeMidCare”. Other members are Linköping University, City of Katrineholm, County Council of Sörmland, “Näringslivscentrum”, Industry, Flodafors Lego, and Screenlab AB.

Close co-operation with the department for Astro and Aeronautics at MIT, Boston (Prof Kristina Lundquist) is on-going in the SafetyChip-project.

ISS attracted funding for the following four projects from EU objective 2:

- ChipVision
  In the EU-project ChipVision there is cooperation with several companies in the Objective-2 region, that can benefit from a fast vision system. One is building grapple harvesters, and a vision system can improve the working conditions for the person handling the system, and thus lessen the probabilities for RSI-injuries.

A couple of other companies need the vision system for Quality Assurance, i.e. inspecting the manufactured parts, to see that there are no defect parts.

- EKEN-Efficient knowledge and experience reuse within the business world

  The goal of the project is to offer the participating companies methods and tools for efficient knowledge and experience management. One of the benefits is also the opportunity and facility to identify people with similar tasks and problems at different companies and share their experience.

- Competence center for microwave imaging

  The aim of the project is to use the competence built up at Mälardalen University within microwave imaging to the benefit of the region. This can be achieved in two ways, one is by knowledge driven development to create new industry; another is through business development of existing companies. Business development through new possible products, and new tehniques for raising the productivity can be achieved by companies facing novel technique at the competence centre for microwave imaging.

- Competence center - Multisensors for better health
  In the project a network between clinics, manufacturers, developers and researchers is formed in order to strengthen the competences and competitiveness in biomedical engineering and sensor technology areas. New technologies, as wearable multisensor-systems for measurements of physiological parameters, as heart activity and breathing, are developed and spread within the areas preventive health care, health care and home care. The regional industry and society will benefit from the development of new technology by an increased competence and competitiveness. Further new products and manufacturing of products might occur, as well as up-starts of new companies.

4 National Graduate Schools

In this section, four special educational programmes with strong relations to the MRTC research are.

4.1 SAVE-IT

SAVE-IT is an industrial graduate school supported by the KK-foundation with 20.8 MSEK during 2004-2010. Matching efforts are provided by participating industries. A SAVE-IT student is employed by a company and enrolled for PhD studies at a Swedish university. In 2006 14 new PhD students were accepted to SAVE-IT, giving a total of 21 students in the school. The new students were a result of a recruitment campain initiated at the beginning of 2006. Two industrial PhD students, both enrolled for PhD studies at MRTC, are also associated to SAVE-IT.

MRTC has the main responsibility for SAVE-IT, and most of SAVE-IT students (10) are also enrolled for their PhD studies at MRTC. SAVE-IT also includes industrial PhD students from Uppsala University (4), KTH (3), Linköping University (1), Halmstad University (1), Blekinge Institute of Technology (1) and Luleå University of Technology (1).

Participating companies, where the industrial PhD students are employed, include ABB Corporate Research, ABB Robotics, Arcticus Systems, Bombardier Transportation, CC Systems, Ericsson, Kalix Electropolis, Mecel AB, Pilotfish Networks AB, SAAB Aerosystems, SAAB Avitronics, Scania, Kumatsu Forest and Volvo CE. Some PhD students are employed by research institutes such as SICS and Skogforsk.

During 2006 SAVE-IT offered, in collaboration with ARTES++ (the Swedish national research school in real-time- and embedded systems), six graduate courses. In 2007 the course collaboration will continue. In 2007, ARTES++ will end, and SAVE-IT will itself be giving the graduate courses. The PhD courses will then be open for both SAVE-IT and other real-time PhD students. During 2006 SAVE-IT initiated cooperation with the industrial research school in Robotics, Automation and Process control (RAP) at Örebro University, thereby allowing SAVE-IT and RAP students to take graduate courses given by both schools.

SAVE-IT arranged during 2006 a number of network activites. During spring 2006 kick-off meetings for newly recruited SAVE-IT students were held both at MDH and LiU. Each meeting ended with a visit at a participating company, ABB Corporate Research and SAAB Aerosystems respectively. During May 2006 the SAVE-IT students travelled to Vienna, for teambuilding activities and to improve international networks and perspectives. The group visited Technical University of Vienna and the companies TTTech and the Seiberdorf Research. During October 2006 SAVE-IT gave a two day meeting at Aronsborg, Bålsta, on how to achieve successful cooperation between industry and academia. The meeting included more than 30 participants, both from academia and industry. Special focus of the two days was the roles of the industrial PhD student and the industrial mentor.

The MRTC staffs involved in SAVE-IT include Andreas Ermedahl (coordinator), Gunnar Widforss (administrator), Hans Hanssson (director) and Paul Pettersson (director of studies). SAVE-IT has a directing board with representatives from both academia and industry.

The following MRTC graduate students were enrolled in SAVE-IT graduate school during 2006:

- Markus Bohlin
- Sigrid Eldh
- Joakim Fröberg
- Håkan Gustavsson
- Kaj Hänninen
- Stefan Johnsson
- Stig Larsson
- Hongyu Pei-Breivold
- Annita Persson-Dahlquist
- Mikael Åkerholm

Following PhD studends are associated to SAVE-IT

- Johan Kraft
- Mathias Ekman

For more information on SAVE-IT, please see the SAVE-IT homepage:
http://www.mrtc.mdh.se/projects/save-it/

4.2 National Graduate School in Computer Science (CUGS)

In 2001 the Swedish National Graduate School in Computer Science (CUGS), based in Linköping, was launched. MDH/IDE participates as one of four nodes in the school. (The others, besides Linköping University, are University of Örebro and University of Skövde. Jönköping University, Lund University and Växjö University are associated members.)

The goal of the school is to produce PhDs that are well-educated in the central parts of core computer science and computer engineering. CUGS puts an emphasis on programming languages, algorithms, software engineering, also including related areas of autonomous systems, real-time systems, embedded systems, knowledge-based systems and artificial intelligence.

The CUGS curriculum consists of a core curriculum, intended to give a both broad and deep understanding of basic computer science and computer engineering at graduate level, and a selection of advanced courses that can be chosen quite freely. 60 course credits are required for a Ph.D. degree, in addition to the thesis. The students are formally enrolled at their home universities, but are also members of CUGS and will receive a special proof of this when obtaining their respective degrees.

Students are selected to CUGS by the respective participating departments. Each department is allocated a number of modules in competition with the other departments. The modules consist of two graduate students plus associated supervising faculty. During 2006 MDH/IDE has two CUGS modules, whereof one, led by Björn Lisper, was renewed, and the other was led by Mats Björkman. The modules had the following PhD students:

- Jan Carlson (High-level languages for hard real-time systems)
- Stefan Bygde (parametric WCET analysis)
- Marcelo Santos (Composable WCET analysis for component-based systems)
- Adam Dunkels (Networks of sensors, embedded systems, and IP networks)
- Jonas Neander (Proxy support for small embedded communicating devices)

4.3 The ARTES++ national graduate school

In 2003, the Swedish Foundation for Strategic Research (SSF) decided to extend the funding of the ARTES national research initiative (www.artes.uu.se) with 7 MSEK. The extension of the programme is in the form of a national graduate school in the area of real-time and embedded systems research, named ARTES++. The school annually admits 20 students that are provided with financial support for participating in graduate courses, conference trips, as well as support for a stay in industry and a longer international visit. ARTES++ annually organizes a set of graduate courses, a Ph.D. student conference, and a summer school associated with an annual meeting organized by the Swedish Real-Rime Association (SNART). Fundings for student employments or research projects are not provided by ARTES++.

In 2006, ARTES++ organized six graduate courses and a one week summer school at Nässlingen with the affiliated SNART meeting organized as a one day meeting at KTH. A one day meeting with focus on embedded systems was also organized in Stockholm by ARTES in collaboration with SNART and a number of research centra including MRTC. The following MRTC graduate students were enrolled in ARTES++ graduate school during 2006:

- Erik Olsson
- PengPeng Ni
- Ewa Hansen
- Christer Gerdtman
- Daniel Flemström
- Johan Lindhult (Eriksson)

In 2006, SFF decided to allow a prolongation of ARTES++ to include 2007. The board of ARTES has decided to admit 20 more students in January 2007, to give five courses, and to organize a summer school and a Ph.D. student conference in 2007.

4.4 The Industrial Research School in Electronic Design (IRSED)

The Industrial Research School in Electronic Design (IRSED) is a research school for multi-disciplinary graduate education in the area of electronic hardware design, involving close co-operation between several Swedish universities and colleges and participating industrial partners.
Program Manager: Peter Leisner, Acreo AB

Participating universities and colleges:

- KTH - Royal Institute of Technology
- Chalmers University of Technology
- Linköping University
- Jönköping University
- Mälardalen University
- Örebro University

Currently, the industrial partners are:

- Kitron Development AB, Jönköping
- RealFast AB, Västerås
- Acreo AB, Norrköping
  SaabTech AB, Jönköping
- Replisaurus Technologies AB, Kista
- Hardware Design Center AB, Västerås

- Syntune AB, Kista
- Ericsson AB, Kumla
- Saab Training Systems AB, Huskvarna
- RFIP AB, Västerås

The initiative to form the school was taken by Acreo and funding for up to 12 students for duration of four (4) years has been made available by the KK-foundation. In the longer perspective, the intention is to find forms for financing of the research school without the direct funding of the KK-foundation. The long-term goal is hence to provide a stable base for education of industrial Ph.D. students targeting a career in the Swedish electronics industry.

The near-time target is to establish a research school producing Ph.D. students within technical areas considered important for the future of the electronics industry in Sweden. The Ph.D. students shall during their studies also acquire skills in non-technical areas, e.g. project management, making them suitable for a future career within the electronics industry. One key point in this program is the close connection between Ph.D. students and participating companies, enabling transfer of research result to industry and transfer of industrial needs to Ph.D. students during the progression of the studies.

From MDH the following PhD students have been admitted to IRSED:

- Susanna Nordström
- Stefan Sjöholm
- Andreas Löfgren

4.5 Graduate School Intelligent Systems for Robotics, Automation and Process Control, RAP

RAP provides multi-disciplinary graduate education in the area of intelligent systems in close co-operation with four Swedish universities: Örebro Universitet, Halmstad University, Mälardalen University, and University of Skövde. All Ph D students admitted to the shool are industrial Ph D students.

Intelligent systems emulate the human ability to **perceive, reason**, **make decisions**, and **act.** Intelligent Systems, comprised of sensors, software and computers, embedded in machines and other devices are the tools that bring the power of computing technology into our daily lives and business practices.

From MDH the following PhD student is admitted to RAP:

- Markus Lindgren

5 Seminars and other events

A number of seminars and lectures were held at IDE providing a forum for presentation and discussion of research within in MRTC, Progress and ISS as well as lectures by external scientists. Additionally, IDE organised several workshops and schools with both external industrial and academic participation.

The IDE seminars are on topics of general interest to the Computer Science and/or Electronics community, with a slight bias towards real-time systems. We also have more focused research talks organised by our different labs.

Conferences and Seminars

CemidCare and Robotdalen

The 5 December the seminar: ***Transport data – not patients*** was helt in Västerås. The seminar attracted 50 participants and was organised by Maria Lindén (MDH), Peter Hult (LiU) and Staffan Dryselius (Robotdalen) and chaired by Maria Lindén. The seminar attracted participants from Sweden, both from industry, community and academia.

MRTC seminars

- Panagiotis Katsaros Petri Nets - *Towards a formal analysis approach based on the use of Colored Petri Nets, Timed Colored Petri Nets and the CPN Tools*
- Ioannis Stamelos and Panagiotis Katsaros *Research at Thessaloniki University*

ISS seminar

In December ISS arranged a research day. The seminar attracted 50 participants both from industry, community and academia.

Progress seminars

- Pasqualina Potena *Composition of non-functional attributes in software systems*
- Cristina Seceleanu *A Methodology for Constructing Correct Reactive Systems*
- Jakob Axelsson *The Role of Uncertainty in Product Development*
- Thomas Nolte *Server-CAN- Share-driven scheduling of CAN*
- Dag Nyström *Data Management in Vehicle Control-Systems*
- Radu Dobrin *Combining Off-line Schedule Construction and Fixed Priority Scheduling in Real-Time Embedded Computer Systems*
- Prof. Frantisek Plasil *Component code model checking against behavior specification*
- Rikard Land Software *Systems In-House Integration: Observations and Guidelines concerning Architecture and Process*
- Insik Shin *Compositional Real-Time Scheduling Framework*

Other seminars

- Cristina Seceleanu *Constructing Correct Reactive Systems*
- Luciano Floridi, Oxford University: *A Subjectivist Interpretation of Relevant Information*
- Filip Sebek *Seminar about trace cacheing*
- Vincent C. Müller *Content in Digital Systems*
- Vincent C. Müller *On the Possibility of Hypercomputing Supertasks*
- Christina Björkman *Seminarium om genus i datavetenskap/teknik*

Conferences
During June 27 - July 1, two conferences have been organized and held MDH:

- 2nd International Conference on the Quality of Software Architectures (QoSA'06)

- The 9th International Symposium on Component-Based Software Engineering (CBSE'06)

with about 150 international participants. The CBSE Symposium is one of the leading events in CBSE.

6 Publications

6.1 Research publications MRTC

Books

1. Hans Hansson: *ARTES – A network for Real-Time research and graduate Education in Sweden*, Uppsala University, ISBN: 91-506-1859-8, February, 2006.
2. Ian Gorton , George Heineman, Ivica Crnkovic, Heinz Schmidt, Judith Stafford, Kurt Wallnau: *Component-Based Software Engineering, 9th International Symposium, CBSE 2006*, Springer, Lecture Notes in Computer Science 4063, ISBN: ISBN 3-540-35628-2, 2006
3. Ivica Crnkovic, Christine Hofmeister, Ralf Reussner: *Quality of Software Architectures, Second International Conference on Quality of Software Architectures, QoSA*, Springer Berlin / Heidelberg, ISBN: ISBN-10: 3-540-48819-7, 2006

Journals

4. Gordana Dodig-Crnkovic, Susan Stuart *(Glasgow University)*: *Special Issue: Selected Papers From ECAP 2005 - Introduction*, tripleC, vol 4, nr 2, November, 2006
5. Rikard Land, Ivica Crnkovic: *Software Systems In-House Integration: Architecture, Process Practices and Strategy Selection*, Journal of Information and Software Technology, Elsevier, September, 2006
6. Thomas Larsson, Tomas Akenine-Möller : *A dynamic bounding volume hierarchy for generalized collision detection*, Computers & Graphics, vol 30, nr 3, p451-460, Elsevier Ltd, June, 2006
7. Gordana Dodig-Crnkovic, Virginia Horniak : *Togetherness and Respect - Ethical Concerns of Privacy in Global Web Societies*, AI & Society, vol 20, nr 3, May, 2006
8. Mikael Åkerholm, Jan Carlson, Johan Fredriksson, Hans Hansson, John Håkansson *(Department of Information Technology, Uppsala University)*, Anders Möller, Paul Pettersson, Massimo Tivoli: *The SAVE approach to component-based development of vehicular systems*, Journal of Systems and Software, Elsevier, May, 2006
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10. Jan Gustafsson, Björn Lisper, Raimund Kirner , Peter Puschner : *Code Analysis for Temporal Predictability*, Real-Time Systems, vol 32, nr 3, p253 - 277, Springer-Verlag, March, 2006
11. Elena Fersman *(Ericsson Research, Sweden)*, Leonid Mokrushin *(Department of Information Technology, Uppsala University)*, Paul Pettersson, Wang Yi : *Schedulability Analysis of Fixed Priority Systems using Timed Automata*, Theoretical Computer Science, vol 354, nr 2, p301-317, Elsevier, March, 2006

Theses

12. Frank Lüders: *An Evolutionary Approach to Software Components in Embedded Real-Time Systems*, Ph D Thesis, Mälardalen University Press, December, 2006
13. Kaj Hänninen: *Introducing a Memory Efficient Execution Model in a Tool-Suite for Real-Time Systems*, Licentiate Thesis, MRTC, September, 2006
14. Rikard Land: *Software Systems In-House Integration: Observations and Guidelines concerning Architecture and Process*, Ph D Thesis, Mälardalen University Press, September, 2006
15. Thomas Nolte: *Share-Driven Scheduling of Embedded Networks*, Ph D Thesis, Mälardalen University Press, May, 2006
16. Ali Fard: *Analysis and Design of Low-Phase-Noise Integrated Voltage-Controlled Oscillators for Wide-Band RF Front-Ends*, Ph D Thesis, Mälardalen University, January, 2006
17. Gordana Dodig-Crnkovic: *Investigations into Information Semantics and Ethics of Computing*, Ph D Thesis, Mälardalen University Press, 2006

Articles in collection

18. Anders Wall, Johan Andersson, Christer Norström: *Decreasing Maintenance Costs by Introducing Formal Analysis of Real-Time Behavior in Industrial Settings*, LNCS 4313: Leveraging Applications of Formal Methods, p 130-145, Springer Berlin/Heidelberg, ISBN: 978-3-540-48928-3, November, 2006
19. Thomas Nolte, Mikael Nolin, Hans Hansson: *Real-Time Server-Based Communication for CAN*, ARTES - A network for Real-Time research and graduate Education in Sweden, p 353-372, ISBN: 91-506-1859-8, Editor(s): Hans Hansson, May, 2006
20. Johan Andersson, Anders Wall, Christer Norström: *A Framework for Analysis of Timing and Resource Utilization targeting Complex Embedded Systems*, ARTES - A network for Real-Time research and graduate Education in Sweden 1997 – 2006, p 297-329, Uppsala University, ISBN: 91-506-1859-8, Editor(s): Hans Hansson, 2006
21. Björn Lisper: *Trends in Timing Analysis*, From Model-Driven Design to Resource Management for Distributed Embedded Systems, p 85-94, Springer Boston, ISBN: 978-0-387-39361-2, 2006

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22. Mikael Åkerholm, Jan Carlson, Johan Fredriksson, Hans Hansson, Mikael Nolin, Thomas Nolte, John Håkansson *(Department of Information Technology, Uppsala University)*, Paul Pettersson: *Handling Subsystems using the SaveComp Component Technology*, Workshop on Models and Analysis for Automotive Systems (WMAAS'06) in conjunction with the 27th IEEE Real-Time Systems Symposium (RTSS'06), Rio de Janeiro, Brazil, Editor(s):Marco Di Natale and Luis Almeida, December, 2006
23. Damir Isovic: *Flexible Media Processing in Resource Constrained Real-Time Systems*, Proceedings of the Eighth IEEE International Symposium on Multimedia (ISM 2006), IEEE Computer Society, San Diego, California, USA, December, 2006
24. Kaj Hänninen, Jukka Mäki-Turja, Markus Bohlin, Jan Carlson, Mikael Nolin: *Determining Maximum Stack Usage in Preemptive Shared Stack Systems*, The 27th IEEE Real-Time Systems Symposium, Rio de Janeiro, Brazil, December, 2006
25. Moris Behnam, Insik Shin, Thomas Nolte, Mikael Nolin: *Real-Time Subsystem Integration in the Presence of Shared Resources*, Proceedings of the Work-In-Progress (WIP) session of the 27th IEEE Real-Time Systems Symposium (RTSS'06), Rio de Janeiro, Brazil, December, 2006
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28. Damir Isovic: *A Web-based Platform for Distance Education*, Proceedings of the 4th IEEE CeTUSS Workshop, IEEE Nordic Education Society Chapter, Uppsala, Sweden, December, 2006
29. Gordana Dodig-Crnkovic: *Philosophy of Information, a New Renaissance and the Discreet Charm of the Computational Paradigm*, L . Magnani, Computing, Philospphy and Cognition - Selected Papers from E-CAP 2004, King's College Publications (Dov Gabbays publisher), London, Editor(s):L Magnani, November, 2006
30. Lucia Lo Bello *(University of Catania, Italy)*, Giordano A. Kaczynski *(University of Catania, Italy)*, Thomas Nolte, Gino Sorbello *(University of Catania, Italy)*, Francesco Sgro *(KORE University, Italy)*, Orazio Mirabella *(University of Catania, Italy)*: *An approach to support UAV to ground station real-time communications in a land monitoring system*, International Congress ANIPLA 2006 - Methodologies for emerging technologies in automation, University of Rome, Rome, Italy, November, 2006
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32. Pengpeng Ni, Damir Isovic, Gerhard Fohler: *User-friendly H.264/AVC for Remote Browsing*, Proceedings of the International ACM Multimedia conferance (ACM 06), Santa Barbara, California, USA, October, 2006
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37. Joakim Fröberg, Peter Wallin, Jakob Axelsson: *Towards Quality Assessment in Integration of Automotive Software and Electronics: An ATAM approach*, Proceedings of the 6th Conference on Software Engineering and Practice in Sweden, Umeå University, Umeå, Sweden, October, 2006
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44. Gordana Dodig-Crnkovic: *On the Importance of Teaching Professional Ethics to Computer Science Students*, Computing and Philosophy Conference, E-CAP 2004, Pavia, Italy, Associated International Academic Publishers, Pavia, Editor(s):L Magnani, August, 2006
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47. Sigrid Eldh, Hans Hansson, Sasikumar Punnekkat, Anders Pettersson, Daniel Sundmark: *A Framework for Comparing Efficiency, Effectiveness and Applicability of Software Testing Techniques*, Testing: Academic and Industrial Conference (TAIC-PART, Windsor, UK, August, 2006
48. *Swedish National Course in Philosophy of Computer Science*, , Rensselaer Polytechnic Institute, North American Computing and Philosophy Conference, August, 2006
49. Gordana Dodig-Crnkovic: *Swedish National Course in Philosophy of Computer Science*, , Rensselaer Polytechnic Institute, North American Computing and Philosophy Conference, August, 2006
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51. Jakob Axelsson: *Cost Models with Explicit Uncertainties for Electronic Architecture Trade-off and Risk Analysis*, Proc. 16th International Symposium of the International Council on Systems Engineering, Orlando, Florida, July, 2006

52. Andreas Johnsson, Mats Björkman: *Measuring the Impact of Active Probing on TCP*, International Symposium on Performance Evaluation of Computer and Telecommunication Systems, Calgary, July, 2006
53. Thomas Nolte, Lucia Lo Bello *(University of Catania, Italy)*, Hans Hansson: *Facilitating subsystem integration by decoupling priority and identifier in CAN messages*, Proceedings of the 5th International Workshop on Real-Time Networks (RTN'06) in conjunction with the 18th Euromicro International Conference on Real-Time Systems (ECRTS'06), Dresden, Germany, Editor(s):Jean-Dominique Decotignie, July, 2006
54. Johan Fredriksson: *Increasing Accuracy of Property Predictions for Embedded Real-Time Components*, 18th Euromicro Conference on Real-Time Systems (ECRTS 06), WiP, July, 2006
55. Irena Pavlova *(Faculty of Math. and Informatics, Sofia University)*, Mikael Åkerholm, Johan Fredriksson: *Application of Built-In-Testing in Component-Based Embedded Systems*, The Role of Software Architecture for Testing and Analysis (ROSATEA'06), Portland, Maine, USA, July, 2006
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60. Jonas Neander, Ewa Hansen, Jukka Mäki-Turja, Mikael Nolin, Mats Björkman: *Prolonging Network Lifetime in Long Distance Sensor Networks using a TDMA Scheduler*, The Fifth Annual Mediterranean Ad Hoc Networking Workshop. Med-Hoc-Net 2006, Lipari, Sicily (Italy), June, 2006
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67. Ivica Crnkovic, Karmela Aleksić-Maslač , Hrvoje Jerković : *Holistic approach in Education – Filling the Gap between Different Disci-plines*, 28th International Conference on Information Technology Interfaces, 2006., p 35-40, IEEE, Cavtat, Croatia, June, 2006
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70. Svante Ekelin, Martin Nilsson, Erik Hartikainen *(Linköping University)*, Andreas Johnsson, Jan-Erik Mångs *(Ericsson)*, Bob Melander, Mats Björkman: *Real-time Measurement of End-to-End Available Bandwidth Using Kalman Filtering*, In proceedings to the Network Operations and Management Symposium, Vancouver, Canada, April, 2006

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78. Jonas Neander, Ewa Hansen, Mikael Nolin, Mats Björkman: *Asymmetric Multihop Communication in Large Sensor Networks*, International Symposium on Wireless Pervasive Computing 2006, ISWPC, Phuket, Thailand, January, 2006

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80. Kaj Hänninen, Jukka Mäki-Turja, Markus Bohlin, Jan Carlson, Mikael Nolin: *Analysing Stack Usage in Preemptive Shared Stack Systems*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-202/2006-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, July, 2006
81. Rikard Land, Peter Thilenius *(School of Business, Mälardalen University)*, Stig Larsson, Ivica Crnkovic: *A Quantitative Survey on Software In-house Integration*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-203/2006-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, July, 2006
82. Hans Hansson: *Annual Report 2005*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-200/2006-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, April, 2006
83. Ylva Boivie, Hans Hansson, Maria Lindén: *Annual Report 2005 - Department of Computer Science and Electronics*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-201/2006-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, April, 2006
84. Hans Hansson: *ARTES - A Network for Real-Time Reasearch and graduate Education in Sweden 1997 - 2006*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-197/2006-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, March, 2006
85. Jonas Neander, Ewa Hansen, Jukka Mäki-Turja, Mikael Nolin, Mats Björkman: *A TDMA scheduler for the AROS architecture*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-198/2006-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, March, 2006
86. Ewa Hansen, Jonas Neander, Mikael Nolin, Mats Björkman: *Efficient Cluster Formation for Sensor Networks*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-199/2006-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, March, 2006
87. Anders Möller, Mikael Åkerholm, Joakim Fröberg, Johan Fredriksson, Mikael Nolin: *Industrial Requirements on Component Technologies for Vehicular Control Systems*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-195/2006-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, February, 2006
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90. Andreas Johnsson: *A doctoral thesis proposal: Implementation, Evaluation and Modeling of IP Network Bandwidth Measurement Methods*, Technical Report, MRTC, August, 2006
91. Damir Isovic, BETSY consortium : *Temporal impact of high-level resources on end-to-end timing of video streaming*, Technical Report, Mälardalen University, Sweden, May, 2006
92. Mikael Åkerholm, Irena Pavlova *(Faculty of Math. and Informatics, Sofia University)*, Johan Fredriksson: *Application of Built-In-Testing in Component-Based Embedded Systems*, Technical Report, MRTC, May, 2006
93. Filip Sebek: *Academic Dishonesty - an IDE perspective*, Technical Report, IDE, March, 2006
94. Birgitta Lindström *(University of Skövde)*, Paul Pettersson: *Model-Checking with Insufficient Memory Resources*, Technical Report, HS- IKI -TR-06-005, School of Humanities and Informatics, University of Skövde, February, 2006

6.2 Research publications ISS

Books

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Journals

2. Gordana Dodig-Crnkovic, Susan Stuart *(Glasgow University)*: *Special Issue: Selected Papers From ECAP 2005 - Introduction*, tripleC, vol 4, nr 2, November, 2006
3. Peter Funk, Ning Xiong: *Case Based Reasoning and Knowledge Discovery in Medical Applications with Time Series*, Journal of Computational Intelligence, vol 22, nr 3/4, p238-253, Blackwell Publishing, August, 2006
4. Ning Xiong, Peter Funk: *Building similarity metrics reflecting utility in case-based reasoning*, Journal of Intelligent & Fuzzy Systems, vol 17, nr 4, p407-416, IOS Press, August, 2006
5. Ning Xiong, Peter Funk: *Construction of Fuzzy Knowledge Bases Incorporating Feature Selection*, Journal of Soft Computing - A Fusion of Foundations, Methodologies and Applications, vol 10, nr 9, p796-804, Spring Verlag, July, 2006
6. Gordana Dodig-Crnkovic, Virginia Horniak: *Togetherness and Respect - Ethical Concerns of Privacy in Global Web Societies*, AI & Society, vol 20, nr 3, May, 2006
7. Gordana Dodig-Crnkovic, Virginia Horniak : *Ethics and Privacy of Communications in Global E-Village*, ENCYCLOPEDIA OF DIGITAL GOVERNMENT, March, 2006
8. Mikael Hedelind *(ABB)*, Peter Funk, Milun Milic *(ABB Automation)*: *Intelligent Buffer Storage System – Enabling Fast and Flexible Assembling with Industrial Robots*, Journal of Intelligent & Fuzzy Systems, p8, IOS Press, March, 2006

Theses

9. Javier Garcia Castaño: *Algorithms and Protocols Enhancing Mobility Support for Wireless Sensor Networks Based on Bluetooth and Zigbee*, Ph D Thesis, Mälardalen Universtiy Press, September, 2006
10. Krister Landernäs: *Implementation of digital-serial LDI/LDD allpass filters*, Ph D Thesis, Västerås, Mälardalens University, September, 2006
11. Jonas Neander: *Using existing infrastructure as support for wireless sensor networks*, Licentiate Thesis, Mälardalen University Press, June, 2006
12. Annika Jonsson: *Pressure Sore Etiology - Highlighted with Optical Measurements of the Blood Flow*, Licentiate Thesis, Mälardalen University Press, May, 2006
13. Ali Fard: *Analysis and Design of Low-Phase-Noise Integrated Voltage-Controlled Oscillators for Wide-Band RF Front-Ends*, Ph D Thesis, Mälardalen University, January, 2006
14. Gordana Dodig-Crnkovic: *Investigations into Information Semantics and Ethics of Computing*, Ph D Thesis, Mälardalen University Press, 2006

Conferences and workshops

15. Gordana Dodig-Crnkovic: *Philosophy of Information, a New Renaissance and the Discreet Charm of the Computational Paradigm*, L . Magnani, Computing, Philospphy and Cognition - Selected Papers from E-CAP 2004, King's College Publications (Dov Gabbays publisher), London, Editor(s):L Magnani, November, 2006
16. Christer Gerdtman, Maria Lindén: *Utveckling av en gyrobaserad datormus för funktionshindrade med begränsad rörelseförmåga*, Svensk Förening för Medicinsk Teknik och Fysik, Svenska Läkaresällskapets Riksstämman, Göteborg, November, 2006
17. Annika Jonsson, Sara Bergstrand , Margareta Lindgren *(Medicine and Care Nursing Science, Faculty of Health Science, Linköpings University)*, Anna-Christina Ek , Maria Lindén: *Blodflödesmätningar för att studera uppkomst uppkomst och förebyggande av trycksår*, Svenska Läkarsällskapets Riksstämman, 29 nov-1 dec, Gothenburg, Sweden, November, 2006
18. Gordana Dodig-Crnkovic: *Professional Ethics in Computing and Intelligent Systems*, Ninth Scandinavian Conference on Artificial Intelligence (SCAI 2006), p 11-18, Espoo, Finland, Editor(s):Eero Hyvönen, Tomi Kauppinen, Jukka Kortela, October, 2006
19. Peter Funk, Ning Xiong: *Discovering Knowledge about Key Sequences for Indexing Time Series Cases*, European Conference on Case-Based Reasoning, 2006, p 15, Springer, Turkey, September, 2006
20. Shahina Begum, Mobyen Ahmed, Peter Funk, Ning Xiong, Bo von Schéele *(PBMStressMedicine AB)*: *Using Calibration and Fuzzification of Cases for Improved Diagnosis and Treatment of Stress*, 8th European Conference on Case-based Reasoning workshop proceedings, p 113-122, Turkey 2006, Editor(s):M. Minor, September, 2006
21. Rikard Lindell: *Assessment, Sorting and Collecting of a Thousand Drawings*, The First International Symposium on Culture, Creativity and Interaction Design (CCID2006) of The 20th BCS HCI Group conference in co-operation with ACM, Springer, London, September, 2006
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23. Gordana Dodig-Crnkovic: *Swedish National Course in Philosophy of Computer Science*, , Rensselaer Polytechnic Institute, North American Computing and Philosophy Conference, August, 2006
24. Peter Funk, Ning Xiong: *Discovering Key Sequences in Time Series Data for Pattern Classification*, 6th Industrial Conference on Data Mining, ICDM 2006, p 492-505, Springer, LNAI 4065, Leipzig, Germany, Editor(s):Petra Perner, July, 2006
25. Linda Rattfält *(Linköping University)*, Christer Ahlström , Lena Berglin , Maria Lindén, Peter Hult *(Linköping University)*, Per Ask , Urban Wiklund, : *A canonical correlation approach to heart beat detection in textile ECG measurements*, MEDSIP 2006, 17-19 July, Glasgow, UK, July, 2006
26. Gordana Dodig-Crnkovic: *Model Validation, Evolutionary Systems and Semantics of Information*, Model-Based Reasoning In Science And Engineering Abduction, Visualization, And Simulation, Pavia, Italy, December 16-18, 2004, King's College Publications, London, Editor(s):L Magnani, June, 2006
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28. Ewa Hansen, Jonas Neander, Mikael Nolin, Mats Björkman: *Energy-Efficient Cluster Formation for Large Sensor Networks using a Minimum Separation Distance*, The Fifth Annual Mediterranean Ad Hoc Networking Workshop, Lipari, Italy, June, 2006
29. Peter Funk, Erik Olsson, Marcus Bengtsson *(IDP)*, Ning Xiong: *Case-Based Experience Reuse and Agents for Efficient Health Monitoring, Prevention and Corrective Actions*, proceedings of the 19th International Congress on Condition, COMADEM 2006, p 445-453, Luleå, Sweden, Editor(s):Kumar, U., Parida A., Rau R.B.K.N., June, 2006
30. Gordana Dodig-Crnkovic: *PI - Swedish National Course in Philosophy of Computer Science*, , Norwegian University for Science and Technology -, June, 2006
31. Gordana Dodig-Crnkovic: *Bildning & Computing*, Ämneskonferens i datavetenskap och numerisk analys, KTH, Stockholm, June, 2006
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37. Pietro Andreani *(Technical University of Denmark)*, Ali Fard: *A 2.3GHz LC-Tank CMOS VCO with Optimal Phase Noise Performance*, IEEE International Solid-State Circuits Conference (ISSCC), February, 2006
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41. Sofi Elfving *(IDP)*, Peter Funk: *Enabling Knowledge Transfer in Product Development and Production – Methods and Techniques from Artificial Intelligence*, The 1st Nordic Conference on Product Lifecycle Management, p 13, Gothenburgh, January, 2006

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45. Annika Jonsson: *New sensor design made to discriminate between tissue blood flow at different tissue depths at the sacral area.*, Technical Report, MRTC, April, 2006
46. Filip Sebek: *Academic Dishonesty - an IDE perspective*, Technical Report, IDE, March, 2006

6.3 MSc Theses

The following MSc-theses have been presented at IDE in 2006:

1. Magnus Tysell, Joel Höglund: Robot Interface Development System on chip solution for I/o interface
2. Anam Mohammad Khairul: Component-based repository
3. Muhammad Qaiser Saleem: Data Warehousing - a university course
4. Ulf Stenlund: Datorgrafik inom svensk industri förr, nu och i framtiden
5. Erik Stenerås: Analys av en optisk pockelscellsteknik för att mäta elektriska fält och ytladdningsfördelningar
6. Ahmed Kamran Mahmood Khan: A Modeling Tool for Component-Based Applications
7. Anders Thorell: Sensortillämpning med Zigbee
8. Jonas Ferm, Thomas Wisborg: Kartläggning av lagerströmmar och statusbestämning av jordlinenät på Forsmark Kraftgrupps kärnkraftverk
9. David Espinosa Alfaro: Simulation of Bluetooth Scatternet for battery life optimization

10. Morten Meek: Development and optimization of test module MPT for ABB´s high voltage products
11. Tommy Sahi: Modellering och reglering av ett pneumatiskt aktuatorsystem
12. Karl Wenjie Huang: Analys av haveririsker för högspända filterbankbrytare HPL 550B2
13. Fredrik Engberg: Den generella veversättningsutrustningen
14. Tiago Silva: Design of a portable meaurement system for detecting the anaerobic threshold
15. Nikola Petrovic, Fawaz Al Gailani: Wireless embedded monitoring systems
16. Annika Hyttinen Lundmark: Electrical calculation of leakage reactance for coarse/fine on-load tap-changers
17. Hans Thyr: Statusbestämning av Övertornshalten för Forsmark 1 och 2
18. Sami Saari: Automatisering av drivsystems testning och rapportering
19. Mikael Lindborg: Tracking multiple objects with kalman filters part II
20. Rajesh Babu Madela: Design of 2.5Gb/s Clock and Data Recovery Circuit
21. Johanna Broddfelt: Tracking multiple objects with kalman filters part I
22. Serrano Diaz Paul: Design of a Gyrofree Inertial Navigation System
23. Per Sandberg: Spectrum Expert System
24. Tobias Helfridsson, Daniel Wennström: A Decision Support System for Executive Business Management
25. Tatjana Grebensjikova, Marie Hjalmarsson: Line converter control with varying switching frequency
26. Piero Belviso, Federico Capvani: Software Component Services for Windows CD
27. Oscar Lagerqvist: Case Retrieval Nets in the Case Base Reasoning Framework jCOLIBRI
28. Johan Nilsson: Design and implementation of method for on-line measurement and characterization of voltage dips
29. Mattias Karlsson, Andreas Selenwall: The analysis and classification of capnography time series by artificial intelligence methodologies
30. Andreas Harnesk, David Tenser: Real-Time Performance of Windows XP Embedded
31. Stefan Hermansson: A customizable and versatile partial discharge measurement framework
32. Erik Hellström: GUI for Rational Robot Programming Logic
33. Miguel Alcon Condori, Homan Mohajeri: Polarization Curves For Marine Experiments
34. Daljit Chadda Padam, Daniel Rydmell: Tillståndsövervakning av högspänningsbrytare Online monitoring of circuit breakers (SEKRETESS)
35. Mikael Säfström, André Berggren: Conventional OCR Technologies in New Domains
36. Ulrik Törnqvist: Dektering av kolbana i solida material till högspänningskomponenter
37. Mari Högström, Janne Välimäki: ABB´s new generation of CVT
38. Lars Lindqvist: Aktiv last för roderservotestbänk
39. Lasse Husdal, Samir Sahuric: Faskompensering
40. Björn Thor: Internet i inbyggda system
41. Nasrullah Iqbal, Ashraf Muhammad Hassan: Evaluation of jCOLIBRI
42. Niklas Bjernekull: Refitting Bounding Boxes for Globally Deformed Objects
43. Anders Rönnholm: Evaluation of Real-Time Operating Systems for Xilinx MicroBlaze CPU
44. Laurens Blankers: Techniques and Process for Assessing Compatibility of Third-Party Software Components
45. Isak Savo, Johan Skarström: Automatic Diagnostic Data Collection
46. Agbaegbu John Bosco, Aluebhosele Maurice: Experience Sharing Over the Internet Case study e-learning
47. Natarajan Rajeshkumar: Denoising of visual evoked potential
48. Kalle Gustafsson: Artificiell Intelligens i Datorspel- En fallstudie för spelet Power House
49. Kuku Babatunde: Efficient Remote Instruction Procedures Using Case Base Reasoning
50. Farshid Atachi, Amir Sejdinovic: Methods for software quality improvement
51. Zoltan Nagy: HW/SW Co-design of embedded systmes within Alteras design environment
52. Aysan Huseyin Ayhan, Jörgen Lidholm, Peter Wallin: An Autonomous Robot for Finding Exhaust Pipes
53. Stefan Bygde: Abstract Interpretation and Abstract Domains
54. Joakim Rosendahl: Axonometri i tvådimensionella spel
55. Markus Pettersson: GIS Platforms For WinCE
56. Joel Ek: CoDeSys on CCP XS for Bromma Conquip
57. Ahsan Jawed, Sardar Mehdi Kazim: Real-Time Database Management Support in a Component Framework
58. Patrik Hildenborg Andrea Massaro: Power House Utveckling och studie av ett pedagogiskt spel
59. Mauricio Villasmil: Dielektrisk dimensionering av 800 KV DC förbikopplare
60. Andreas Hjertström: Simulation Control Panel
61. Maria Karlsson: Test System for Improved Hardware Tests

62. Muhammad Asif: UDP Software for Ethernet_Lite
63. Faisal Khizer, Gurjodh Dhillon, Ahmad Shoaib: Use of Software Component Models in Embedded Real-Time Systems
64. Charbel Thoumy, Joel Verpers: Implementering av ett säkert trådlöst nätverk på SMHI
65. Simon Rydberg: Using the Principle of Refactoring to Implement a Graphical User Interface
66. Joel Byrén, Bingxin Song: Implementation of bridge and server for historical data
67. Martin Collberg, Erik Hugne: Performance Monitoring using built in processor support in a complex real time environment
68. Katharina Wennerström: Environment for Brake By Wire System Development
69. Khan Hassan Bin Tariq, Malik Khurram: Quality-aware frame skipping for MPEG-2 video based on interframe similarity
70. Riasat Abbas: User Perceived Quality-of-Service in Multimedia Applications
71. David Haglund: Systemanpassad Transmissionslänk för Flygmätning
72. Martin Ekström: Small wireless ECG with Bluetooth communication to a PDA
73. Anjum Abdullah, Gorbani Majid, Shahzad Khurram: Master Education Management System
74. Fadi Hanna, Fareed Humud: Utveckling av en högpreciserad noninvasiv teknik för detektering av Ocular Micro-Tremor med IR-ljus
75. Peter Larsson: Sensor communication characteristics a comparison of LIN, PS15, ACL and PWM
76. Murali Krishna Ganta: Building high- security web applications
77. Johan Krüger:Developing a Product Data Management prototype system