Annual Report
2005

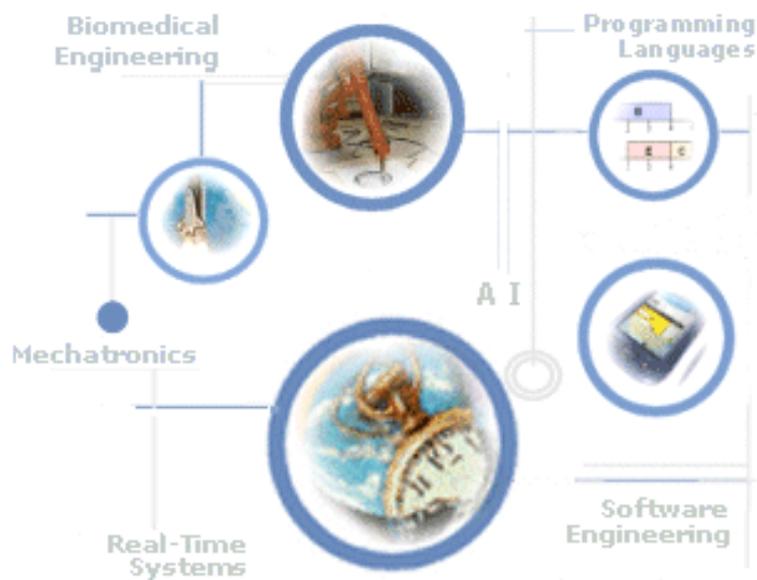## Department of
Computer Science
and Electronics

MRTC

MÄLARDALEN REAL-TIME
RESEARCH CENTRE

ISS
Intelligent Sensor Systems

www.mrtc.mdh.se
Annual Report 2005
Summary

The Department of Computer Science and Electronics is the most research intensive department at Mälardalen University (MdH), with 11 professors, several additional senior researchers and more than 50 postgraduate students. The research is organized in two different research profiles – Mälardalen Real-Time Research Centre (MRTC) and the newly established 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 a merging profile and as such also receive dedicated funding. The plan is to submit an application for establishment of a research profile to the KK-foundation in 2006.

This report presents the organisation, projects and achievements of IDE in 2005, a year of reorganisation and preparations for the future, with the following high-lights:

- Eleven Ph.D. theses (Baran Cürüklü, Jukka Mäki-Turja, Markus Nilsson, Tomas Lenvall, Radu Dobrin, Gustaf Næser, Dag Nyström, Christina Björkman, Magnus Jansson, Mia Folke, Kai Pietiläinen) were successfully defended.
- Twelve Licentiate theses (Mikael Åkerholm, Anders Möller, Adam Dunkels, Johan Fredriksson, Andreas Johnson, Stig Larsson, Johan Andersson, Erik Olsson, Waldemar Kocjan, Annita Persson Dalhqvist, Jens Lönnblad, Tord Johnsson) were successfully defended.
- 3 new Ph.D.-students have been enrolled
- 43 MSc-theses, and 139 publications, many presented at leading conferences world-wide.
- The strategic centre proposal PROGRESS was in the toughest of national competitions awarded 43 MSEK by the Swedish Foundation for Strategic Research.
- Three new different projects were granted funding from the KK-foundation, a total of 7.4 MSEK
  - Extract
    A project aiming at improving maintainability of complex software systems.
  - Multex
    Our ongoing project MultEx received external funding in December. 2.9MSEK over three years was granted from the Knowledge Foundation (KKS)
  - WCET
    The Programming Languages group was awarded a grant from the KK-foundation to continue its research in WCET analysis.
- The MRTC profile was evaluated, and the peer-review report stated the following:
  "Overall, the panel found that, despite the short space of time the MRTC has had to establish itself as one of Sweden's leading contributors to real-time research and its limited funding for basic research, it has been very successful in implementing its three-pronged vision, albeit to varying degrees."
- SSF granted 41 MSEK during 4 years to Factory-in-a-Box with Peter Funk as co-applicant.

MÄLARDALENS HÖGSKOLA

MED STÖD AV
STIFTELSEN FÖR KUNSKAPS-
OCH KOMPETENSUTVECKLING

Preface

2005 has been a year of transition. It was not only the first year without profile grant from KKS, it was additionally the first year under the umbrella of the department of Computer Science and Electronics, which was established January 1st 2005 by merging IDt with the department of Electronics (IEl). As a result, the organisation of research has been restructured into two separate profile areas: Intelligent Sensor Systems (ISS) and MRTC. In this restructuring, the AI, Robotics, and Sensor Networks research previously within in MRTC have joined the Biomedical Engineering and Mechatronics research from IEl to form the ISS profile. A plan with clear ambitions for the coming years for both ISS and MRTC has been developed. For ISS the ambition is to consolidate and integrate activities further and to submit an application to KKS to obtain a profile grant. For MRTC, the main ambitions are further increase of quality and international recognition, as well as continued strong industrial cooperations and commercializations. Extensive efforts have been spent in 2005 to package these ambitions into two major grant applications. The PROGRESS application was in very tough national competence awarded 43 MSEK for the coming five years by the Swedish Foundation for Strategic Research. The second application, VinnMRTC, is currently being evaluated by Vinnova. These proposals both have a focus on Component-based Development of Embedded Software, but are complementary in that PROGRESS includes more long-term basic research, whereas VinnMRTC is a competence centre with industrial participation in research projects and stronger focus on deployment of research results.

Despite the substantial mental energy invested in the future, 2005 was also a year of continued high production in research; with 11 PhDs, 12 Licentiates, and 139 peer-reviewed publications. On the other hand, due to shortage of funding we could only recruit 3 new PhD-students. This creates a slight structural problem in the organisation, but since plans and funding are available for recruiting students in 2006 we expect the long-term effects to be relatively small.

2005 was also a year of closing the books of the KK-funded MRTC-profile. During autumn 2005 an evaluation of the results and impact of the MRTC profile grant was performed by Faugert & Co and Technopolis on the behalf of the KK-foundation. The evaluation consisted of two main parts:

- An evaluation performed by Faugert & Co based on a self-evaluation and other documents provided by MRTC, and on interviews with MRTC and MdH staff and with industrial and other cooperation partners
- A scientific peer-review conducted by the internationally reputed scientists Wolfgang Halang, Leo Motus, and Joseph Sifakis

The full evaluation report is available at the KK-foundation web-site www.kks.se. In appendix A the main conclusions of the evaluation are presented.

2005 has been a year of hard work and restructuring with focus on paving the way for a strong and prosperous future. It is extremely satisfying that this work seems to have paid off; in terms of funding, as well as in a strong organisation with lots of people that believe in what they are doing and that are prepared to take the next step.

Hans Hansson
Research Director IDE
Västerås, March 2006

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1 Department of Computer Science and Electronics

During the year 2004 the dept. of Computer Science and the dept. of Electronics merged together in the same building and during 2005 the merge was completed in such a way that the two departments fused into one – the Department of Computer Science and Electronics (IDE). The fusion was completed unexpectingly smooth and has actually surpassed our expectations. This is manifested through new and fruitful collaborations between research groups that earlier did barely know of each other.

IDE is the most research intensive department at MdH, with 11 professors, several additional senior researchers and more than 50 postgraduate students. The research is organized in two different research profiles – Mälardalen Real-Time Research Centre (MRTC) and the newly established 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 12 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; Senior lecturer Sasikumar Punnekkat and 7 PhD students, five of them industrial PhD students, 4 licentiate theses 2005, 2 PhDs planned for 2006, focusing on research related to software engineering in industrial setting, 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 Dag Nyström, 6 graduate students; 2 licentiates and 1 PhD 2005; focusing on Embedded Systems Software Engineering (e.g. for automotive and industrial robotics systems); funding from SSF, ABB, Volvo, KKS, Vinnova and MdH.

c) **Predictably Flexible Real-Time Systems group** – headed by Prof. Gerhard Fohler; lecturer Damir Isovic, 4 graduate students; 2 PhD 2005; 1 PhD planned for 2006; focusing on static and dynamic real-time scheduling, combining flexibility and predictability; funding from EU, SSF, and MdH.

d) **Monitoring and Testing group** – headed by Dr. Henrik Thane; 3 graduate students; 2 PhD planned for 2006; focusing on monitoring, testing, and debugging of real-time systems; funding from SSF, KKS, and MdH.

e) **Real-Time Systems Design group** – headed by Prof. Hans Hansson; Researcher Docent Mikael Nolin, Senior researcher Dr Jukka Mäki-Turja, 4 graduate students; 1 PhD and 1 lic 2005, 2 PhD and 2 Lic planned for 2006; focusing on design methods, architectures and communication for real-time systems; funding from SSF, Vinnova, KKS, EU, and MdH.

f) **Scalable Architecture for Real-time Application (SARA) group** – headed by Prof. Lennart Lindh; 4 graduate students; 2 licentiates planned for 2006; focusing on scalable multiprocessor systems, system-on-chip, and moving software functions into hardware; funding from KKS and MdH.

g) **The Programming Languages group** – headed by Prof. Björn Lisper; Senior Lecturer Docent. Jan Gustafsson and Researcher Dr. Andreas Ermedahl; 9 graduate students (three external); 1 licentiate in 2005; 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

ISS

h) **The Intelligent Systems group** – headed by Docent Peter Funk; two senior researchers, 5 (+3 associated) PhD students; 2 PhDs and one licentiate (+3 by associated students) in 2005; 9 MSc students, all focusing on applications of artificial intelligence methods and techniques in industrial and medical domains; funding from SSF and KKS.

i) **Safety-Critical Systems group** – headed by Prof. Lars Asplund; 1 associated researcher (Dr. Martin Nilsson); 4 graduate students; 1 PhDs 2005; focusing on hardware architectures for safety-critical systems and robotics sensory systems; funding from KKS and MdH.

j) **Communication Performance Predictability and Analysis group** – headed by Prof. Mats Björkman; Researcher Dr. Bob Melander; Researcher Svante Ekelin; 5 graduate students; 2 licentiates 2005; 1 licentiate and 1 PhD planned for 2006; focusing on communication for small embedded devices, and traffic measurement and analysis; funding from VR, Vinnova, KKS, CUGS, and MdH.

k) **Mechatronics group** – headed by Dr. Denny Åberg; Researcher, Prof. Lennart Harnefors (leaving the group), Dr. Sanbau Xu (leaving the group), Dr. Johnny Holmberg (leaving the group); 7 graduate students (3 leaving the group during 2005); 2 PhDs planned 2006; research areas within electric motor drive control, RF circuits, microwave sensors and imaging, funding from Vinnova, KKS and MdH.

l) **Sensors and Biomedical Engineering** – headed by Dr. Maria Lindén; Professor Ylva Bäcklund, Senior Lecturer Dr. Mikael Ekström, Senior Lecturer Dr. Mannan Mridha; Researcher Dr. Mia Folke; 3 PhD students; one of them Industrial PhD student; focusing on wearable multisensor systems also including artificial intelligence. The wireless communication enables free mobility and several of our projects are based on the Bluetooth™ technology. Funding from Vinnova, KKS, EU and MdH.

1.1 *Recent developments*

This section highlights some of the new initiatives, decisions and projects during 2005 that we regard 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.

1.1.1 Progress – Strategic Centre for Predictable Embedded Software Systems

In December 2005 the decision from the Swedish Foundation for Strategic Research was made public - The PROGRESS application was in very tough national competence awarded 43 MSEK for the coming five years.

PROGRESS will be 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. Competence in this area is a key strategic issue for industrial sectors, such as the automotive, telecom, and automation industries. PROGRESS' vision is to be a worldwide-recognised centre in software engineering of embedded real-time systems with extensive contacts/exchange with other leading universities and to be the preferred partner for the industry. Research will include 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.

1.1.2 Industrial PhD students in cooperation with SMEs

During 2005 two new industrial graduate students were accepted with funding from the KK-foundation in cooperation with SMEs.

One of the students is Christer Gerdtman, employed at ElektronikMekanik AB. The project deals with alternative, wireless input and control devices for disabled

The other student is PengPeng Ni employed at Ardendo AB, and whose research project concerns aims at supporting effective and quick browsing of multimedia content over network through full Video Cassette Recording (VCR) functionality.

1.1.3 Factory-in-a-box

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.

1.1.4 SAVE-IT

SAVE-IT is an industrial graduate school supported by the KK-foundation with 20.8 MSEK during a six-year period 2004-2009. Matching efforts will be provided by participating industries. MRTC has the main responsibility for SAVE-IT. Additional partners include

Linköping University (IDA/RTSLAB), KTH (DAMEK), Uppsala University (IT/UppAal), and currently the following industries: ABB Research, ABB/Robotics, Bombardier Transportation, Ericsson, Saab, and Volvo CEC.

In 2005 seven new industrial graduate students were accepted to SAVE-IT. A massive campaign for recruiting further students was initiated, and the result from this are expected to be seen in 2006.

1.1.5 Intelligent integrated sensor systems for diagnosis, treatment and healthcare

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.

Several important results have been established during the first year
- One PhD thesis (Mia Folke)
- Continued work on the novel way to measure CO2 in expired air through a resonant sensor.
- Development of a new principle to estimate the lactate level through correlation to the CO2-level.

1.1.6 Extract

The Extract project's aim is to improve the maintainability of the complex software systems found in advanced industrial products such as trains, industrial robots or telecom systems by developing a solution for automated extraction of models targeting analysis of dynamic properties

1.1.7 Multex -

The last few years MRTC and Arcticus Systems have been cooperating in the MultEx project. Using newly acquired funding from the Knowledge Foundation (KKS), the MultEx project is now expanded with more time from senior researchers and 2 new partner companies: CC Systems and Volvo Construction Equipment.

In MultEx we study how the software development process for embedded control systems can be made more efficient, with respect to development time, achieved software quality and hardware utilisation. Specifically, we 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.

1.1.8 Worst-Case Execution Time (WCET)

The Programming Languages group was awarded a three-year grant from the KK-foundation for a project in) analysis. This research was previously supported by Vinnova through the ASTEC competence center in Uppsala, and the new grant allows the continuation of this research. The goal of the project is to develop WCET analysis methods

that are more automated, in order to make the analysis tools easier to use. The research will be carried out in close cooperation with both tool vendors and end user companies.

1.1.9   Major application to Vinnova

VinnMRTC (Funded by Vinnova 350 KKR) was a proposal for building Vinnova Excellence Center. Its focus was on methods and tools required for developing future embedded systems. Embedded software is a key element behind the success of numerous Swedish export products. However, growing complexity of software systems, fast-evolving technology and increasing customer requirements make software a bottleneck in system development. Renewal of the industrial expertise in embedded systems technology is imperative, both for shorter term benefits and to secure Sweden's long term industrial competitiveness. VinnMRTC approach builds on proven excellence in research and innovation in cooperation between academia and industry, and upon a substantial body of research in real-time and component-based software engineering. The main idea of VinnMRTC is to adopt the proven approaches from other engineering disciplines:

- Coping with complexity by increasing abstraction and applying composition i.e. model-ling systems and constructing systems from the existing components
- Focusing on predictability by construction
- A holistic approach, towards theories and methods, technologies and processes

VinnMRTC has got a high support from Industry (promising involvement of 140 MKr), but unfortunately has not been selected as one of future Vinnova excellence centers.

1.1.10   Institute Excellence Centre

A proposal for establishing the SICS Centre for Networked Systems (CNS) was submitted to Vinnova in response to a call for Institute Excellence Centres funded by VINNOVA, the KK-foundation and SSF. The proposal was coordinated by Bengt Ahlgren at the Swedish Institute for Computer Science (SICS), with participation by Mats Björkman and Hans Hansson at IDE.

CNS is guided by the vision of *The Reliable Internet*, a secure and reliable infrastructure for industry and society:

- which provides the predictable service that users and applications need,

- which enables robust applications on heterogeneous networks, fixed as well as mobile, including extreme networks such as sensor networks,

- which is secure and free from spam and denial-of-service,

- and which at the same time is easier to manage.

Within CNS, methods and results from networking, distributed systems, and intelligent systems will be combined. The center will create an environment, a creative meeting place, where SICS and the participating industry and university partners will collaborate. Parners in CNS are in addition to SICS and MdH/IDE: KTH, Uppsala University, ABB, Ericsson, OptiMobile, Saab Systems, TeliaSonera, T2 Data, and a cluster of SMEs.

A decision to fund the centre was made in April 2006. The details and implications of this decision are not known at the time of completion of this report.

1.2 Organisation and Management

MRTC has a scalable matrix-organisation with 6 different laboratories as vertical entities, as shown below. A lab is a 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, as well as administration of the lab (e.g. handling the budget and representing the lab externally).

The following are labs at IDE:
- Real-Time Systems Design Lab
- Computer Science Lab
- Software Engineering Lab
- NetCenter
- Sensors och Biomedicine Lab
- Mechatronics Lab
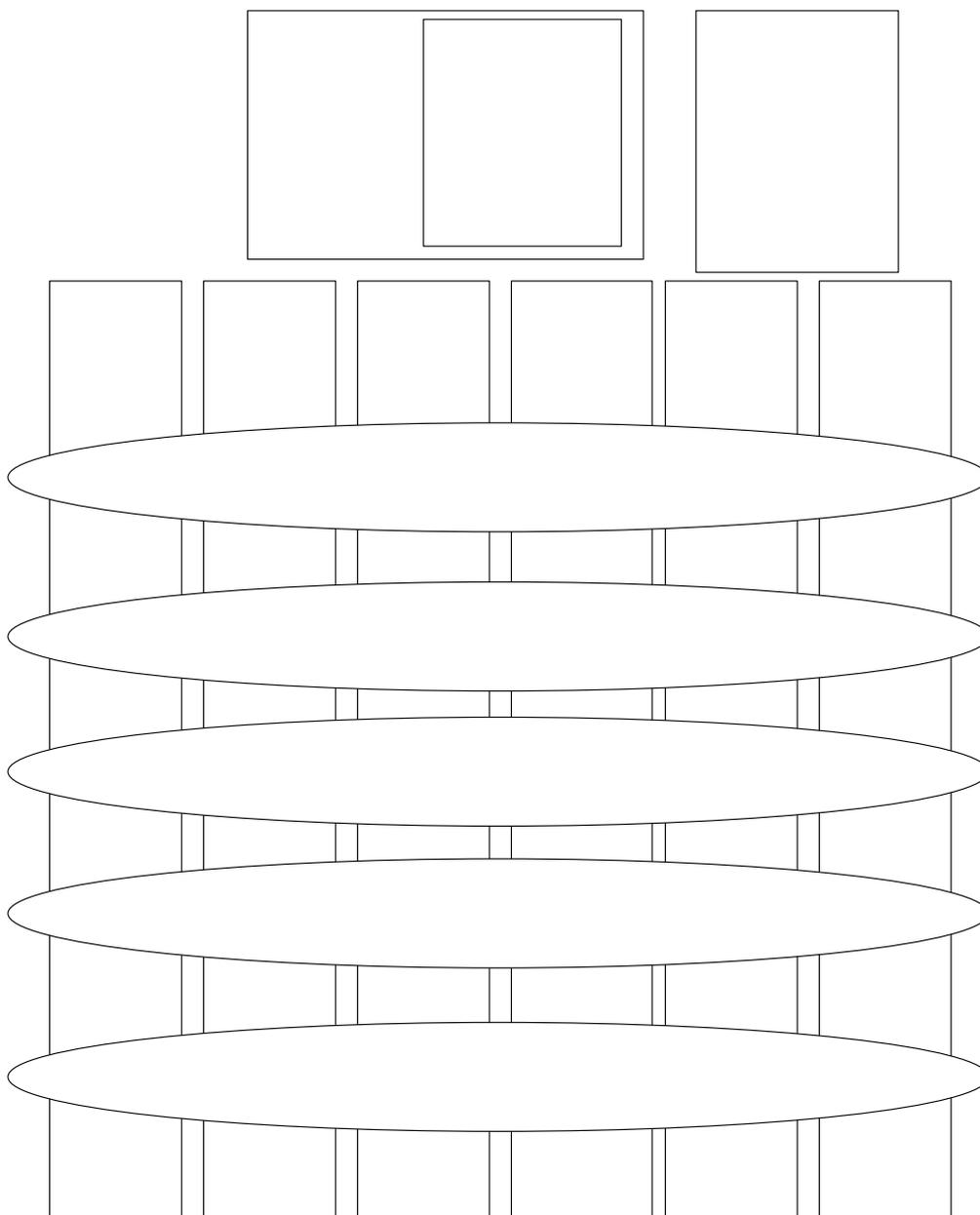
The research labs represent competence areas in which basic research, as well as postgraduate and undergraduate education is conducted. The laboratories are responsible for performing research and providing resources in terms of teachers and supervisors for the following horizontal entities:

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 school of which SAVE-IT is an important part is a separate programme within the postgraduate school, with annual admission of a group of industrial graduate students.

The international master years are one-to one and a half year programmes for special education of students towards 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.

The management of IDE is handled by

IDE Steering group consisting of the head of the Department, Prof. Ylva Bäcklund, the Research Director, Hans Hansson, the Director of Undergraduate Education, Åsa Lundkvist and the controller Else-Maj Sillén.

Main tasks include to
- Propose distribution of funds to labs, projects, undergraduate courses and programmes
- 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.

1.2.1 Staff

1.2.1.1 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 the "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 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.

Else-Maj Sillén is Controller and Departmental Bursar

1.2.1.2   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

Bertil Hoffmann is Departmental Technician

Ylva Boivie is research co-ordinator at MRTC.

Henrik Kroon is Financial Officer

Mika Seppänen is laboratory assistant, **Roger Hassel** is Computer Engineer, **Jan Österberg** is Computer Engineer and **Monica Wasell** is executive administrator and director of undergraduate studies at IDE.

1.3 Funding

In 2005 the total outcome for the department amounted to 80 MSEK. 53% (43 MSEK) of the revenues are related to research activities and the rest (37 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 KK-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 to approximately 11 MSEK yearly, and is typically funding of industrial graduate students, and expertise.

The following graph shows the distribution among the different sources of research funding for 2005 including the in-kind funding from industry.
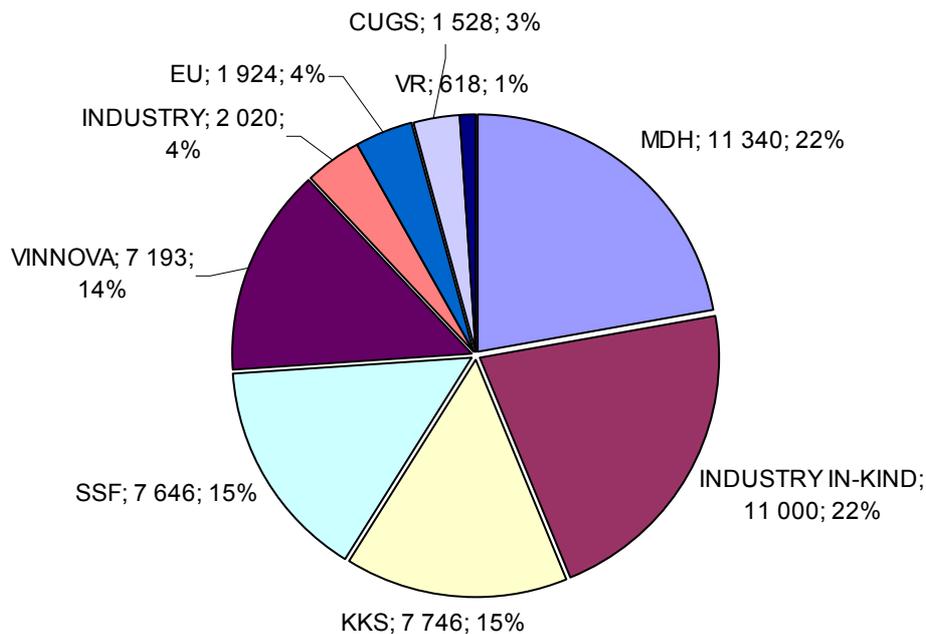
In Undergraduate education the main source of funding is the support from the University (90%, 33,5 MSEK) , followed by the revenues from Contract Teaching (10%, 3,5MSEK).

1.4 Undergraduate Education and International Master of Science Programmes

1.4.1 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". The Department is also responsible for five different programmes taught in Swedish:

- Civilingenjörsprogrammet i datateknik och systemteknik , 180 poäng
- Civilingenjörsprogrammet i robotik, 160 - 180 poäng
- Datavetenskapliga programmet, 80 - 180 poäng
- Mekatronikprogrammet, 120 - 180 poäng
- Programmet för Spelutveckling och interaktion, 120 - 160 poäng

NetCenter is a lab at the Department which mainly 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.

For more information about Undergraduate education please refer to www.mdh.se/ide/

1.4.2 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 2005, 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
- International Project Management
- Real-time Systems
- Robotics
- 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.

1.4.2.1 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.

1.4.2.2 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.

1.4.2.3 International Project Management

The program in International Project Management focuses on skills in managing large projects in an international context, by creating an environment where students develop their professional competence by focusing on human relations and commercial aspects of successful Project Management. The programme puts emphasis on how the Project Manager performs, communicates and manages all the project stakeholders. By focusing on the professional aspects of Project Management each participant's capacity to guide his/her project to successful completion, i.e. to deliver the right quality in time and with profitability is supported.

1.4.2.4 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.

1.4.2.5 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

1.4.2.6 Staff

Mia Harwig is student counselor at IDE

Cecilia Fernström is student administrator

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.

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.

Gunilla Eken is lecturer and director of undergraduate studies for the Computer Science programme at Mälardalen University. She is a member of the board for undergraduate studies 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.

Ralf Elvsén is moving from theoretical physics to computer science. At present he takes courses and also gives elementary courses. He received his Ph.D from the University of Umeå in 1993. At this time he was working on non-linear wave phenomena in kinetic plasmas. He will subsequently join the research in real-time systems.

Filip Sebek is a lecturer and director of undergraduate studies with focus on quality and pedagogic issues. He received his Bachelor of Science in Applied Computer Engineering from Mälardalen University, Sweden (1995) and his Licentiate thesis with the title "Cache Issues in real-time systems" was defended in October 2002.

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.

Olof Andersson is lecturer at IDE.

Joop Lundqvist is lecturer at IDE.

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.

Ingrid Runnérus is lecturer at NetCenter.

Joakim Rydén is lecturer at NetCenter.

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 interest are in security and motorcykles.

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

In addition to the staff above the Arne Andersson was lecturer at the Department. Unfortunately, Anre, passed away in the end of 2005. Arne was a highly appreciated teacher and colleague.

The re-organization of the Department led to some teachers and lecturers leaving the Department for other position either within MdH or outside: Boje Augustsson, Ghassan El Bhatal, Leif Karlsson and Mridha Mannan

1.5 Postgraduate Education

1.5.1 Postgraduate Courses

During 2005, MRTC has offered 7 postgraduate courses:
- Advanced Topics in Component-Based Software Engineering
- Program Analysis
- Research Methodology for Computer Science and Engineering
- Research Planning
- Professional Ethics in Science and Engineering
- Distributed Software Development
- Software Architecture for Industrial Systems

The postgraduate students can also select courses from other universities, courses given by national networks such as ARTES, courses from CUGS, common postgraduate courses at MdH, and local D-level courses that are qualified enough to also serve as postgraduate level courses. During 2005 the following Computer Science and Engineering D-level courses were given by MRTC-staff at MdH:
- Component-based Software Engineering, 5 p
- Computer Graphics, advanced course, 5p
- Component-based Design of Single-Chip Systems, 5p
- Safety-Critical 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
- Robotics - project course, 20 p

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.

1.5.2 MRTC Theses (Computer Science and Engineering)

In 2005, eight PhD theses and ten Licentiate theses were presented by MRTC staff.

PhD theses:

Baran Cürüklü, *A Canonical Model of the Primary Visual Cortex*. PhD Thesis, April.

Jukka Mäki-Turja, *Engineering Strength Response-Time Analysis*. PhD Thesis, May.

Markus Nilsson, *Retrieve and Classify*. PhD Thesis, August.

Tomas Lenvall, *Adapting to varying demands in resource constrained real-time devices*. PhD Thesis, September

Radu Dobrin, *Combining off-line schedule construction and fixed priority scheduling in real-time computer systems*. PhD Thesis, September.

Gustaf Næser, *A Formal Approach to Embedded High-Integrity Real-Time Systems*. PhD Thesis, October.

Dag Nyström, *Data Management in Vehicle Control-Systems*. PhD Thesis, October.

Christina Björkman, *Crossing Boundaries, Focusing Foundations, Trying Translations: Feminist Technoscience Strategies in Computer Science*, PhD Thesis, May (presented at Blekinge Tekniska Högskola).

Licentiate theses:

Mikael Åkerholm, *A Software Component Technology for Vehicle Control Systems*. Licentiate Thesis, February.

Anders Möller, *Component Technologies for Heavy Vehicles*. Licentiate Thesis, March.

Adam Dunkels, *Towards TCP/IP for Wireless Sensor Networks*. Licentiate Thesis, March.

Johan Fredriksson, *Transformation of Component Models to Real-Time Models - Optimizing Resource Usage*. Licentiate Thesis, April.

Andreas Johnson, *Bandwidth measurements in Wired and Wireless networks.* Licentiate Thesis, April.

Stig Larsson, *Improving Software Product Integration*. Licentiate Thesis, June.

Johan Andersson, *Modeling the Temporal Behavior of Complex Embedded Systems - A Reverse Engineering Approach*. Licentiate Thesis, June.

Erik Olsson, *Diagnosis of Machines within Industry using Sensor Signals and Case-Based Reasoning*. Licentiate Thesis, October.

Waldemar Kocjan, *Symmetric Cardinality Constraints*. Licentiate Thesis, December.

Annita Persson Dalhqvist, *Product Data Management and Software Configuration Management Integration.* Licentiate Thesis, December.

1.5.3 ISS Theses (Electronics)

In 2005, three PhD theses and two Licentiate theses were presented by ISS staff.

PhD theses:

Magnus Jansson, *On Stabilization of Sensorless Synchronous Motor Drives and Traction Converters*. PhD Thesis, September.

Mia Folke, *Measurements of Respiratory Carbon Dioxide*. PhD Thesis, September.

Kai Pietiläinen, *Voltage Sag Ride-Through of AC Drives: Control and Analysis*. PhD Thesis, October (presented at KTH).

Licentiate theses:

Jens Lönnblad, Monitor *the heart simply and smooth - with less artefact using Bluetooth™.* Licentiate Thesis, February.

Tord Johnson, *Design and Analysis of Charge-Pump Based Frequency Synthesizers*. Licentiate Thesis, April.

1.5.4 List of Postgraduate Students

The tables below list the MRTC and ISS postgraduate students and their advisory groups at the end of 2005. The list is sorted according to main advisor. Bold face marks the "de facto"-advisor. The column "Enrolled at" indicates the university where the student is formally enrolled as a Ph.D.-student.

MRTC postgraduate students (Computer Science and Engineering)

Ph.D.-student	Formal main advisor	Advisor	Advisor	Employed at	Enrolled at
Susanna Nordström	Lars Asplund	**Denny Åberg**	Lennart Lindh	RealFast	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	Ivica Crnkovic	**Kristian**		MdH	MdH

(lic)		**Sandström**			
Rikard Land (lic)	**Ivica Crnkovic**	Christer Norström		MdH	MdH
Stig Larsson (lic)	**Ivica Crnkovic**	Fredrik Ekdahl (ABB)		ABB	MdH
Frank Lüders (lic)	**Ivica Crnkovic**	Björn Lisper		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
Larisa Rizvanovic	**Gerhard Fohler**	Damir Isovic		MdH	MdH
Pengpeng Ni	**Gerhard Fohler**	Damir Isovic		Ardendo AB	MdH
Erik Olsson (lic)	**Peter Funk**	Ning Xiong	Mats Jackson (IDP)	MdH	MdH
Rikard Lindell (lic)	Jan Gustafsson	**Jonas Löwgren** (Malmö Högskola)	Jussi Karlgren (SICS)	MdH/SICS	MdH
Andreas Löfgren	**Hans Hansson**	Mats Björkman		RealFast	MdH
Sigrid Eldh	**Hans Hansson**	Sasikumar Punnekkat, Henrik Thane	Christer Norström	Ericsson	MdH
Joel Huselius (lic)	**Hans Hansson**	Sasikumar Punnekkat	Henrik Thane	MdH	MdH
Thomas Nolte (lic)	**Hans Hansson**	Christer Norström	Sasikumar Punnekkat	MdH	MdH
Anders Pettersson (lic)	Hans Hansson	**Henrik Thane**		MdH	MdH
Daniel Sundmark (lic)	Hans Hansson	**Henrik Thane**	Christer Norström	MdH	MdH
Johan Stärner	Hans Hansson	**Lars Asplund**		MdH	UU
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)		SICS	MdH
Jan Carlson (lic)	**Björn Lisper**	Christer Norström		MdH	MdH
Johan Lindhult (former Erikson) (lic)	**Björn Lisper**	Jan Gustafsson	Janet Wennersten (Ericsson)	MdH	MdH
Roger Jonsson	Björn Lisper	**Jacek Malec** (Lund U.)	Peter Funk	MdH	MdH
Waldemar Kocjan (lic)	Björn Lisper	**Per Kreuger** (SICS)		-	MdH
Thomas Larsson (lic)	**Björn Lisper**	Dr. Tomas Akenine-Möller (Chalmers)		MdH	MdH
Christer Sandberg	**Björn Lisper**	Jan Gustafsson		MdH	MdH

Mikael Sandberg	**Björn Lisper**	Jan Gustafsson		-	MdH
Gordana Dodig-Crnkovic	Björn Lisper	**Lars-Göran Johansson** (UU)	Jan Gustafsson	MdH	MdH
Kaj Hänninen	**Mikael Nolin**	Jukka Mäki-Turja	Christer Norström	MdH/Arcticus	MdH
Anders Möller (lic)	**Mikael Nolin**	Hans Hansson		CC-systems	MdH
Markus Lindgren (lic)	**Christer Norström**			ABB	MdH
Johan 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

ISS postgraduate students (Electronics)

Ph.D.-student	Formal main advisor	Advisor	Advisor	Employed at	Enrolled at
Ewa Hansen	**Mats Björkman**	Mikael Nolin		MdH	MdH
Jonas Neander	**Mats Björkman**	Mikael Nolin		MdH	MdH
Javier Garcia Castano	Ylva Bäcklund	**Mikael Ekström**		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
Annika Jonsson	Ylva Bäcklund	**Maria Lindén**	Margareta Lindgren	MdH	MdH
Ali Moftakhari Khezri Fard	Ylva Bäcklund	**Denny Åberg**		MdH	MdH
Peder Norin	Ylva Bäcklund	**Denny Åberg**		MdH	MdH
Krister Landernäs	**Lennart Harnefors**	Johnny Holmberg	Mark Vesterbacka	MdH	MdH

1.6 Industrial co-operation

One of the cornerstones of IDE is the many 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.

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/Fredrik Ekdahl 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, both within telecom platforms (Lars-Olof Gustafsson, Christer Norström), and MICROWAVE (Ove Gustavsson, 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
Susanna Nordström	RealFast	Lennart Lindh	
Stig Larsson (lic)	ABB Corporate Research	Fredrik Ekdahl	Ivica Crnkovic
Frank Lüders (lic)	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
Pengpeng Ni	Ardendo AB	Isak Jonsson	Gerhard Fohler

Andreas Löfgren	RealFast	Stefan Sjöholm	Hans Hansson
Sigrid Eldh	Ericsson	Mike Williams	Hans Hansson, Henrik Thane
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
Markus Lindgren (lic)	ABB	George Fedor, Anders Wall	Christer Norström
Johan Andersson (lic)	ABB Robotics	Peter Eriksson	Christer Norström
Joakim Fröberg (lic)	Volvo CEC	Nils-Erik Bånkestad	Christer Norström
Mathias Ekman	Bombardier	Erik Gyllenswärd	Christer Norström
Christer Gerdtman	Elektro Mekanik AB	Bertil Pettersson	Ylva Bäcklund

- 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]

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 www.mrtc.mdh.se. An associated database enables easy and convenient update and retrieval of information. Currently, the web contains information about MRTC and ISS and 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 ARTIST 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
- Via the MRTC Industrial Day, which is an annual event with the purpose of presenting and discussing our achievements to industry in general and to our co-operation partners in particular. Since one day is not enough to present the multitude of projects and activities at MRTC, each industrial day has a special focus corresponding to a specific research direction.
- 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 is now participating in the implementation of this programme. Anders Martinsen is managing one of four regions in this programme.
- Giving commercial courses on topics of our expertise. In 2005 the IDE staff has given several instances of shorter industrial courses on real-time systems, reliability and circuit design
- Spin-off companies, where the main development in 2005 was a continued commercialization of research results within the RealFast group. Another spin-off company - Zealcore Embedded Solutions AB – was subject to investment from KTH Seed Capital, and received a patent on the methods behind the BlackBox technology, the debugging technology developed in the Tatoo project

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 and 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.

MRTC is organized in the following interrelated and mutually supportive sub-programmes:
1. The MSc programmes in Computer Science and Real-Time Systems, which are research oriented MSc programmes integrated with the MRTC research.
2. The Graduate School, including a Ph.D.-programme and Licentiate-school.
3. Research projects, including application oriented industrial co-operation projects, as well as more traditional research projects.
4. 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).

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 2005 we had concrete co-operations with the following companies:

- ABB (Automation, Robotics, and Corporate Research)
- AbsInt Angewandte Informatik GmbH (Germany)
- Arcticus Systems
- Bombardier Transportation
- CC-Systems
- CompFab
- Enea Embedded Technologies AB
- Ericsson (Microwave, Radio Systems, Research, and Utveckling)
- Funkai Intelligent Solutions
- Gatorhole AB
- Hectronic AB
- IAR Systems
- Level TwentyOne AB
- Mimer Information Technology AB
- Mitsubishi research labs, Boston, US
- Mecel AB
- Outocumpu, Avesta Steel Mill
- PBM StressMedicine AB
- Philips Research, The Netherlands
- Prevas
- Protang AB
- RealFast AB
- Rolls Royce aircraft engine design, UK
- Saab (Aerospace, Avionics)
- SenseBoard Technologies AB
- Siemens Business Systems, Germany
- SKF
- TeliaSonera
- Thomson Multimedia
- Tieto Enator
- Tidorum Oy (Finland)
- TTTech, Austria
- Volcano Communication Technologies AB
- Volvo Car
- 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 2005 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.

2.2.1 Industrial Software Engineering group

Headed by Prof. Ivica Crnkovic; Senior lecturer Sasikumar Punnekkat and 7 PhD students, five of them industrial PhD students, 4 licentiate theses 2005, 2 PhD planned for 2006, focusing on research related to software engineering in industrial settings, funding from ABB, Ericsson, EU, SSF, KKS, CC-systems and MdH

Scientific achievements

The major results of this research in 2005 group were:
- Licentiate Thesis – Mikael Åkerholm, Johan Fredriksson, Annita Persson-Dahlqvist, Stig Larsson
- Organization of Euromicro Conference Porto, Portugal September 2005.
- Co-Organization CBSE 2005 symposium at 26th International Conference of Software Engineering, St. Louis, May 2005.
- Organization of Swedish Fifth Conference on Software Engineering Research and Practice in Sweden, Västerås, November 2005

2.2.2 Embedded Systems Software Engineering group

headed by Prof. Christer Norström; Prof. Jakob Axelsson, Senior Lecturer Dr. Kristian Sandström; Dr Dag Nyström, 6 graduate students; 2 licentiates 2005 and 1 PhD 2006; focusing on Embedded Systems Software Engineering (e.g. for automotive and industrial robotics systems); funding from SSF, ABB, Volvo, KKS, Vinnova and MdH.

Scientific achievements

The major results of this research group in 2005 were:
- One licentiate thesis (Johan Andersson)
- One PhD thesis (Dag Nyström)
- Many papers at international conferences.
- A paper in the Industrial Information Technology Handbook, Publisher IEEE CRC Press, jan 2005.
- Development of a common lab between Ericsson an MdH at MdH.

2.2.3 Predictably Flexible Real-Time Systems group

Headed by Prof. Gerhard Fohler; 2 graduate students, 2 PhDs in 2005; focusing on static and dynamic real-time scheduling, combining flexibility and predictability and application in media processing; funding from EU, KKS, SSF, and MdH.

Scientific achievements 2005:

- Work on using advanced real-time methods to ensure quality-of-service in resource constrained multimedia systems (CE devices). Published in a journal (International Journal of Embedded Computing, 2005)
- Work on static scheduling as a general technique for solving the problem of satisfying complex timing constraints in hard real-time systems. The conclusion is that pre-run-time scheduling is essential to meeting such constraints in large systems. Published in a journal (Real-Time Systems Journal).
- Developed new algorithms (based on servers) to enable coexististence of the diverse scheduling schemes (Fixed-priority, Earliest Deadline First and Offline Scheduling). Published in a PhD thesis.
- Wireless networking for in-home entertainment network. Adapting to varying capabilities of the wireless network when it is used for video streaming in the presence of other network traffic. Published in a PhD thesis.
- Quality-of-Service architecture for system state information in home entertainment networks. The architecture provides for a decentralized interface between devices and resource management. On-going work.
- Work to support effective and quick browsing multimedia content over network. To enable user friendly browsing, a key technique is to provide full Video Cassette Recording (VCR) functionality. Targeting on applications in an existing video processing system, we propose an encoding scheme based on the latest MPEG coding standard and several video streaming options to solve the research problem. Several concrete evaluation methods are discussed and put in the work plan of 2006.

2.2.4   Monitoring and Testing group

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

Scientific achievements 2005:

- Work on adapting in-house real-time kernel Asterix for teaching, with the purpose of introducing research results (including WCET- and schedulability analysis) in undergraduate education.
- Work on structural system-level testing of embedded real-time systems. Development and formulation of algorithm for extracting system-level control flow graph for small embedded real-time systems.
- Work on representation of corresponding system-level control flow for more complex real-time systems.
- Work on, and description of, replay-based dynamic instrumentation monitoring method for automatically extracting large quantities of data from real-time systems without introducing probe effects.
- Work has been done to further refine methods and techniques for applying replay technology to regression testing of multi-tasking systems, focusing on real-time systems. The refinement includes in depth analysis of the execution behavior during testing and re-testing at system level, i.e., testing when tasks runs in a concurrently manner and are competing for resources.
- An analysis of how code changes propagate and have impact on the temporal behavior when software is operational has been performed. This, as a step forward to

understand and solve the problem of inadequate knowledge of what and how the temporal behavior is influenced when code is modified in order to correct faults.

- Work has been done on finding methods for dynamic instrumentation of embedded systems for on-the-fly patching. Boundary conditions are on-the-fly patching with minimal or no preparation of the target system. Related work studies and initial experiments have been performed

2.2.5   Real-Time Systems Design group

headed by Prof. Hans Hansson; Researcher Dr. Mikael Nolin, 4 graduate students; focusing on design methods, architectures and communication for real-time systems; funding from SSF, Vinnova, KKS, EU, and MdH.

Scientific achievements 2005:
- Our previous approaches to improve the schedulability tests of tasks with offset have been merged. Instead of a set of different incompatible techniques we have now presented a unified solution where tight (near-optimal) response-times can be calculated several orders of a magnitude faster than with previous methods.
- The previous work on server-based scheduling for embedded communication has been extended with hierarchical scheduling, combining native CAN, server-based CAN, and different queuing disciplines to allow a predictable mix of communications with different quality-of-service requirements.
- Needs and requirements were investigated for component based software engineering within the Swedish vehicular industry. One conclusion from this study is that no technology today meets all requirements. On the positive side, we found that each requirement was supported by one or more technologies. Hence, it should be possible to derive a technology suitable for vehicular software. Our investigation also showed that there are certain areas, such as analysis, testing and debugging, that are particularly important but that are not handled well by existing technologies. In response to these shortcomings we have proposed a concept of run-time monitoring to support, e.g., analysis, testing and debugging.

2.2.6   The Programming Languages group

headed by Prof. Björn Lisper; Senior Lecturer Dr. Jan Gustafsson and Researcher Dr. Andreas Ermedahl; 9 graduate students (three external); 1 licentiate in 2005; 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 2005:
- A number of practical experiments and case studies where WCET analysis was applied to industrial real-time production code.
- Further development of methods for automatic flow analysis in WCET analysis tools
- A formal semantics for the SaveCCM component model has been defined.
- The SaveCCM model has been extended with an event triggering mechanism, based on our previous work on event algebra.
- A formal semantics for PLEX programs executing in the parallel "CMX" model, and a comparison with the semantics for sequential PLEX which shows that some PLEX programs works incorrectly when run in parallel.

2.2.7 Scalable Architecture for Real-time Applications Lennart

headed by Lennart Lindh; 4 graduate students; focusing on platform and real-time operating systems in hardware design for real-time systems; funding from KKS, industry and MdH.

Scientific achievements 2005:
- Investigate UDP protocols in hardware.
- Investigate modulation and configuration of small real-time Kernels.

2.3 Industrial Software Engineering group

2.3.1 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 senior lecturer and 7 PhD students, five of them industrial PhD students

The major results of this research in 2005 group were:
- Licentiate Thesis – Mikael Åkerholm, Johan Fredriksson, Annita Persson-Dahlqvist, Stig Larsson
- Organization of Euromicro Conference Porto, Portugal September 2005.
- Co-Organization CBSE 2005 symposium at 26th International Conference of Software Engineering, St. Louis, May 2005.
- Organization of Swedish Fifth Conference on Software Engineering Research and Practice in Sweden, Västerås, November 2005

In 2005 the following projects have been active:
- 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 FP5 ARTIST Network of Excellence
- EU IST FP6 ARTIST2 Network of Excellence

2.3.2 Research projects

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.

Publications:

Theses
- Improving Software Product Integration, Stig Larsson, Licentiate Thesis, Mälardalen University Press, June, 2005

Conferences and workshops
- Case Study: Software Product Integration Practices, Stig Larsson, Ivica Crnkovic, Product Focused Software Process Improvement: 6th International Conference, PROFES 2005, Springer, Lecture Notes in Computer Science, Volume 3547 / 2005, Oulu, July, 2005
- Concretizing the Vision of a Future Integrated System - Experiences from Industry, Rikard Land, Ivica Crnkovic, Stig Larsson, 27th International Conference Information Technology Interfaces (ITI), IEEE, Cavtat, Croatia, June, 2005
- Component-based Development Process and Component Lifecycle, Ivica Crnkovic, Stig Larsson, Michel Chaudron (Technical University Eindhoven), 27th International Conference Information Technology Interfaces (ITI), IEEE, Cavtat, Croatia, June, 2005

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.

Publications:

Theses
- Product Data Management and Software Configuration Management Integration, Annita Persson-Dahlqvist, Licentiate Thesis, Mälardalen University Press, December, 2005

MRTC reports
- Important Factors for a Successful Integration of Product Data Management and Software Configuration, Annita Persson-Dahlqvist, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-194/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, November, 2005

FLEXCON - flexible controllers

Project Leader:	Karl-Erik Årzén Program director,
	Ivica Crnkovic, local project leader
Members:	Ivica Crnkovic
	Johan Fredriksson
Partners:	LTH Lund University
	KTH - Royal Institute of Technology
	HSV - Högskola Shövde
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.

Publications (from MRTC/SEL):

Theses
- Transformation of component models to real-time models, Johan Fredriksson, Licentiate Thesis, Mälardalen University Press, April, 2005

Conferences and workshops
- A component-based development framework for supporting functional and non-functional analysis in control system design, Johan Fredriksson, Massimo Tivoli (former), Ivica Crnkovic, 20th IEEE/ACM International Conference on Automated Software Engineering (ASE 2005), p 368-371, ACM 2005, Long Beach, CA, USA, November, 2005
- Component-Based Context-Dependent Hybrid Property Prediction, Anders Möller, Ian Peake (Monash University), Mikael Nolin, Johan Fredriksson, Heinz Schmidt (external), ERCIM - Workshop on Dependable Software Intensive Embedded systems, ERCIM, Porto, Portugal, September, 2005

- A component-based approach for supporting functional and non-functional analysis in control loop design, Massimo Tivoli (former), Johan Fredriksson, Ivica Crnkovic, Tenth International Workshop on Component-Oriented Programming, Glasgow, Scotland, July, 2005
- Optimizing Resource Usage in Component-Based Real-Time Systems, Johan Fredriksson, Kristian Sandström, Mikael Åkerholm, the 8th International Symposium on Component-based Software Engineering (CBSE8), May, 2005

MRTC reports
- Component-Based Development of Safety-Critical Vehicular Systems, Ivica Crnkovic, DeJiu Chen (KTH), Johan Fredriksson, Hans Hansson, Jörgen Hansson (external), Joel G Huselius, Ola Larses (external), Joakim Fröberg, Mikael Nolin, Thomas Nolte, Christer Norström, Kristian Sandström, Aleksandra Tesanovic (external), Martin Törngren (external), Simin Nadjm-Tehrani (external), Mikael Åkerholm, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-190/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, September, 2005

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.

Publications:
- Architectural Concerns When Selecting an In-House Integration Strategy – Experiences from Industry, Rikard Land, Laurens Blankers, Stig Larsson, Ivica Crnkovic, Fifth IEEE/IFIP Conference on Software Architecture (WICSA), IEEE, Pittsburgh, PA, November, 2005
- Software Systems In-House Integration Strategies: Merge or Retire - Experiences from Industry, Rikard Land, Laurens Blankers, Stig Larsson, Ivica Crnkovic, Fifth Conference on Software Engineering Research and Practice in Sweden (SERPS), p 21-30, Mälardalen University, Västerås, Sweden, October, 2005
- Architectural Reuse in Software Systems In-house Integration and Merge – Experiences from Industry, Rikard Land, Ivica Crnkovic, Stig Larsson, Laurens Blankers, First International Conference on the Quality of Software Architectures (QoSA 2005), Springer Verlag, Erfurt, Germany, September, 2005
- Process Patterns for Software Systems In-house Integration and Merge – Experiences from Industry, Rikard Land, Ivica Crnkovic, Stig Larsson, 31st Euromicro Conference on Software Engineering and Advanced Applications (SEAA), Track on Software Process and Product Improvement (SPPI), IEEE, Porto, Portugal, Editor(s):Paul Grünbacher, August, 2005
- Concretizing the Vision of a Future Integrated System - Experiences from Industry, Rikard Land, Ivica Crnkovic, Stig Larsson, 27th International Conference Information Technology Interfaces (ITI), IEEE, Cavtat, Croatia, June, 2005
- Interviews on Software Integration, Rikard Land, Stig Larsson, Ivica Crnkovic, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-177/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, April, 2005

Articles in collection

- Adopting a Component-Based Software Architecture for an Industrial Control System – A Case Study, Frank Lüders, Ivica Crnkovic, Per Runeson (Lund University), Component-Based Software Development for Embedded Systems, p 232-248, Springer, LNCS 3778, ISBN: 3-540-30644-7, Editor(s): Colin Atkinson, Christian Bunse, Hans-Gerhard Gross, Christian Peper, 2005
- Software Component Services for Embedded Real-Time Systems, Frank Lüders, Daniel Flemström, Anders Wall (former), Proc. Fifth Working IEEE/IFIP Conference on Software Architecture, December, 2005
- Software Component Services for Embedded Real-Time Systems, Frank Lüders, Daniel Flemström, Anders Wall (former), Proc. Fifth Conference on Software Engineering Research and Practice in Sweden, p 123-128, Mälardalen University, Västerås, Sweden, October, 2005
- Component-Based Software Engineering, 8th International Symposium, CBSE 2005, George Heineman (external), Ivica Crnkovic, Heinz Schmidt (external), Judith Stafford (external), Kurt Wallnau (external), Springer, Lecture Notes in Computer Science,, ISBN: 3-540-25877-9, August, 2005
- Guidelines for a Graduate Curriculum on Embedded Software and Systems, Paul Caspi at al. (external), Ivica Crnkovic, ACM Transactions on Embedded Computing Systems,, vol 4, nr 3, p587–611, ACM, August, 2005
- Automated Component-Based Software Engineering, Ivica Crnkovic, Heinz Schmidt (external), Judith Stafford (external), Kurt Wallnau, Journal of Systems and Software, vol Volume 74, nr 1, Elsevier, January, 2005
- Report of the International Symposium on Component-Based Software Engineering, Ivica Crnkovic, Heinz Schmidt (external), Judith Stafford (external), ACM SIGSOFT Software Engineering Notes, p 1-9, ACM, SIGSOFT, Editor(s): SIGSOFT, May, 2005
- Concerning Predictability in Dependable Component-Based Systems: Classification of Quality Attributes, Ivica Crnkovic, Magnus Larsson (former), Otto Preiss (ABB CRC), Architecting Dependable Systems III,, p pp. 257 – 278, Springer, LNCS 3549, Editor(s): R. de Lemos et al. (Eds.):, 2005
- Component-Based System Development - Embedded Systems Design,, Ivica Crnkovic, The ARTIST Roadmap for Research and Development, Volume 3436 / 2005, Springer, ISBN: 3-540-25107-3, Editor(s): Bruno Bouyssounouse, Joseph Sifakis, 2005
- Professional Ethics in Software Engineering Curricula, Gordana Dodig-Crnkovic, Ivica Crnkovic, Cross-disciplinarity in Engineering Education, CeTUSS, Uppsala, December, 2005
- Component based vs. Model based development: A comparison in the context of Vehicular Embedded Systems, Martin Törngren (external), DeJiu Chen (KTH), Ivica Crnkovic, Euromicro SEAA, IEEE, Porto, Portugal, August, 2005
- Component-based Software Engineering for Embedded Systems, Ivica Crnkovic, International Conference on Software engineering, ICSE'05, ACM, St. Luis, USA, May, 2005
- COTS Component-Based Embedded Systems - A Dream or Reality?, Ivica Crnkovic, Jakob Axelsson, Susanne Graf (external), Magnus Larsson (former), Rob van Ommering (external), Kurt Wallnau, 4th International Conference, ICCBSS 2005, Springer, Bilbao, Spain, February, 2005

2.3.3   Theses

Mikael Åkerholm, Licentiate Thesis, Mälardalen University Press

Software is fantastic! Numerous modern high-tech products incorporate software. This thesis focuses on software for vehicles. As high-tech products, modern vehicles contain much software that provides advanced functionality, e.g., efficient engine control, anti-spin systems, and adaptive-cruise control. However, software engineering is not without problems! Software can contain errors, is often delivered later than promised and the cost of its development constitutes a major part of the total development cost of the vehicle. These problems are consequences of the complexity of the systems we build with software, in combination with the immaturity of an evolving discipline. We therefore need improved approaches to software engineering. Component- based software engineering is a promising approach. It is analogous with approaches used in other engineering domains. For examples, mechanical engineers build systems using well-specified components such as nuts and bolts,

and the building industry uses components as large as walls and roofs (in turn assembled from smaller components). It has proven to be effective in application domains such as desktop and web-applications. However, it has not yet been widely adopted for use in the development of vehicular software; one of the reasons being that the commercial component technologies are developed specifically for other domains and to support other types of applications. This research aims at developing a component technology for embedded control systems in vehicles. Such a technology would enable software engineers in the vehicular domain to make use of component-based software engineering. We have addressed questions concerning quality attributes, and how component-based applications should be built and modeled, in the context of vehicular systems. Furthermore, based on our answers we have implemented, and evaluated a prototype component technology in cooperation with industry. The results confirm the suitability of our prototype, but also show that it must be further developed if it is to meet wider industrial requirements.

Johan Fredriksson, Licentiate Thesis, Transformation of component models to real-time models

Industry is constantly looking for new developments in software for use in increasingly complex computer applications. Today, the development of component-based systems is an attractive area for both Industry and Academia. The systems we focus on in this thesis are embedded computers, in particular those in automotive systems. A modern car incorporates several embedded computers that control different functions of the car, e.g., anti-spin and anti-lock breaks. The main purpose of this thesis is to investigate how component technologies for use in embedded systems can reduce resource usage without compromising non-functional requirements, such as timeliness. The component-technologies available have not yet been used extensively in the vehicular domain. To understand why this is the case we have conducted a survey and performed evaluations of the requirements of the vehicular industry with respect to software and software development. The purpose of the evaluation was to provide a foundation for defining models, methods and tools for component-based software engineering. The main contribution of this work is the implementation and evaluation of a framework for resource-efficient mappings between component-models and real-time systems. Few component technologies today consider the mapping between components and run-time tasks. We show how effective mappings can reduce memory usage and CPU-overhead. The implemented framework utilizes genetic algorithms to find feasible, resource efficient mappings. We show how component-models designed for resource constrained safety-critical embedded real-time systems can use powerful compile-time techniques to realize the component-based approach and ensure predictable behavior. Further, we propose a resource reclaiming strategy for component-based real-time systems, to decrease the impact of pessimistic execution time predictions. In our approach, components run in different quality levels as unused processor time is accumulated.

Stig Larsson, Licentiate Thesis, Improving Software Product Integration

The idea with product integration is that separate components are combined into a working system. However, this process of assembling parts into bigger units, products and systems is not well performed in industry, especially not when a substantial part of the product functionality is implemented in software. Many faults that are introduced in early phases are found as late as in the product integration phase, or even worse, in the verification or validation of the final delivery, or after delivery of the product or system. This leads to high

costs for error correction and additional efforts for re-testing. There is consequently a need to further investigate the area of product integration to understand how the performance can be improved. Different practices have been described in standards and models, but the area is still under development. No widely agreed upon body-of-knowledge has so far been defined for product integration. A large part of the development of products containing software for industrial use is conducted in small or medium sized teams. This requires that any data collection methods used to acquire reliable information regarding performance in a project or organization minimize the intrusion. A facilitating approach was needed to understand how units with distinct characteristics should be approached. Based on several years of interaction with different types of organization, the presented research includes an analysis of various methods for data collection. The result is a proposed method for selecting different sizes of investigations based on the openness and maturity of the organization. The main purpose of this research is to understand which factors influence the integration process and what can be done to improve the execution of it. It includes investigations to understand if the described best practices are appropriate, and if there are other means to achieve successful product integration. The research combines investigations of existing compilations of best practices with case studies in industry. Our conclusion is that the type of organization that we have investigated can reduce problems in the product integration process by following the basic practices described in standards and reference models. Problems found in product integration can in most cases be related to the fact that the organization does not follow the proposed practices. The investigations have revealed that the practices are not used in a sufficient way, that additional efforts must be put into fulfilling the requirements in standards and models, and that it is difficult to implement the practices. We have also found indications that specific technology, component based software, may assist in executing the practices. Finally, we conclude that not all standards and models include support to avoid all types of problems in product integration. This is an indication that the on-going development of the area is necessary and that an increased agreement on what can be considered to be best practices is needed.

Annita Persson-Dahlqvist, Licentiate Thesis, Product Data Management and Software Configuration Management Integration

Today, many products are built from both hardware and software components, this especially being true for technologically high-end and complex products such as cars, aircrafts, or mobile phones. Development of such products requires an integrated support that encompasses different domains such as electronics, mechanics, and software. Previously separated, the development of hardware and software components is becoming a common undivided process, which also requires integration of tools providing this support. One of the today's key factors for an integrated product information management is the possibility of integrated and uniform use of Product Data Management (PDM) and Software Configuration Management (SCM). These tools have similar purpose: providing an overall support for building and managing information infrastructure and collaboration between stakeholders. Yet, the integration of these tools and supporting processes has proven to be difficult and challenging for many companies. The main objective of this thesis is to study the feasibility of achieving an integrated, consistent and efficient support to the complex products life cycles by PDM and SCM, either as separated or integrated tools. This objective has been achieved by several research activities: (i) analysis of the main characteristics of PDM and SCM, i.e. their key functionalities and relations between them, (ii) numerous

industrial case studies of PDM and SCM usage and their interoperability, and (iii) a discussion of the hypothesis that the three factors, namely, technologies and architectures, processes, and stakeholders' cultural differences, are of a vital importance for a successful integration. As a result the thesis provides a basis for thorough understanding of PDM and SCM and the prerequisites for their successful integration. The research is primarily based on literature studies, industrial case studies, and long experience from work in industry.

2.3.4   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 70 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.

Sasikumar Punnekkat has joined as a Senior Lecturer at Department of Computer Engineering in November 2004. He received Master Statistics (1982) and Master of Technology in Computer Science with 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 for his thesis on "schedulability analysis of fault tolerant real-time systems". Dr. Punnekkat was a post-doctoral research fellow (1999-2000) at Mälardalen University and had worked on Real-Time aspects of Control Area Networks. 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. Dr Sasikumar Punnekkat has more than 20 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 software testing.

Daniel Flemström is a lecturer at Mälardalen University since June 1999. He received his Master Of Science from Mälardalen University, Sweden 1995. He is teaching courses in programming languages, algorithms and data structures (C++/Java) and Component Based Technologies. Daniel is also giving a series of courses in advanced Industrial IT programming (VB and C++) at the ABB Academy.

Frank Lüders is an industrial Ph.D. student, employed jointly by Mälardalen University and ABB Automation Products AB. His research interests include software engineering, software architecture, and distributed real-time systems. Frank received a BSc in Electronics Engineering from the Vestfold College, Norway in 1993, and a MSc in Electrical Engineering/Computer Systems from the Technical University of Denmark in 1997. He worked as a systems engineer at ABB Norway until November 1999.

Rikard Land has been employed by Westinghouse since 1998 where he has worked as a software developer. The topic for his Master's thesis was a case study on software architecture at Westinghouse, and he received a M.Sc. at Mälardalen University 2001. Since then he has been employed at Mälardalen University as a Ph.D. student. His interests are software architecture and component-based software as a means of understanding and managing software evolution and integration. His licentiate thesis "An Architectural Approach to Software Evolution and Integration" was presented in September 2003.

Mikael Åkerholm is a PhD student at SEL. 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. 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.

Johan Fredriksson (MSc. 2002, BSc. 2001) is a Ph.D. student at SEL, a part of the Department of Computer Science and Engineering (IDE) at Mälardalen University (Mdh), and has been so since the beginning of 2003. Previous to commencing his graduate education, he was an undergraduate at the department between 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.

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.

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. She has been working for Ericsson AB since 1985.

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.

2.3.5   National and International research co-operation

The group cooperates with the following national partners (academic only, industrial partners are listed in Section 1.1):

- Uppsala University, IT Dept., on real-time and component-based technology, in projects ARTIST, SAVE and within ASTEC
- KTH, on embedded systems and component-based approach in projects SAVE and FLEXCON
- Linköping University, on embedded systems, component-based approach in project SAVE
- Skövde Högskola, 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, on Software Engineering.

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

Ivica Crnkovic
- has been active in ARTIST and ARTIST2 EU-IST Network of Excellence
- has continued cooperation with L'aquila University, Italy, which resulted in students' exchanges, and a visiting PostDocs
- has continued cooperation with University of Zagreb, Croatia in performance of a common course.
- has continued cooperation with several universities and faculties in Croatia (Osijek, Split, Varazdin, Business and Management School n Zagreb)
- has continued cooperation with Technical University Eindhoven, The Netherlands- mutual guest lectures have been organized. Work on a book has been started

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, US
- Monash University, Melbourne, Australia
- University of Zagreb, Croatia
- Technical University in Eindhoven, The Netherlands
- L'aqiula University, Italy
- Tufts University, Boston, US
- Software engineering Institute, Carnegie Mellon University

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 2005 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).
- SEI was actively involved in Euromicro CBSE conference track organized by Ivica Crnkovic

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 time discussing SAVE and other related projects. Prof. Heinz Schmidt is a member of the

advisory board for the SAVE project. Johan Fredriksson stayed at Monash University for six months.

University 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 2004 as a common course (examinators prof. Mario Zagar, Zagreb, and Prof. Ivica Crnkovic, MdH).

Eindhoven University of Technology (TUE)
- Close cooperation with Mathematics and Computer science Department, in particular with Prof. Michel Chaudron. During 2005 we had a visiting master student Laurens Blanker from TU/e.

Sofia University, Sofia, Bulgaria
- Cooperation in research and education. During 2005 a PhD student Aleksandar Dimov stayed at MdH during 6 months.

L'aquila University
- 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.

2.3.6 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 2004:

Ivica Crnkovic
- Organiser of IEEE Euromicro Conference in Porto, Portugal, September 2005
- The opponent on the PhD theses of Tomas Panas at Växjö University, Nov 2005
- Tutorial CBSE for embedded systems at ICSE, ST. Louis, May. 2005
- General chair of Euromicro conference
- PC Chair of Euromicro conference, CBSE track
- General Chair of SERPS 05, Västerås, Sweden
- PC member for following conferences, symposia and workshops: CBSE 2005, WICSA 2005, QoSA 2005, WADS 2005, etc.
- Expert evaluator for several applications to different European Foundations
- Co-editor of a special issue of Elsevier's Journal of Systems and Software-Component-based Software Engineering.

2.4 Embedded Systems Software Engineering group

2.4.1 Focus

The core to a successful system is the 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. The basic approach is to formulate hypothesis and thereafter strengthen that hypothesis by extensive case studies, and finally prototype development. In 2004 we have performed several case studies, including starting the work to document existing knowledge about constructing complex software systems by interviews of architects of leading Swedish industries. This work aims at directly sharing experience between Swedish industries and to perform scientific analysis of available data and make results available to participating companies as well as the research community.

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.
- Architectures, analysis and techniques for Open control system with extremely high demands on reliability.

The group consists of two professor, one senior lecturer, and 5 PhD students, 3 of them industrial PhD students.

The major results of this research group in 2005 were:
- One licentiate thesis (Johan Andersson)
- One PhD thesis (Dag Nyström)
- Many papers at international conferences.
- A paper in the Industrial Information Technology Handbook, Publisher IEEE CRC Press, jan 2005.
- Development of a common lab between Ericsson an MdH at MdH.

Acquired funding from
- Vinnova for a joint project with 2 PhD students between Volvo Cars, Volvo Truck, Volvo CE, Chalmers and MdH with the title "Affärsmässig konceptutveckling av elektroniksystemarkitektur och plattformar i fordon"
- KKS for continuation of Remodel into Extract.
- ABB for an industrial PhD student (Markus Lindgren).
- Scania for an industrial PhD student (Håkan Gustavsson).
- ABB, Volvo, Ericsson, and Level21 for an industrial PhD student for studying development efficiency.
- SSF for Progress.
- SSF for commercialization of embedded RT databases.

In 2005 the following projects have been active:
- SAVE/ ComponentModel
- DRIVE
- COMET - COMponent-based Embedded real-Time database system
- REMODEL

2.4.2 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.

Results and achievements in 2005:

Two Licentiate thesis, both focusing on software component technologies for embedded systems.

Publications:

Thesis
- Mikael Åkerholm, A Software Component Technology for Vehicle Control Systems, Licentiate Thesis, Mälardalen University Press, February, 2005
- Johan Fredriksson, Transformation of component models to real-time models, Licentiate Thesis, Mälardalen University Press, 2005

Conferences and Workshops
- Mikael Åkerholm, Thomas Nolte, Anders Möller, Building Distributed Embedded Systems from Large Software Components, Proceedings of the 2nd Embedded Real-Time Systems Implementation Workshop (ERTSI'05) in conjunction with the 26th IEEE International Real-Time Systems Symposium (RTSS'05), Miami, USA, December, 2005
- Mikael Åkerholm, A Software Component Technology for Vehicle Control Systems, Fifth Conference on Software Engineering Research and Practice in Sweden, Västerås, Sweden, October, 2005
- Mikael Åkerholm, Anders Möller, Hans Hansson, Mikael Nolin, Towards a Dependable Component Technology for Embedded System Applications, 10th IEEE International Workshop on Object-Oriented Real-Time dependable Systems (WORDS 2005), IEEE, Sedona, Arizona, January, 2005
- Anders Möller, Mikael Åkerholm, Joakim Fröberg, Mikael Nolin, Industrial Grading of Quality Requirements for Automotive Software Component Technologies, Embedded Real-Time Systems

Implementation Workshop in conjunction with the 26th IEEE International Real-Time Systems Symposium, 2005 Miami, USA, December, 2005

- Jan Carlson, Mikael Åkerholm, An event algebra extension of the triggering mechanism in a component model for embedded systems, Formal Foundations of Embedded Software and Component-Based Software Architectures (FESCA), p 107-121, ENTCS, Edinburgh, Editor(s):J. Küster-Filipe and I. Poernomo and R. Reussner and S. Shukla, April, 2005

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 analysing the business needs for a given organisation and providing guidance for design of architecture, selection of technology and methods for designing 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 technical measures to achieve safety and reliability 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 2005:
- Article in IEEE Handbook on Information Technology in Industrial Automation.
- Conference paper presented in 5th IFAC International Conference on Fieldbus Systems and their Applications.
- Studies on the case study research method.
- Article in 2nd International ICSE workshop on Software Engineering for Automotive Systems, St. Louis, May, 2005
- A study of three cases of electronic integration in an industrial automotive setting.
- A technical report compiled from the cases studies.
- A research plan with directions for study to complete PhD.

Publications:

- A Comparative Case Study of Distributed Network Architectures for Different Automotive Applications, Jakob Axelsson, Joakim Fröberg, Hans Hansson, Christer Norström, Kristian Sandström, Björn Villing (external), The Industrial Information Technology Handbook, p 57-1 to 57-20, CRC Press, ISBN: 0-8493-1985-4, Editor(s): Richard Zurawski, January, 2005
- Industrial Grading of Quality Requirements for Automotive Software Component Technologies, Anders Möller, Mikael Åkerholm, Joakim Fröberg, Mikael Nolin, Embedded Real-Time Systems Implementation Workshop in conjunction with the 26th IEEE International Real-Time Systems Symposium, 2005 Miami, USA, December, 2005
- Business Situation Reflected in Automotive Electronic Architectures: Analysis of Four Commercial Cases, Joakim Fröberg, Kristian Sandström, Christer Norström, 2nd International ICSE workshop on Software Engineering for Automotive Systems, St. Louis, May, 2005
- Component-Based Development of Safety-Critical Vehicular Systems, Ivica Crnkovic, DeJiu Chen (KTH), Johan Fredriksson, Hans Hansson, Jörgen Hansson (external), Joel G Huselius, Ola Larses (external), Joakim Fröberg, Mikael Nolin, Thomas Nolte, Christer Norström, Kristian Sandström, Aleksandra Tesanovic (external), Martin Törngren (external), Simin Nadjm-Tehrani (external), Mikael Åkerholm, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-190/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, September, 2005

Future plans:

Focus on issues of electronic component integration in vehicle systems - PhD Thesis 06

COMET - COMponent-based Embedded real-Time database system

Project leaders:	Christer Norström, MdH
	Jörgen Hansson, LiU
Members:	Dag Nyström, Ph.D. (October 05), MdH
	Aleksandra Tesanovic, Ph.D.-student, LiU
	Mikael Nolin, MdH
Partners:	Volvo Construction Equipment Components AB,
	Mimer Information Technology AB
Funding:	SAVE/SSF

Project description:

This is a joint project between Mälardalen University and Linköping University. The goal of this research is to bridge the gap between embedded systems, real-time systems and database systems, with a particular focus on the software development tools. Significant amount of research has focused on how to incorporate database functionality into real-time systems without jeopardizing timeliness and how to incorporate real-time behavior into embedded systems. However, research is sparse for embedded databases used in embedded real-time systems, which explicitly address (i) the development and design process, and (ii) the limited amount of resources in embedded systems. This type of research inherits the challenges from component-based software engineering, embedded systems, and real-time systems. Further, this research explicitly addresses system resource demand in the design of the embedded database in order to minimize system resource usage.

The goal is to build an experimental research platform for building embedded databases for embedded real-time systems. At a high-level, the platform consists of two parts. First, we intend to develop a component library, which holds a set of components that can be used when building an embedded database. Initially, we will develop a set of components that deal with concurrency control, scheduling, and main-memory techniques. At the next step, we develop tools that, based on the application requirements, will support the designer

when building an embedded database using these components. More importantly, we want to develop application tools and techniques that support the designer in the composition and tailoring of an embedded database for a specific system using the developed components, and where the application requirements are given as an input. Further, we want to provide support to the designer when analysing the total system resource demand of the compositioned embedded database system; and help the designer by recommending components and methods if multiple components can be used, based on the application requirements.

Results and achievements in 2005:

Some of the results of the project include:
- Implementation and finalization of a version of COMET, denoted MiniLine that is a static real-time database management system intended for small control-nodes.
- Development on distribution mechanisms for COMET. The mechanisms allow distributed real-time systems to be stimulated and monitored during run-time.
- Completion and successful defense of Dag's Ph.D. thesis.
- Awarded a grant of 1.4MSEK from SSF for commercialization of research results.

Publications:
- Dag Nyström, Mikael Nolin, and Christer Norström, "Snapshots in Real-Time Databases using Database Pointer Transactions" In the 11th International conference on Real-Time Computing Systems and Applications (RTCSA), IEEE, Hong-Kong, August, 2005
- Thomas Nolte and Dag Nyström, "Introducing Substitution-Queries in Distributed Real-Time Database Management Systems", In Proceedings of 10th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA'05), p 707-714 (volume 2), IEEE Industrial Electronics Society, Facolta' di Ingegneria, Catania, Italy, September, 2005
- Dag Nyström, "Data Management in Vehicle Control-Systems", Ph.D. Thesis, Mälardalen University Press Dissertations, October, 2005

Future plans:

The COMET project (or projects derived from it) is intended to continue in three different directions:
- Further development of real-time database mechanisms, in areas such as concurrency-control and data distribution. (1 Ph.D. student planned)
- Information-centric development of embedded systems (INSENCE). This project aims to investigate how real-time data management and component-based software engineering can be merged into an information centric development method. (1 Ph.D. student planned)
- Commercialisation of achieved results in a spin-off company. A collaboration-project with Mimer Information Technology has been initiated.

Remodel

Project leaders:	Christer Norström
Members:	Johan Andersson
	Anders Wall
	Björn Lisper
	Peter Eriksson, ABB
	Magnus Larsson, ABB
Partners:	ABB
Funding:	ASTEC, ABB

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. For systems containing several communicating processes with real-time requirements there is also a risk of introducing errors related to timing or resource usage. Such errors may be very costly as they can easily be missed during testing and are hard to reproduce when discovered. If such errors can be predicted when adding or changing features of complex software systems, companies can cut development costs and development time, as problems can be avoided. However, to predict the impact on timing manually is very hard, especially if the system is large. Our approach is based on the construction of a model that describes the interactions between tasks in the system, their resource usage and timing. The model is then analyzed using a set of tools in order to predict properties of the system and to analyze the impact of changes. For this purpose we have developed the ART-ML modeling language, a simulator for ART-ML models and a tool for analysis and visualization of the simulation output. We have also developed the probabilistic property language (PPL) together with a PPL analysis tool. PPL allows for queries on properties (requirements) on both timing and resource usage. Our main research question in this project is how to construct and validate such models, and to what extent they can be automatically generated based on information from both the implementation (static analysis) and run-time recordings of the running system (dynamic analysis).

Results and achievements in 2005:

During 2005, the project has produced three main results:
- A licentiate thesis presenting a framework for enabling impact analysis of complex embedded legacy systems with respect to system behavior properties such as timing and resource utilization. The thesis is a monograph summarizing the previous Remodel publications (2003-2004) and elaborating further in several areas, such as cost of system monitoring, model construction and model validation.
- An industrial evaluation of automatic model synthesis from execution traces recorded from complex embedded legacy systems, together with of Joel Huselius.
- The tools for simulation, analysis, and execution trace visualization have been improved. Our industrial partner, ABB Robotics, are very pleased with the tools and are using them more and more (especially the "Tracealyzer" tool). Our users at ABB are very positive and have suggested several of improvements, of which most have been implemented.

Publications:
- Modeling the Temporal Behavior of Complex Embedded Systems - A Reverse Engineering Approach. Licentiate thesis, ISBN: 91-88834-71-9, Mälardalen University Press, 2005. Author: Johan Andersson.
- Model Synthesis for Real-Time Systems, in Proceedings of the 9:th European Conference on Software Maintenance and Reengineering (CSMR), p 52-60, Manchester, UK, March, 2005. Authors: Joel G Huselius and Johan Andersson.

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

Project leaders: Jakob Axelsson, MdH and Volvo Cars
Members: Peter Wallin, MdH
                              Christer Norström, MdH
                              Ana Magazinovic, 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 2005:

In 2005, the major task was project planning and application for funding which was approved in the fall, followed by recruitment of Ph. D. students.

Future plans:

The project will start formally in March 2006 when the Ph. D. students are in place.

Tentative title: 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 2005:

The project started in late 2005.

Future plans:

Refine the problem formulation and complete a state-of-the-art report within the area. Prepare a research plan with the goal of completing a PhD Thesis in 2008.

2.4.3   Theses

In 2005 one PhD and 2 Licentiate theses were presented by SEL staff.

2.4.3.1   Licentiate theses

Johan Andersson: Modeling the Temporal Behavior of Complex Embedded Systems – A Reverse Engineering Approach

Software systems embedded in complex products such as cars, telecom systems and industrial robots are typically very large, containing millions of lines of code, and have been developed by hundreds of engineers over many years. We refer to such software systems as complex embedded systems. When maintaining such systems it is difficult to predict how changes may impact the system behavior, due to the complexity. This is especially true for the temporal properties of the system, e.g. response times, since the temporal behavior is dependent on many factors that are not visible in the implementation, such as execution time. The state-of-the-practice is therefore often the trial-and-error approach, i.e. implement and test. However, errors related to the temporal behavior are often hard to find while testing the system and may cause major economic losses if they occur post-release, since they typically result in system failures.

This thesis presents a method for predicting these types of errors in an early stage of development. The specific method proposed is called behavior impact analysis, which aims to predict if a specific change to the system may result in errors related to the temporal behavior. The method especially targets complex embedded systems and by using this analysis method in the software development process, the number of errors introduced when maintaining the system can be reduced. This results in an increased productivity in maintenance as well as an improvement in system reliability. This thesis focuses on the construction and validation of the temporal behavior model necessary for performing a behavior impact analysis. The conclusion of the thesis is that a combination of dynamic analysis and reverse engineering is suitable for modeling the temporal behavior of complex embedded systems. Regarding validation of temporal behavior models, the thesis proposes a process containing five increasingly demanding tests of model validity. Tools are presented that support the model construction and validation processes.

2.4.3.2 PhD Thesis

Dag Nyström: Data Management in Vehicle Control-Systems

As the complexity of vehicle control-systems increases, the amount of information that these systems are intended to handle also increases. This thesis provides concepts relating to real-time database management systems to be used in such control-systems. By integrating a real-time database management system into a vehicle control-system, data management on a higher level of abstraction can be achieved. Current database management concepts are not sufficient for use in vehicles, and new concepts are necessary. A case-study at Volvo Construction Equipment Components AB in Eskilstuna, Sweden presented in this thesis, together with a survey of existing database platforms confirms this. The thesis specifically addresses data access issues by introducing; (i) a data access method, denoted database pointers, which enables data in a real-time database management system to be accessed efficiently. Database pointers, which resemble regular pointers variables, permit individual data elements in the database to be directly pointed out, without risking a violation of the database integrity. (ii) two concurrency-control algorithms, denoted 2V-DBP and 2V-DBP-SNAP which enable critical (hard real-time) and non-critical (soft real-time) data accesses to co-exist, without blocking of the hard real-time data accesses or risking unnecessary abortions of soft real-time data accesses. The thesis shows that 2V-DBP significantly outperforms a standard real-time concurrency control algorithm both with respect to lower response-times and minimized abortions. (iii) two concepts, denoted substitution and subscription queries that enable service- and diagnostics-tools to stimulate and monitor a control-system during run-time. The concepts presented in this thesis form a basis on which a data management concept suitable for embedded real-time systems, such as vehicle control-systems, can be built.

2.4.4 Staff

Jakob Axelsson is adjunct professor in software and systems engineering. Systems. 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 Car 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 was until recently 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 Software Engineering Lab at the Department of Computer Science and MRTC Mälardalen University. Joakim Fröberg is an Industrial Ph.D. student employed Volvo Construction Equipment Components AB where he is working with electronic system architecture guidelines and 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.

Dag Nyström is a researcher at the department. Dag is a former undergraduate student from the "Datateknikprogrammet". He earned his Ph.D. in October 2005, with a thesis entitled "Data management in Vehicle Control-Systems" During his Ph.D. studies, Dag has lectured in a number of courses such as Operating systems, Databases and Introduction to Datalogiprogrammet. He has been head (Programansvarig) of the MIMA Software Engineering programs (2 programs). Currently, Dag works part time as a researcher and supervisor within Progress Furthermore, Dag works part time in a spin-off project together with Mimer Information Technology.

Johan 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.

Goran Mustapic is an industrial PhD student working at ABB Automation Technologies AB/ Robotics in Västerås. He received Electrical Engineering degree from University of Zagreb, Croatia in 1994. After spending several years in industry, working as a Software Engineer, he enrolled the PhD program at MdH in 2002. In December 2004, he received Technology Licentiate degree. The licentiate thesis title is "Architecting Software for Complex Embedded Systems - Quality Attribute Based Approach to Openness". Research interests include: Software Quality and Quality Modeling, Software and Systems Architecture, and their application in open complex real time systems.

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.

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.

Peter Wallin is a Ph.D. student at SEL. He 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 Car 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.

2.5 Programming Languages Group

2.5.1 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, one senior lecturer, one researcher, and nine Ph.D. students, whereof three 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 two Ph.D. students participating in the school during 2005. Finally, the group has participated in the Vinnova-supported ASTEC competence centre in Uppsala, with two active research projects plus one member of the board.

Publications:

Journals
- Clustered Worst-Case Execution- Time Calculation, Andreas Ermedahl, Friedhelm Stappert (Siemens VDO Automotive AG, Germany), Jakob Engblom (Virtutech, Sweden), IEEE Transactions on Computers, vol 54, nr 9, p1104--1122, September, 2005
- Infinite unfolding and transformations of nondeterministic programs, Björn Lisper, Fundamental Informaticae, vol 66, nr 4, p415-439, April, 2005

Conferences and workshops
- SaveCCM: An Analysable Component Model for Real-Time Systems, Jan Carlson, John Håkansson (external), Paul Pettersson (external), International Workshop on Formal Aspects of Component Software, Elsevier, Macao, October, 2005
- Formal Semantics for PLEX, Johan Lindhult, Björn Lisper, 17th Nordic Workshop on Programming Theory, NWPT05, p 65-66, Copenhagen, Denmark, October, 2005
- Two Formal Semantics for PLEX, Johan Lindhult, Björn Lisper, 3rd APPSEM II Workshop, APPSEM'05, Frauenchiemsee, Germany, September, 2005
- Experiences from Industrial WCET Analysis Case Studies, Andreas Ermedahl, Jan Gustafsson, Björn Lisper, Real-Time in Sweden (RTiS2000), Skövde, August, 2005
- Using a WCET Analysis Tool in Real-Time Systems Education, Samuel Petersson (external), Andreas Ermedahl, Anders Pettersson, Daniel Sundmark, Niklas Holsti (Tidorum LTD), Real Time in Sweden (RTiS) 2005, p 125--128, Skövde, Sweden, Editor(s):Sten F. Andler, August, 2005
- Experiences from Industrial WCET Analysis Case Studies, Andreas Ermedahl, Jan Gustafsson, Björn Lisper, Proc. Fifth International Workshop on Worst-Case Execution Time (WCET) Analysis, Palma de Mallorca, Editor(s):Reinhard Wilhelm, July, 2005
- Applying Static WCET Analysis to Automotive Communication Software, Susanna Byhlin (external), Andreas Ermedahl, Jan Gustafsson, Björn Lisper, 17th Euromicro Conference of Real-Time Systems, (ECRTS'05), Mallorca, Spain, July, 2005
- Using a WCET Analysis Tool in Real-Time Systems Education, Samuel Pettersson (external), Andreas Ermedahl, Anders Pettersson, Daniel Sundmark, Niklas Holsti (Tidorum LTD), Fifth International Workshop on Worst-Case Execution Time (WCET) Analysis, Palma de Mallorca, Spain, Editor(s):Reinhard Willhelm, July, 2005
- An event algebra extension of the triggering mechanism in a component model for embedded systems, Jan Carlson, Mikael Åkerholm, Formal Foundations of Embedded Software and Component-Based Software Architectures (FESCA), p 107-121, ENTCS, Edinburgh, Editor(s):J. Küster-Filipe and I. Poernomo and R. Reussner and S. Shukla, April, 2005

- Towards a Flow Analysis for Embedded System C Programs, Jan Gustafsson, Andreas Ermedahl, Björn Lisper, The 10th IEEE International Workshop on Object-oriented Real-time Dependable Systems (WORDS'05), Sedona, USA, February, 2005

MRTC reports
- Using a WCET Analysis Tool in Real-Time Systems Education, Samuel Pettersson (external), Andreas Ermedahl, Anders Pettersson, Daniel Sundmark, Niklas Holsti (Tidorum LTD), MRTC report ISSN 1404-3041 ISRN MDH-MRTC-178/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, April, 2005
- Maintaining Consistency of Dynamic Cardinality Constraints with Costs, Waldemar Kocjan (former), Per Kreuger (external), Björn Lisper, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-168/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, January, 2005

Technical reports
- A Constant-memory Event Algebra with Intuitive Algebraic Properties, Jan Carlson, Technical Report, MRTC, December, 2005
- Licentiate Thesis Proposal: An Operational Semantics for Parallel Execution of Re-entrant PLEX, Johan Lindhult, Technical Report, MRTC, June, 2005
- Licentiate thesis proposal: Improvements of the Flow Analysis in WCET Tools, Christer Sandberg, Technical Report, MRTC, February, 2005

2.5.2   Research projects

Worst-case execution time analysis (WCET)

Project leader:	Björn Lisper
Project members:	Björn Lisper,
	Andreas Ermedahl,
	Jan Gustafsson,
	Christer Sandberg
Partners:	AbsInt GmbH,
	Tidorum Ltd
	Volvo CE,
	CC-Systems AB,
	IAR Systems,
	Arcticus Systems
Funding:	KKS
	SSF
	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 2005:

A number of case studies have been made, where WCET tool technology has been tested on real industrial code. There is now a working version of the prototype tool SWEET.

The group has participated in the tool integration work carried out within the Compilers and Timing Analysis cluster, which is part of the ARTIST2 NoE.

Future plans:

A new grant from KKS has enabled us to continue the development of WCET analysis methods and their evaluation on real industrial real-time codes. Our research will focus on methods for automatic flow analysis, and we will componentize our flow analysis so it can be used with other WCET tools. This work is done within the ARTIST2 NoE. Within Progress, we will investigate how WCET analysis can be applied to component-based embedded software.

Dimensional Inference in Strongly Typed Specification Languages
Project leader: Björn Lisper
Members: Mikael Sandberg (Ph.D. student)

Project description:

Modelling languages such as Modelica and gPROMS specify dynamic systems for simulation. Current implementations lack the ability to detect if physical units and dimensions are correctly specified in the models. The goal of this project is to develop and evaluate efficient methods to verify that equations use dimensions in a consistent way. This is done through a form of type inference, which in the end boils down to the problem of solving a system of linear equations.

Results and achievements in 2005:

A report has been written on EKL, a small kernel language for equations. This report will be included in Mikael Sandberg's Licentiate thesis.

Future plans:
- Implement a translator for a subset of Modelica into EKL.
- Evaluate the effectiveness of the proposed solution methods by analyzing some realistic Modelica models.
- Licentiate Thesis (Mikael Sandberg)

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 an 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 a 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 2005:

The event detection model has been integrated with the SaveCCM component model. A workshop paper (FESCA 2005) has been presented.

Future plans:

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

Parallel Execution of PLEX Programs

Project leader:	Björn Lisper
Members:	Jan Gustafsson
	Johan Lindhult
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 a 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 2005:

A semantics for parallel PLEX has been defined, and a workshop paper (APPSEM-05) has been presented. A preliminary model how to safely parallelize PLEX programs has been defined. A code study has been initiated, where the model will be tested on some selected PLEX blocks.

Future plans:
- A licentiate thesis based on the results achieved so far is planned for the spring of 2006.
- 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.

2.5.3 Other projects

The Siblings Project

Project leader:	Rikard Lindell
Members:	Rikard Lindell
	Jussi Karlgren (SICS)
	Ivica Crnkovic
	Peter Funk
Partners:	SICS
Funding:	Internal

Project description:

The aim of the project is to develop a verified and applicable framework for design of interactive systems where information content is the base for all interaction between users and system. Content information elements, in users\ \ \ \ \ \ \' locus of attention, offer the available actions and functions. We will create a software framework by bringing together the partners – users: musicians, illustrators, and animators; and developers of music, illustration, and animation systems – to investigate the user experience and design of content centric interactive systems and how users can work and collaborate in an unbroken activity flow.

Publications:
- The Data Surface Interaction Paradigm, Rikard Lindell, Thomas Larsson, Theory and Practice in Computer Science, p 155-162, Eurographics Association, University of Kent, Canterbury, United Kingdom, Editor(s):Louise Lever, Mary McDerby, June, 2005

Global Constraints in Constraint Programming and Local Search

Project leader:	Björn Lisper
Members:	Per Kreuger (SICS/Kista)
	Björn Lisper (MdH)

	Marcus Bohlin (SICS/Västerås)
	Waldemar Kocjan (MdH)
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.

Publications:
- *Symmetric Cardinality Constraints*, Waldemar Kocjan *(former)*, Licentiate Thesis, MRTC, December, 2005
- *Maintaining Consistency of Dynamic Cardinality Constraints with Costs*, Waldemar Kocjan *(former)*, Per Kreuger *(external)*, Björn Lisper, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-168/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, January, 2005

Results and achievements in 2005:

Waldemar Kocjan presented his Licentiate thesis.

3D Graphics Simulation

Project leader:	Björn Lisper
Members:	Tomas Larsson
	Thomas 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.

Publications:
- *A Dynamic Bounding Volume Hierarchy for Generalized Collision Detection*, Thomas Larsson, Tomas Akenine-Möller *(external)*, Proceedings of the 2nd Workshop on Virtual Reality Interactions and Physical Simulations, p 91-100, Pisa, Italy, November, 2005

Results and achievements in 2005:

A workshop paper on collision detection was presented.

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 (main supervisor)
	Jan Gustafsson
	Lars-Göran Johansson (external supervisor, UU)
Funding:	Internal
	KK-foundation

Project description:

Philosophy of Information and Computing brings together scientific, philosophical and ethic perspective. That sort of analysis has not yet been done, and it is under development internationally within CAP (Computing And Philosophy) project. It is important for many reasons. For students, in contrast to the short-term knowledge of present day tools and technologies, it identifies long-term goals and context of the field. For Computing community it establishes standards to assess the quality of research and its acceptability from the ethical and societal point of view. By bringing together contemporary ideas PICO provides an introduction to a fundamental area of research that is rapidly growing. This year we make a contribution to the research area by organising E-CAP 2005, European Computing and Philosophy Conference.

Results and achievements in 2005:

We arranged the European Computing and Philosophy Conference (E-CAP) 2005. A conference paper was presented, and a number of papers were submitted or prepared for submission. Several of them have been accepted, and will appear during 2006.

Publications:
- Game Ethics - Homo Ludens as a Computer Game Designer and Consumer, Gordana Dodig-Crnkovic, Thomas Larsson, International Journal of Information Ethics, vol 4, nr 12, p20-23, ICIE, December, 2005
- Professional Ethics in Software Engineering Curricula, Gordana Dodig-Crnkovic, Ivica Crnkovic, Cross-disciplinarity in Engineering Education, CeTUSS, Uppsala, December, 2005
- Good to Have Someone Watching Us from a Distance? Privacy vs. Security at the Workplace, Gordana Dodig-Crnkovic, Ethics of New Information Technology, Proceedings of the Sixth International Conference of Computer Ethics: Philosophical Enquiry, CEPE 2005, Brey P, Grodzinsky F and Introna L., University of Twente, Enschede, The Netherlands, July, 2005
- System Modeling and Information Semantics, Gordana Dodig-Crnkovic, Proceedings of the Fifth Conference for the Promotion of Research in IT, Studentlitteratur, Lund, Editor(s): Bubenko jr. J., Eriksson O., Fernlund H. & Lind M., April, 2005

Future:

A Ph.D. degree is planned for 2006.

Computer Science Paradigms in Gender Research Perspective

Project leader:	Lena Trojer (Blekinge Institute of Technology)
Members:	Christina Björkman
	Lena Trojer
Partners:	Blekinge Institute of Technologies
Funding:	VR, BTH

Project description:

The aim of this project is to develop new possible, broader understandings and interpretations of Computer Science and its practices, starting in analysis of existing paradigms and knowledge processes within Computer Science and how these interact in forming the activities within the discipline (education, research and development of applications). A starting point and special target of the project is the underrepresentation of women within Computer Science, where possibly the way that Computer Science is defined, described and taught can be a factor of importance. Broadening the definition and understanding of the nature of Computer Science is of vital importance for a sustainable increase in women's participation in Computer Science.

Computer Science is a fairly young science, which is still under formation and subject of many discussions regarding core character and content. Examples of interesting questions deal with how male and female students and faculty understand and create knowledge and images of concepts, for example how male and female students learn and understand programming. The aim of this research is to create knowledge in the field, which would strengthen and improve education, and possibly also influence research, within Computer Science.

Results and achievements in 2005:

Completion and successful defense of Christina's Ph.D. thesis at Blekinge Institute of Technology.

2.5.4 Theses

One Licentiate thesis was presented by the Programming Languages group in 2005:

Waldemar Kocjan. Symmetric Cardinality Constraints, Licentiate Thesis.

This thesis contains previously published papers concerning different aspects of symmetric cardinality constraints. A symmetric cardinality constraint generalizes cardinality constraints like constraint of difference and global cardinality constraint. The algorithms formulating the basis for consistency checking and filtering of a symmetric cardinality constraint can be successfully used to model and solve several other problems like cardinality matrix problems, Latin square problems and rostering problems. This thesis begins with an introduction to constraint satisfaction and describes several problems, mainly dynamic scheduling problems, which can be modeled using this framework. The two following papers introduce symmetric cardinality constraint and its weighted version. They also provide methods for computing their consistency and algorithms for filtering their domains. Finally, the last paper describes methods for maintaining consistency of a symmetric cardinality constraint with costs, in the context of dynamic constraint satisfaction.

One PhD was presented by

Christina Björkman, Crossing Boundaries, Focusing Foundations, Trying Translations: Feminist Technoscience Strategies in Computer Science, PhD Thesis, May (presented at Blekinge Tekniska Högskola).

In this thesis I explore feminist technoscience strategies in computer science, starting in "the gender question in computer science", and ending up in communication and translation between feminist technoscience research and computer science educational practice.

Necessary parts in this work concern issues of boundary crossings between disciplines, and focusing on the foundations of computer science: what it means to "know computer science".

The point of departure is in computer science (CS), in particular CS education. There are at this starting point two intertwined issues: the gender question in computer science (often formulated as "what to do about the situation of women in computer science?") and the foundation question: "what does it mean to know computer science?" These are not primarily questions looking for answers; they are calls for action, for change and transformation. The main focus and goal of this thesis concerns how to broaden the meaning of "knowing computer science"; to accommodate epistemological pluralism and diversity within the practices and among the practitioners of CS.

I have identified translation as fundamental, to make feminist research and epistemological perspectives communicable into the community of computer science practitioners. In this, questions of knowledge and how knowledge is perceived and talked about are central. Communication and translation also depend on the ability and willingness to cross boundaries, to engage in "world-traveling" (Lugones). Additional issues of importance are asking questions open enough to invite to dialogues, and upholding critical (self) reflection.

An important goal for feminist research is transformation. Because of this, interventions have been part of my research, interventions in which I myself am implicated.

The work has been based in feminist epistemological thinking, where the concepts of positioning and partial perspectives (Haraway) have been of particular importance.

2.5.5 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 ASTEC competence centre in Uppsala, and of the steering group of the National Research School in Computer Science (CUGS). His current research interests are in programming language issues, targeting 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 Engineering at Mälardalen University since 1985. He has been the head of the department 1993 - 1997 and 1998 - 1999, and is one of the founders of the department, its educational programmes and its research.

He worked at ABB Västerås, Sweden 1975 - 1985 with development of real-time industrial control systems and was manager for the Base System Development (operating system, data communication and database system). He received a B.Sc. in Mathematics, Physics, Astronomy and Computer Science at Uppsala University, 1974, and a

Licentiate degree in Machine Elements (Computer Controlled Mechanics) at KTH, Stockholm, Sweden, 1994. His current research concerns high-level analysis of real-time programs to calculate annotations to be used in WCET (Worst-Case Execution Time) analysis. His research is partly connected to ASTEC at Uppsala University. In May 2000 he graduated at Uppsala University.

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.

Andreas Ermedahl is a researcher at CSL. He holds a recent Ph.D on WCET analysis from Uppsala University. He now works in the WCET project at CSL.

Christina Björkman is Lecturer and. She holds a recent PhD on Gender issues in Computer Science Education from Blekinge Institute of Technology. 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.

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 Engineering at Mälardalen University. His main interests are within the fields of real-time computer graphics, virtual reality and visualisation. He received a bachelor of computer engineering degree in 1996 a master of science degree, in computer engineering, in 1999, and a licentiate in computer science in 2003. Currently, he his working towards his PhD degree in the area of computer graphics.

Mikael Sandberg was a Ph.D. student and Lecturer at CSL until September 2004, and he is still enrolled as a Ph.D. student. He received a BSc in Computer Science from Mälardalen University (1999).

Jan Carlson is a Ph.D. student and lecturer at CSL. 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.

Waldemar Kocjan is a Ph.D. student at CSL. Before 2004 he was employed by SICS, and January-June 2004 he was employed at CSL. He is still enrolled as a Ph.D. student. His area of research is efficient methods for solving dynamic constraint programming problems.

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.

2.5.6   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,
- IDA, LiU on the modelling language Modelica,
- SICS on constraint programming, and human-machine interaction

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.

2.5.7   Services to the Community

The following is a list of the most important services to the scientific community by members of CSL in 2005:

Björn Lisper:
- was on the program committees of the International Conference on Engineering of Reconfigurable Systems and Algorithms 2005,
- was session chair at the 5th International Workshop on Worst Case Execution Time Analysis, Palma de Mallorca, Spain, June 2005,
- was on the grading committee of Erik Lindskog (IMIT/KTH),
- served on the board for the ASTEC competence centre in Uppsala,
- was a member of the steering group of CUGS (National Graduate School in Computer Science) seated in Linköping.
- reviewed a number of papers for conferences and journals.

Jan Gustafsson:
- was member of the PC committee of ISORC 2006 (The IEEE International Symposium on Object-oriented Real-time distributed Computing),
- was member of the grading committee for the PhD exam of Gustaf Naeser at IDE, MdH,
- was examiner at the licentiate presentation of Waldemar Kocjan at IDE, MdH,
- was member of the Steering Group for the International Workshop on Worst Case Execution Time Analysis.

Andreas Ermedahl:
- was on the program committees of the Fifth International Workshop on Worst Case Execution Time Analysis, and the Embedded World 2006 conference,
- was invited speaker at the DATE2005 (Design, Automation & Test in Europe) conference.

Gordana Dodig-Crnkovic:
- was coordinator of the PI-network: The Swedish national network on Philosophy of Informatics,
- was member of the grading committee of Krister Landernäs at IDE, MdH,
- organized the E-CAP 2005 international conference,
- reviewed a proposed book, and a number of conference papers.

2.5.8   Interactions with society

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

Andreas Ermedahl has coordinated and supervised a number of industrial case studies, where advanced timing analysis methods are being disseminated into industry.

Thomas Larsson has participated in the "Young Energy" project, which aims at raising the awareness of energy saving issues among the youth through especially designed computer games.

2.6 Real-Time Systems Design

2.6.1 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:	Sigrid Eldh
	Joel Huselius
	Kaj Häninen
	Anders Möller
	Thomas Nolte
	Jukka Mäki-Turja
Partners:	CC-Systems (Jörgen Hansson)
	Arcticus Systems (Kurt-Lennart Lundbäck)
	Volvo Technology (Henrik Lönn)
	Volvo Construction Equipment (Nils-Erik Bånkestad)
	LiU/RTSLAB (Jörgen Hansson/Simin Nadj-Tehrani)
	KTH/DAMEK (Martin Törngren/Ola Redell)
	UU/UppAal (Paul Pettersson/Wang Yi)

Details of our projects are given below:

2.6.2 Research projects

SAVE

Project leader:	Hans Hansson
Members:	Mikel Nolin
	Thomas Nolte
	Henrik Thane
	Joel Huselius
Partners:	LiU/RTSLAB (Jörgen Hansson/Simin Nadjim-Tehrani)
	KTH/DAMEK (Ola Redell/Martin Törngren)
	UU/UppAal (Paul Pettersson/Wang Yi)
Funding:	SSF

Project description:

SAVE (Component Based Design of Safety Critical Vehicular Systems) is a national project supported by the Swedish Foundation for Strategic research (SSF) with 17MSEK during 2003-2005. SAVE is co-ordinated by Hans Hansson, and additional partners in SAVE are MRTC/ISE, LiU/RTSLAB, KTH/DAMEK, and UU/UppAal.

The goal of SAVE is to establish an engineering discipline for systematic development of component-based software for safety critical embedded systems. This will be vital to the Swedish industry, and paves the way for establishing an industry for safety-critical and other components.

The main innovation of SAVE is the interdisciplinary combination of architectural and component based design with analysis and verification, in the specific context of safety and real-time. The focus on a single application area (vehicular systems) will reduce the overall project complexity to a manageable level.

The main challenges in component-based development of safety critical applications are to handle the multitude of conflicting requirements, including safety vs. cost and time-to-market. Reuse of earlier work and integration of external components and sub-systems are essential in reducing cost and time-to-market, and the use of proper design methods and architectures is instrumental to accomplish this. Structuring is equally important, together with verification, to ensure safety.

SAVE is addressing the above by developing a general framework for component-based development of safety-critical vehicular systems, including
- Methodology and process for development of systems with components
- Component specification and composition, providing a component model which includes the basic characteristics of safety-critical components and infrastructure supporting component collaboration.
- Techniques for analysis and verification of functional correctness, real-time behaviour, safety, and reliability.
- Run-time and configuration support, including support for assembling components into systems, run-time monitoring, and evaluation of alternative configurations.

During 2005 our main activities within SAVE has been

- Research on component models for embedded systems. Design and development of the SAVEComp component technology and SaveCCM (the SaveComp component model) [Hans Hansson/Mikael Nolin].
- Joel Huselius extended his work on Dynamic Model synthesis with a method for automatic model validation. The essence of the work is to, by using recordings of the execution of a running system; create a model that can deliver the same behaviour as that observed. The developed validation procedure validates the faithfulness of a generated model, by comparing its behaviour with observed behaviours of the real system. The intended use for the models is in impact analysis and in model verification.
- Thomas Nolte has extended his research on server-based scheduling of vehicular communications, by providing timing-analysis and by simulation-based evaluations. Thomas has also been working with vehicular communications technologies, looking at, for example, CAN and FlexRay. This has resulted in several publications, including a journal publication. The results will be presented in a PhD-thesis in May 2006.
- Management: Project management (Hans Hansson), including preparation of the SAVE++ application for a two year funding extension (Hans Hansson)

Academic co-operation

Participation in the EU Network ARTIST – Action line on Component Based Design

Hans Hansson and Thomas Nolte collaborated with Guillermo Rodriguez-Navas and Julian Proenza Arenas at the Universitat de les Illes Balears, regarding safety, fault-tolerance and modelling/verification.

Thomas Nolte and Hans Hansson cooperated with prof. Lucia Lo Bello at the University of Catania in Italy working on vehicular communications. Thomas will spend a 6 month PostDocs-period in Catania in 2006.

Industrial co-operations

There are close links with the project HEAVE at MdH. HEAVE is a co-operation between RTS Design, Volvo Construction Equipment (Eskilstuna) and CC-Systems (Uppsala/Västerås) with the goal to enable the use of modern Component Based Software Engineering (CBSE) techniques within the industrial segment of heavy vehicles. Mikael Nolin is project leader for HEAVE (working 50% in the project). Industrial graduate student Anders Möller (CC-Systems, 75%) has additionally interacted with SAVE.

The debugging work of Joel Huselius and Henrik Thane is performed in co-operation with ABB Robotics and Zealcore.

MultEx

Project leader:	Mikael Nolin, MdH
Members:	Jukka Mäki-Turja, MdH
	Kaj Hänninen, MdH & Arcticus Systems
Partners:	Arcticus Systems, Volvo Construction Equipment
Funding:	MRTC, SAVE-IT/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 2005:

Jukka Mäki-Turja completed and defended his PhD-thesis "Engineering Strength Response-Time Analysis – A Timing Analysis Approach for the Development of Real-Time Systems". As a side effect of the thesis defense, a cooperation with the timing analysis group at Univ. of Cantabria (Prof. M. Gonzalez-Harbour) was initiated.

External funding for the continuation was sought and approved from the KKS, Funding of 2.9MSEK over 3 years was obtained. In this continuation a third external partner, CC Systems AB, will participate.

The cooperation with Arcticus has resulted in the introduction of a novel execution model in the Rubus real-time OS.

A larger industrial survey of industrial requirement on development tools and real-time OSes was performed with interviews of engineers in a series of Swedish companies.

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 2005:

In the beginning of 2005 Anders Möller presented his licentiate thesis "Software Component Technologies for Heavy Vehicles". Anders then performed a 6 month research visit to Prof. H. Schmidt's group at Monash University (Melbourne, Australia). The visit resulted in many new ideas of how to apply the basic theoretical research performed at Monash in real industrial settings.

Continued funding for HEAVE was sought for in cooperation with CC Systems from VR. VR approved the funding of an industrial graduate student starting in 2006.

Continued cooperation with the SAVE project have resulted in techniques for handling large software components.

2.6.3   Theses

In 2005 RTS Design staff presented the following theses:

Jukka Mäki-Turja: PhD thesis: Engineering Strength Response-Time Analysis – A Timing Analysis Approach for the Development of Real-Time Systems

Andes Möller Licentiate Thesis: Software Component Technologies for Heavy Vehicles

Below, these theses are presented in more detail.

2.6.3.1   PhD Thesis

Jukka Mäki-Turja: Engineering Strength Response-Time Analysis – A Timing Analysis Approach for the Development of Real-Time Systems

Date: May 27.

Opponent: Prof. Michael Gonzalez-Harbour, Univ. of Cantabria.

Committee members: Doc Jan Jonsson (Chalmers University), Dr Lucia Lo Bello (Univ. of Catania), Dr Ken Tindell (ETAS/Live Devices)

Main Supervisor: Mikael Nolin

Assistant Supervisor: Christer Norström

Abstract:

When developing computer systems that are part of larger systems, as in control systems for cars, airplanes, or medical equipment, reliability and safety is of major concern. Developers of these systems want to keep the production and development costs to a minimum while maximizing customer benefit by increasing the functionality of the product. Increasing the number of functions, along with the added complexity that it entails, places a demand on better development methods, models, and tools. Response-Time Analysis (RTA) can be a useful method for these systems by able to guarantee a system's temporal behavior. This thesis presents new techniques aimed at improving currently existing RTA methods. Specifically, these techniques lead to the following improvements:
- The precision in the calculated response times are significantly higher than with previous methods, with typically 15% shorter response times.
- The analysis, itself, can be made more 100 times faster than with previous implementations. By combining these independent techniques of precise (tight)

response times and fast analysis, as shown in this thesis, one can get the benefits of both in a single analysis method.

High precision response-time estimates enable either increased functionality within a given hardware cost, or a lower cost for a given functionality. Faster RTA will increase the usefulness of RTA by enabling the use of RTA in development tools for real-time systems with hundreds, or even thousands of tasks. RTA can be particularly beneficial for safety critical applications that have even higher requirements on reliability and safety, and often undergo expensive and lengthy certification processes. We illustrate the possible advantages by applying RTA for tasks with offsets in a real industrial context. The benefits consist of simplifying the development process as well as enabling an efficient resource usage.

2.6.3.2 Licentiate Thesis

Anders Möller, Software Component Technologies for Heavy Vehicles

Date: January 28

Opponent: Dr. Henrik Lönn, Volvo Technology Corp.

Examiner: Prof. Mats Björkman, MRTC

Main Supervisor: Mikael Nolin

Assistant supervisor: Hans Hansson

Abstract:

Control-systems for heavy vehicles have advanced from an area where mainly mechanic and hydraulic solutions were used, to a highly computerised domain using distributed embedded real-time computer systems. To cope with the increasing level of end-customer demands on advanced features and functions in future vehicle systems, sophisticated development techniques are needed. The development techniques must support software in numerous configurations and facilitate development of systems with requirements on advanced functionality, timeliness, and safety-criticality. In order to meet these requirements, we propose the use of component-based software engineering. However, the software component-technologies available on the market have not yet been generally accepted by the vehicular industry. In order to better understand why this is the case, we have conduced a survey - identifying the industrial requirements that are deemed decisive for introducing a component technology. We have used these requirements to evaluate a number of existing component technologies, and one of our conclusions is that none of the studied technologies is a perfect match for the industrial requirements. In addition, we have implemented and evaluated the novel component model SaveCCM, which has been designed for safety-critical automotive applications. Our evaluation indicates that SaveCCM is a promising technology which has the potential to fulfill the industrial requirements. However, tools are still immature and incomplete. In the final part of this work, we propose the use of monitored software components, as a general approach for engineering of embedded systems. In our approach, a component's execution is continuously monitored and experience regarding the behaviour is accumulated. As more and more experience is collected the confidence in the component grows.

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.

Mikael Nolin is an associate professor at SDL. He is responsible for the projects HEAVE and MultEx. 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.

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.

Kaj Hänninen received a MSc in Computer Engineering from Mälardalen University, 2003. His research focus on software engineering of embedded real-time control systems using multiple execution paradigms. Kaj is a member of the MultEx project.

Anders Möller is an Industrial Ph.D. student employed by CC Systems AB and by MdH. He is working in the HEAVE project at SDL, a project to identify, define and evaluate a component technology for software components within the business segment of heavy vehicles. He received a M.Sc. in Engineering Physics at Uppsala University 2003. and presented his licentiate thesis in January 2005.

Thomas Nolte is a Ph.D. student at SDL, working in the SAVE project. His research interests include distributed embedded real-time systems, especially communication issues, scheduling of real-time systems, automotive and vehicular systems.

Thomas took his Licentiate degree in May 2003 where he defended a probabilistic analysis method for the Controller Area Network (CAN) together with a method for server-based scheduling of CAN. During spring 2002, he was a visiting Jr. Specialist at the at the Department of Electrical and Computer Engineering, University of California, Irvine (UCI), Los Angeles, USA, and during autumn 2004 he was a visiting researcher at the Department of Computer Engineering and Telecommunications, University of Catania, Italy

Thomas is the PhD representative (doktorandombud) of all Ph.D. students at Mälardalen University since September 2003. Moreover, he is the M.Sc./B.Sc. Thesis Coordinator at the Department of Computer Science and Electronics (IDE) since October 2002. Prior to becoming Ph.D. student, Thomas has been an undergraduate student at IDE since 1997. He is a Student Member of IEEE.

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.

2.6.5 National and International research co-operation

The following is a partial list of national and international research co-operation by RTS-Design staff in 2005:

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
- is coordinator for the national industrial graduate school SAVE-IT. SAVE-IT is supported by KKS and is a joint effort of MdH, UU, KTH and LiU. Participating companies include ABB, Arcticus Systems, Bombardier, Ericsson, Saab, and Volvo Construction Equipment.
- Arranged a research visit for Anders Möller to Monash Univ., Melbourne Australia.

RTS Design has concrete co-operations with the following national and international researchers and groups:
- Martin Törngren, Jan Wikander: DAMEK group at KTH, Stockholm, Sweden
- Paul Pettersson, Wang Yi: The UppAaal-group at Computer systems, Uppsala University, Sweden
- Simin Nadj-Tehrani, Jörgen Hansson: RTSLAB at IDA, Linköping University
- Guillermo Rodriguez-Navas and Julian Proenza Arenas at the Universitat de les Illes Balears
- Lucia LoBello at the University of Catania
- Heinz Schmidt at Monash University
- Michael Gonzalez-Harbour at University of Cantabria

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.

2.6.6 Services to the Community

The following is a list of the most important services to the scientific community by members of RTS Design in 2005:

Hans Hansson
- is associate editor of Kluwer's Journal of Real-Time Systems
- is member of the International Advisory Board for the Embedded Systems Handbook, IEEE CRC Press.
- is member of the steering-committee of the FLEXCON national research programme

- 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
- is member of the board of TekniQ (KKS-supported technology transfer initiative)
- was on the opponent at Luis Lino Ferreira's PhD-dissertation in Porto, Portugal, and on the grading committee at four PhD dissertations (Sorin Manolache, LiTH, Diana Szentivanyi, LiTH, Roger Johansson CTH, and Fredrik Wernstedt, BTH)
- was scientific evaluator of the EU Fifth Framework Project NEXT-TTA and for the 6th Framework Integrated Project DECOS.
- was/is on the programme committee for: FeT 2005 - 6th IFAC International Conference on Fieldbus Systems and their Applications; 7th International Conference on Principles of Distributed Systems OPODIS-2004; IEEE Real-Time and Embedded Technology and Applications Symposium - RTAS 2005; The 8th IEEE International Symposium on Object-oriented Real-time distributed Computing - ISORC-2005; Embedded Real-Time Systems Implementation Workshop 2004; ETFA'2005 - 10th IEEE International Conference on Emerging Technologies and Factory Automation; RTCSA - Real-Time and Embedded Computing Systems and Applications Conference 2005.
- was external evaluator for the appointment of a Senior Lecturer at KTH
- was Guest Editor for a Special issue on Factory Comm. Systems of IEEE Tr. on Ind. Informatics
- was invited speaker and panelist at the Swedish SITI-conference
- was mentor within a programme organised by "Gender Forum" at MdH
- was evaluator for NSERC in Canada
- 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 2005.
- served in the grading committee for Harald Svensson PhD-disertation. "Developing Support for Agile and Plan-Driven Methods". KTH, Stockholm, December 2005.
- acted as reviewer for (e.g.) The Computer Journal (British Computer Society), Journal of Systems and Software (Elsevier), IEEE Micro (IEEE).

Jukka Mäki-Turja and Daniel Flemström
- has been at Ericsson Älvsjö for two months to study their platform (used for example in their radio base stations, radio network controllers, and media gateways). The purpose of the visit is to study and learn the system which will be the basis for master students doing the master thesis on Ericssons systems, which will be placed at MdH, and supervised by personnel at MdH.

2.7 Monitoring and Testing group

Group leader: Henrik Thane
Members: Anders Pettersson
                      Daniel Sundmark
                      Mathias Ekman
                      Hans Hansson (associated)
Partners: ABB Robotics
                      ABB Corporate Research
                      Bombardier Transportation
                      ENEA Real-Time AB
                      SAAB Avionics
                      Volvo Construction Equipment Components AB
                      Zealcore Embedded Solutions AB
                      Level Twenty One AB
                      Ericsson
                      IAR Systems
                      Skövde University

2.7.1 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).
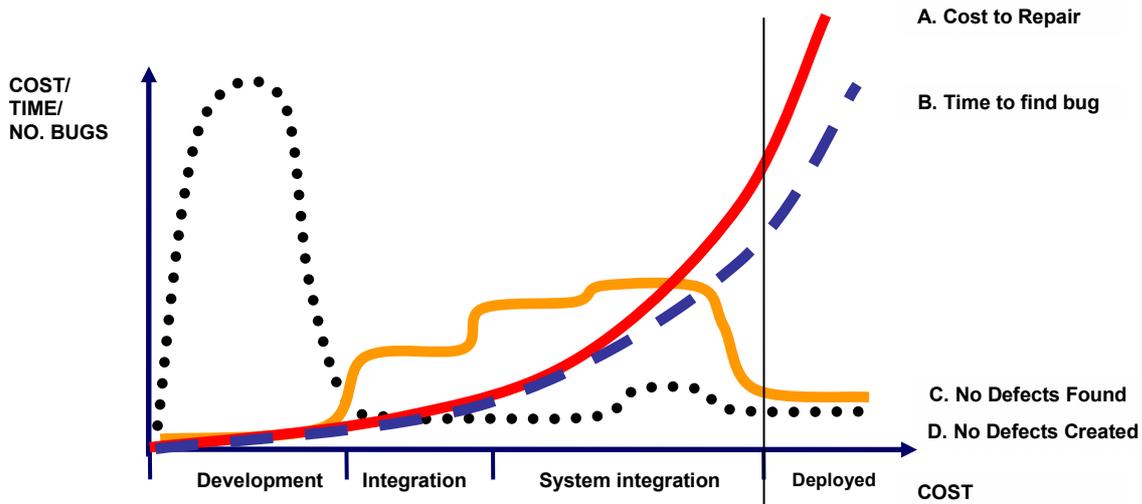
Figure 1. Graph *D*, shows the number of bugs introduced per lifecycle phase. Graph *C*, shows the number of bugs found per phase. That is, bugs are often introduced early but found late. Graph *B*, shows the relative time it takes to find one bug. More complex bugs are only found during later stages 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 2005:

During 2005 a number of publications were published and presented

Reviewed conference articles
- *Using a WCET Analysis Tool in Real-Time Systems Education*, Samuel Petersson (external), Andreas Ermedahl, Anders Pettersson, Daniel Sundmark, Niklas Holsti (Tidorum LTD), Real Time in Sweden (RTiS) 2005, p 125--128, Skövde, Sweden, Editor(s):Sten F. Andler, August, 2005
- *Using a WCET Analysis Tool in Real-Time Systems Education*, Samuel Pettersson (external), Andreas Ermedahl, Anders Pettersson, Daniel Sundmark, Niklas Holsti (Tidorum LTD), Fifth International Workshop on Worst-Case Execution Time (WCET) Analysis, Palma de Mallorca, Spain, Editor(s):Reinhard Willhelm, July, 2005
- *Efficient System-Level Testing of Embedded Real-Time Software*, Daniel Sundmark, Anders Pettersson, Sigrid Eldh, Mathias Ekman, Henrik Thane, Work-in-Progress Session of the 17th Eurmicro Conference on Real-Time Systems, p 53-56, Palma de Mallorca, Spain, Editor(s):Isabelle Puaut, July, 2005
- *Regression Testing of Multi-Tasking Real-Time Systems: A Problem Statement*, Daniel Sundmark, Anders Pettersson, Henrik Thane, Work-In-Progress Session of the 11th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS 2005), San Francisco, California, March, 2005

2.7.2 Research projects

LESS BUGS

Project leader:	Henrik Thane
Members:	Daniel Sundmark
	Anders Pettersson
	Mathias Ekman
Partners:	Bombardier Transportation
	Level Twenty One AB
	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.

2.7.3 Staff

Henrik Thane is a Senior Lecturer 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 nine 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 is also the CEO and President of ZealCore Embedded Solutions AB, a company focused on bringing state-of-the-art research debugging to the industry. Among the products provided are the unique BlackBox ReplicatorTM and the BlackBox RecorderTM for embedded systems

Mathias Ekman is an industrial Ph.D student at SDL, and is 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 at SDL. 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.

2.7.4 National and International research co-operation

The following is a partial list of national and international research co-operation by the MTD staff in 2005:

- Discussions with and invitations to various research groups, at e.g, Uppsala (Dr. Paul Pettersson), Philadelphia (Prof. Insup Lee), and Ghent (Dr. Michiel Ronsse).

2.7.5 Interactions with society

The members of MTD are interacting with society in several ways, in 2005 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.
- One of MTD members 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.

2.8 Predictably Flexible Real-Time Systems group

2.8.1   Focus

The staff and partners in this group are:

Group leader: Gerhard Fohler

Members: Damir Isovic
Tomas Lennvall
Radu Dobrin
Larisa Rizvanovic
Pengpeng Ni
Mathias Strandberg

Partners: Krithi Ramamritham, Indian Institute of Technology (IIT), Mumbay, India.
Giorgio Buttazzo, Scuola Superiore S.Anna, Pisa, Italy
Pau Marti, Josep Fuertes, Universitat Politecnica de Catalunya, Barcelona, Spain
Liesbeth Steffens, Philips Research, The Netherlands
Alan Burns, University of York, UK
Michael Gonzalez-Harbour, University of Cantabria, Spain
CSEM Switzerland
Thomson Multimedia, France
TU Eindhoven, The Netherlands
IMEC, Belgium
University of Cyprus, Cyprus
C-LAB, Germany
Industrial System Institute, Greece

Area description:

Predictability and flexibility have often been considered as contradicting requirements, in particular from the scheduling perspective. This strong exclusion, however, holds only for predictability on a very detailed level, which is not demanded in most scenarios. 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.

Real-time systems need to be reliable in order to be applicable in real-world environment. Our approach to reliability follows the lines of timeliness: Instead of providing for static solutions only, we provide for adaptive fault tolerance and self-evolving systems. Issues include scheduling, dynamic reconfigurations of hardware structures, and reliability measures.

In addition to these core areas, we have been extending the aforementioned principles in the areas of wireless networking and multimedia streaming under limited resources. We use the scheduling and resource reservation mechanism above to flexibly process MPEG-2 video streams.

2.8.2 Research projects

FIRST - Flexible Integrating Scheduling Technology – EU IST Project

(Successfully closed in 2005)

The objective of the proposed research is to develop a real-time scheduling framework for applications demanding various types of tasks, constraints, and scheduling paradigms within the same system. The FIRST project investigated the following issues:

- co- operation and coexistence of standard real-time scheduling schemes, time-triggered and event-triggered, dynamic and fixed priority based, as well as off-line based.
- integration of different task types such as hard and soft, or more flexible notions, e.g., from control or quality-of-service demands, and fault-tolerance mechanisms
- temporal encapsulation of subsystems in order to support the composability and reusability of available components including legacy subsystems

FIRST provided functionality for the schemes for POSIX compliant operating systems, including monitoring and maintenance of control systems over the Internet.

Project leader:	Gerhard Fohler
Members:	Radu Dobrin
	Tomas Lennvall
	Robert Johansson, Research engineer
Partners:	University of York , UK
	Universidad de Cantabria Spain
	Scuola Superiore S. Anna Pisa, Italy

BETSY - BEing on Time Saves EnergY – EU IST Project

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.

Project leaders:	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

Real-time Architecture for Networked Multimedia Streaming systems
(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.

Project leader: Gerhard Fohler
Members: Larisa Rizvanovic

User friendly H.264 for Realtime Editing
(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.

Project leader: Gerhard Fohler
Members: Pengpeng Ni, Ardendo

FLEXCON - Flexible Embedded Control Systems – SSF

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.

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 and ABB Automation Product

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/

ARTIST II – Advanced Real-time Systems, EU Network of Excellence, FP6

In Cluster Adaptive Real-time: this is a more recent approach to embedded systems design, where temporal constraints can be relaxed, which allows optimized use of resources. This includes applications – where managing the Quality of Service (QoS) is essential, such as telecommunication systems, multi-media, and wide-area networked applications. In this relatively new area, there is a recognized lack of design theory and tools.
Partners: http://www.artist-embedded.org/FP6/Overview/

2.8.3   Group publications 2005

Journals
- Damir Isovic, Gerhard Fohler, Liesbeth Steffens *(external)*: *Real-time issues of MPEG-2 playout in resource constrained systems*, International Journal of Embedded Systems, vol 1, issue 2, nr ISSN 1740-4460, Cambridge International Science Publishing, June, 2005
- Weirong Wang *(external)*, Al Mok *(external)*, Gerhard Fohler: *Pre-Scheduling*, Real-Time Systems Journal, vol to appear, Kluwer, May, 2005

Theses
- Radu Dobrin: Combining Off-line Schedule Construction and Fixed Priority Scheduling in Real-Time Computer Systems, Ph D Thesis, Mälardalens University Press, September, 2005
- Tomas Lennvall: Adapting to Varying Demands in Resource Constrained Real-Time Devices, Ph D Thesis, Mälardalen Univerity Press, September, 2005

Articles in collection
- Gerhard Fohler: *Adaptive Real-time Systems (contribution)*, Embedded Systems Design - The ARTIST Roadmap for Research and Development, Springer, ISBN: 3-540-25107-3, Editor(s): Bouyssounouse, Bruno; Sifakis, Joseph, February, 2005

Conferences and workshops

- BETSY consortium *(external)*, Gerhard Fohler, Damir Isovic: *The BETSY project on timeliness and energy aspects of video streaming*, International Workshop on Wireless Ad-hoc Networks (IWWAN 2005), London, UK, June, 2005
- FIRST Consortium *(external)*, Gerhard Fohler, Radu Dobrin, Tomas Lennvall: *FSF: A Real-Time Scheduling Architecture Framework*, 12th IEEE Real-Time and Embedded Technology and Applications Symposium, San Jose, California, United States, April, 2005
- Tomas Lennvall, Gerhard Fohler: *Providing Adaptive QoS in Wireless Networks by Traffic Shaping*, Resource management for media processing in networked embedded systems (RM4NES), Eindhoven, Netherlands, March, 2005

2.8.4   Theses

In 2005 the PredFlex group presented two PhD theses:

Ph D Thesis

Radu Dobrin: Combining Off-line Schedule Construction and Fixed Priority Scheduling in Real-Time Computer Systems

Date: September, 2005

Opponent: Prof. Guiseppe Lippari, RETIS Lab Italy

Abstract:
Off-line scheduling and fixed priority scheduling (FPS) are often considered as complementing and incompatible paradigms. A number of industrial applications demand temporal properties (predictability, jitter constraints, end-to-end deadlines, etc.) that are typically achieved by using off-line scheduling. The rigid off-line scheduling schemes used, however, do not provide for flexibility. On the other hand, FPS has been widely studied and used in a number of industrial applications, mostly due to its simple run-time scheduling and small overhead. It provides more flexibility, but is limited with respect to predictability, as actual start and completion times of executions depend on run-time events.

In this thesis we first show how off-line scheduling and FPS can be combined to get the advantages of both -- the capability to cope with complex timing constraints while providing run-time flexibility. The proposed approach assumes that a schedule for a set of tasks with complex constraints has been constructed off-line. We present methods to analyze the off-line schedule and derive FPS attributes such that the runtime FPS execution matches the off-line schedule. In some cases, i.e., when the off-line schedule can not be expressed directly by FPS, we split tasks into instances (artifacts) to obtain a new task set with consistent task attributes. Our method keeps the number of newly generated artifact tasks minimal.

At the same time, we investigate the behavior of the existing FPS servers to handle non-periodic events, while the complex constraints imposed on the periodic tasks are still fulfilled. In particular, we provide a solution to server parameter assignment to provide non-periodic events a good response time, while still fulfilling the original complex constraints on the periodic tasks.

Secondly, we apply the proposed method to schedule messages with complex constraints on Controller Area Network (CAN). We analyze an off-line schedule constructed to solve complex constraints for messages, e.g., precedence, jitter or end-to-end deadlines, and we

derive attributes, i.e., message identifiers, required by Can's native protocol. At run time, the messages are transmitted and received within time intervals such that the original constraints are fulfilled.

Finally, we propose a method to reduce the number of preemptions in legacy FPS systems consisting of tasks with priorities, periods and offsets. Unlike other approaches, our algorithm does not require modification of the basic FPS mechanism. Our method analyzes off-line a set of periodic tasks scheduled by FPS, detects the maximum number of preemptions that can occur at run-time, and reassigns task attributes such that the tasks are schedulable by the same scheduling mechanism while achieving a lower number of preemptions. In some cases, there is a cost to pay for achieving a lower number of preemptions, e.g., an increased number of tasks and/or reduced task execution flexibility. Our method provides for the ability to trade-off between the number of preemptions and the cost to pay.

Tomas Lennvall: Adapting to Varying Demands in Resource Constrained Real-Time Devices

Date: September, 2005

Opponent: Prof. Jean-Dominique Decotignie, CSEM Switzerland.

Abstract:
In-home entertainment systems are becoming popular because they allow a variety of consumer electronic (CE) devices to be connected, using a wireless network, to form a system capable of handling multimedia content. Using such a system provides the end-users the possibility of transparently streaming multimedia content between devices of varying capabilities. This is possible because the system adapts the multimedia content to match the capabilities of the receiving device. What looks simple to the end-user is actually a very complex system that manages all existing multimedia streams and resources. It must manage all the varying resource demands, on all the constrained devices, in such a way that the resulting quality (video or audio playback) is acceptable to all the end-users of the system. In this thesis we investigate two different, but still related, issues within the in-home entertainment network. First, we look at how we can adapt to the capabilities of the nodes, which contains processors of varying capabilities and also operating systems which also provide different capabilities. Secondly, we have to adapt to the varying capabilities of the wireless network when it is used for video streaming in the presence of other network traffic. For nodes, we present two scheduling methods that are extensions to the off-line scheduling paradigm. The first method aims at improving the handling of soft aperiodic tasks in an off-line scheduled system, which is normally handled in the background resulting in long response times. The method creates space within an off-line schedule in order to allow a Total Bandwidth Server to use it during run-time in order to improve the response times. The second method deals with overload caused by firm aperiodic tasks in an off-line scheduled system. The method deals with the overload by selecting which aperiodic tasks to execute, and which tasks to drop, without disturbing the execution of the more critical off-line scheduled tasks.

We also present a third scheduling related method that presents a plug-in based scheduling architecture with the purpose of allowing easy change of scheduling algorithm within operating systems. In order to deal with the wireless network issues we present an

architecture that decreases the network congestion in order to improve packet delivery reliability and decrease packet delays. In order to accomplish this, the architecture continuously predicts the available bandwidth, and then uses this information to adapt the transmission rate of the node in order not to exceed what is available.

2.8.5   PredFlex Staff

Gerhard Fohler, professor, leader of the predictably flexible real-time systems group at SDL. He received his Ph.D. from Vienna University of Technology in 1994 for research towards flexibility for offline scheduling in the MARS system. He then worked at the University of Massachusetts at Amherst as postdoctoral researcher within the SPRING project. During 1996-97, he was a researcher at Humboldt University Berlin, investigating issues of adaptive reliability and real-time. Gerhard Fohler is currently chairman of the Technical Committee on Real-Time Systems of EUROMICRO.

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".

Radu Dobrin, Ph D since September 2005. He finished his master thesis in computer engineering at Mälardalen University in Västerås in august 2000. He worked as a research engineer at SDL during the second half of 2000. His research interests are flexible and predictable real-time systems, fixed priority scheduling and optimisation methods.

Tomas Lennvall, Ph.D since September 2005. He received a MSc Computer Engineering and a Licentiate Thesis from Mälardalen University in 2000 and 2003, respectively. His current research interests are real-time systems, quality of service, multimedia, and wireless networks.

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.

Mathias Strandberg is a MsC in Computer Science, with special interests in Real-Time, at MDH, Västerås. During 2005, he was employed as research engineer in PredFlex group on streaming video to hand-held devices.

2.8.6 National and International research co-operation

The group members participated in the following international activities:
- Gerhard Fohler participated (together with Hans Hansson and Ivica Crnkovic, SEL) in the European Thematic Network ARTIST (Advanced Real-Time Systems) which started in 2002. Also, he is a participant of the follow up network ARTIST2 - a Network of Excellence in the 6th Framework Programme – started in 2004.
- Gerhard Fohler coordinated the European IST project FIRST – Flexible real-time systems technology; partners University of York, UK, University of Cantabria, Spain, Scuola S. Anna, Italy.
- 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
- Radu Dobrin visited University of Cantabria, Spain, January-February 2005
- Tomas Lennvall visited the University of Santa Cruz, California, January-February 2005
- Larisa Rizvanovic visited Philips Research, Eindhoven, the Nederlands, Feb-March 2005

PredFlex group has concrete co-operations with the following national and international research groups and companies:
- Scuola Superiore S.Anna, Pisa, University of Pavia, Italy
- Universitat Politecnica de Catalunya, Barcelona, Spain
- Carlos Pereira: Universidade Federal do Rio Grande do Sul, Brasil

- Philips Research, Netherlands
- IMEC, Belgium
- University of Cyprus, Cyprus
- C-LAB, Germany
- Universität Stuttgart, Germany
- Industrial System Institute, Greece
- Technische Universiteit Eindhoven, Netherlands
- CSEM, Suisse
- University of York , UK
- Universidad de Cantabria Spain
- Ardendo, Sweden

2.8.7   Services to the Community

Gerhard Fohler
- is Chairman of the Technical Committee on Real-time Systems of Euromicro, which organizes ECRTS, the major European Real-Time Conference
- is member of the Executive Board of the IEEE Technical Committee on Real-time Systems
- is member of the Executive Team of the IEE Professional Network on Real-time Systems
- was co-program chair of the real-time subtrack at Design, Automation and Test in Europe - DATE 05
- was European Publicity Chair, Real-Time Applications and Technology Symposium, 2005

Damir Isovic
- acted as reviewer for IEEE Transactions on Computing Journal
- acted as reviewer for ECRTS 05, RTSS 05, RTAS 05
- was interviewed by two newspapers

2.9 Scalable Architecture for Real-time Applications

2.9.1   Focus

The project is currently focusing on
- Computer architectures, with special emphasis on scalable multiprocessor systems,
- 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)

2.9.2   Research projects

SARA - Scalable Architecture for Real-time Application group

Project leader:	Lennart Lindh
Project members:	Lennart Lindh
	Susanna Nordström
	Stefan Sjöholm
	Andreas Löfgren
	Stefan Stjernen
Partners:	Georgia Institute of Technology, USA
	MENTOR GRAPHICS
	XILINX
	Altera
	KTH
	RealFast

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.

Publications 2005
- An analysis of FPGA-based UDP/IP stack parallelism for embedded Ethernet connectivity", Andreas Löfgren, Lucas Lodesten, Stefan Sjöholm, Hans Hansson, Norchip '05, November 21-22, 2005, Oulu, Finland.
- S. Nordström, L. Lindh, L. Johansson and T. Skoglund. *Application Specific Real-Time Microkernel in Hardware,* 14th IEEE-NPSS Real-Time Conference, Stockholm, June 2005.
- *2nd FPGAworld CONFERENCE*, Lennart Lindh, Vincent John Mooney III *(external)*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-188/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, September, 2005
- *Programerbara Kretsar - Utveckling av Inbyggda System*, Lennart Lindh, Tommy Klevin *(external)*, Studentlitteratur, ISBN: 9144037139, 2005

New universities that are testing research results from the group:
- Pedro Guerra, Universidad Politecnica de Madrid, Madrid, Spanien
- Atanas Desev, PhD student, University of Food Technologies, Bulgaria
- Patrick Stakem, Professor, Loyola College, Baltimore, USA

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.

Subprojects

The current research in SARA is performed in the following sub-projects:

Project members: Stefan Stjernen
                              Lennart Lindh (supervisor)
                              Stefan Sjöholm (advisor)

Project description

The main focus for this project was to create test stimuli's and make models (in VHDL) for the testing of the FPGA. The FPGA is designed to communicate with a CPU over a PCI target interface between the local PCI bus and the FPGA. A model of the CPU was created in VHDL. All of the PCI calls from the CPU to the FPGA was initiated from the 'VHDL' CPU model and then sent to the FPGA over the PCI bridge.

Project members: Stefan Sjöholm
                              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.

Results and achievements in 2005

- An analysis of FPGA-based UDP/IP stack parallelism for embedded Ethernet connectivity", Andreas Löfgren, Lucas Lodesten, Stefan Sjöholm, Hans Hansson, Norchip '05, November 21-22, 2005, Oulu, Finland.

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 2004

- S. Nordström, L. Lindh, L. Johansson and T. Skoglund. *Application Specific Real-Time Microkernel in Hardware,* 14th IEEE-NPSS Real-Time Conference, Stockholm, June 2005.

2.9.3 Staff

Lennart Lindh. Lennart Lindh graduated from Lund Technical University 1980 with the MSc degree in Electrical Engineering. After five years at ABB Robotics, Västerås, as a system engineer, he was appointed a senior lecturer at Mälardalen University, Västerås in 1985. His main focuses are implementation of complex functions in hardware, Real-Time operating systems and flexible multiprocessor systems. He is today responsible for the guidance of Ph.D. candidates, PC member in some academic workshops/conferences and board member in Euromicro (European academic organisation). He is today dividing his time between Mälardalens University and the company RealFast AB.

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.

Stefan Stjernen is industrial Ph.D. student. His research is targeted at industrial hardware verification methods, and their suitability for VHDL. The research is conducted in corporation with RFHC RealFast hardware Consulting AB, Västerås.

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

At the national level, we have established collaboration with the Electronic Design Department at KTH within the area of low-power techniques and real-time systems. As part of this collaboration we have a Ph.D. student sharing his time between CAL and KTH.

2.9.5   Services to the Community

Lennart Lindh was program committee member of EUROMICRO Digital Systems Design, CAD&CG (Asia), and different Swedish workshops, such as SNART

Also, the laboratory organised workshops in Stockholm (FPGAworld.com) together with Vincent Mooney from Georgia institute of Technology, USA.

2.9.6   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 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 and Robotdalen.

3 Intelligent Sensor Systems (ISS)

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 affectivity 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, Robotics and Mechatronics, which are research oriented MSc programmes integrated with the ISS research.
- 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:

- ABB
- AbMedica
- AI Labs
- Activio
- Arbexa
- Avesta Steel Mill
- Bombardier Transportation
- Comosys
- Ericsson
- Elektronikmekanik AB
- Euroling AB
- Eyescream
- Flodafors Lego
- FOI
- Funkai Intelligent Solutions
- Hök Instruments
- IFP Research AB
- Lectus sängar AB
- Medicus
- 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
- 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. Some details about these co-operations:

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 2005 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.

3.2.1   The Intelligent Systems group [Peter]

Headed by Docent Peter Funk; two senior researchers, 5 (+3 associated) PhD students; 2 PhDs and one licentiate (+3 by associated students) in 2005; 9 MSc students, all focusing on applications of artificial intelligence methods and techniques in industrial and medical domains; funding from SSF and KKS.

Scientific achievements 2005:
- 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.
- 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 help desk that uses a range of AI methods and techniques to help engineers, or provide customer support. Research results are turned into a product in a spin off company.
- An AI based floating storage enabling Robots to maintain their own buffer storage on free floor space. This releases the robot from requiring input pallets and enables production of a variety of products without delay. Part of research result used in production at ABB Automation (a robot cell with a floating storage).
- Organised the yearly Swedish Artificial Intelligence Seminar in Västerås, a three day event with over 80 participants.

3.2.2   Communication Performance Predictability and Analysis group [Mats]

headed by Prof. Mats Björkman; Researcher Dr. Bob Melander, Dr. Svante Ekelin; 5graduate students; 3 licentiates planned for 2005; focusing on communication for small embedded devices, and traffic measurement and analysis; funding from VR, Vinnova, KKS, CUGS, and MdH.

Scientific achievements 2005:
- Development of algorithms for the hierarchical scheduling of communication in layered sensor networks.
- Continued work on the characterization of network flow sizes and their impact on network performance. This is of importance for routing decisions in interior routing protocols.

- A light-weight measurement and analysis algorithm for active bandwidth measurements has been developed and implemented as an available tool.
- Initial measurements in wireless networks, where characteristics are fundamentally different from wired networks.

3.2.3 Mechatronics

headed by Dr. Denny Åberg; Researcher Prof. Lars Asplund, Prof. Lennart Harnefors (leaving the group), Dr. Sanbau Xu (leaving the group), Dr. Johnny Holmberg (leaving the group); 7 graduate students (3 leaving the group during 2005); 1 associated researcher (Dr. Martin Nilsson); 2 PhDs planned 2006; research areas within electric motor drive control, RF circuits, microwave sensors and imaging, robotics; funding from Vinnova, KKS and MdH.

Scientific achievements 2005:
- A speed and positioning estimation algorithm for speed-sensorless controlled synchronous machines was developed.
- Voltage sag response of PWM rectifiers as well as ride-through of inverter drives were thoroughly investigated.
- A closed form theoretical proof was given for the optimal phase-noise performance configuration of LC-voltage controlled oscillators, a missing piece in RF circuit theory since 1930's.
- A novel low power high speed frequency divider was presented.
- A nonlinear state-space model of frequency synthesizers for fast and accurate high-speed simulations was presented.

3.2.4 Sensors and Biomedical Engineering

headed by Dr. Maria Lindén; Professor Ylva Bäcklund, Senior Lecturer Dr. Mikael Ekström, Senior Lecturer Dr. Mannan Mridha; 3 PhD students; one of them Industrial PhD student; focusing on wearable multisensor systems also including artificial intelligence. The wireless communication enables free mobility and several of our projects are based on the Bluetooth™ technology. Funding from Vinnova, KKS, EU and MdH.

Scientific achievements 2005:
- 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.
- Development of a new principle to estimate the lactate level through correlation to the CO_2-level. An application for patent for the principle has been submitted.
- One PhD thesis (Mia Folke)

3.2.5 Safety Critical Systems for Embedded Systems

headed by Prof. Lars Asplund; 1 associated researcher (Dr. Martin Nilsson); 4 graduate students; 1 PhDs 2005; focusing on hardware architectures for safety-critical systems and robotics sensory systems; funding from KKS and MdH.

Scientific achievements 2005:
- A component-based formal model of a hardware-implemented run-time kernel. Published in the proceedings of the 17th Euromicro Conference on Real-Time Systems
- Temperal skeletons for verifying time, an intermediate notation used in the framework for verification of real-time properties. Published in the proceedings of SIGAda, 2005
- An evaluation of the characteristics of different designs of delay queues designed for application tailored Ravenscar hardware real-time kernels. Published in the proceedings of the 3rd ACM-IEEE International Conference on Formal Methods for Codesign, 2005
- Complete design of a SafetyChip. Published in the proceedings of SIGAda, 2005
- Complete model of a Ravenscar compliant run-time kernel
- Mehtod for transforming timing skeletons to Timed Automata

3.3 The Intelligent Systems Group

3.3.1 Focus

The Intelligent Systems group consists of one associate professor, one assistant professor, 5 Ph.D. students (2 associated with IDP) and a number of master year students with AI research profile. 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 2005:
- 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.
- 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.
- Markus Nilsson successfully defended his PhD thesis 2005 (main supervisor Peter Funk, IDE).
- Erik Olsson successfully defended his licentiate thesis 2005 (main supervisor Peter Funk, IDE).
- Mälardalen University and the AI group was given the trust to organize the yearly Swedish AI and Learning Systems event (3 days) and Peter Funk was elected organizer and chair for the event.
- Collaboration with spin-off company AI Labs, 5 former AI students commercialising research ideas based on research projects in the AI group.

3.3.2 Research projects

AIM, Artificial Intelligence in Medical Applications

Project leader:	Peter Funk (IDE) & Bo von Schéele (SMAB)
Members:	Markus Nilsson (Ph.D. student)
	Mikael Sollenborn (Ph.D. -2004)
	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
	Mälardalen University
	teknIQ

Project description:

The AIM project addresses sensor readings in medical applications 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 2005:

One PhD (Markus Nilsson), a number of Masters Thesis projects, numerous publications and participation at international events (conferences, workshops). Also funding for project building upon the projects result has been secured 3.9 MSEK during 3 year (application together with Ylva Bäcklund, the main applicant).

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 student, MdH, IDP
	Milun Milic, PhD student, ABB Automation, IDP
	Erik Olsson, PhD student, ABB Automation, IDE
	Sofi Elfving, PhD student, Mälardalen University, IDP
	Anette Brannemo, PhD student, Volvo CEC, IDP
	Anna Andersson, PhD student, Volvo CEC, IDP
	Mikael Hedelind (M.Sc. ABB)
	Adam Blomberg (M.Sc.)
	Henrik Bovin (M.Sc.)
	Peter Sävström (M.Sc.)
Partners:	ABB automation, Volvo, SKF, Underhållsföretagen
Funding:	ABB automation, Volvo, SKF, Underhållsföretagen
	SSF

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 2005:

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.

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 2006.

Layout and Function of the Intracortical Connections within the Primary Visual Cortex

Project leader: Anders Lansner (KTH)

Members: Baran Çürüklü (Ph.D. Student)

Björn Lisper (local supervisor)

Peter Funk (second local supervisor)

Partners: KTH, SANS, NADA

Funding: CUGS (National Graduate School in Computer Science)

Project description:

The intention of this project is to reveal the mechanisms behind vision. A computer model of the cat's visual cortex is currently developed for this purpose. The model explains the interactions between neurons that populate the visual cortex, and hence demonstrates how cats and other species can see simple shapes, such as lines and contours.

Results achieved 2005:

One PhD and two conference papers.

Future Plans:

Post doc abroad.

3.3.3   Theses

Baran Çürüklü, A Canonical Model of the Primary Visual Cortex. PhD Thesis,

In this thesis a model of the primary visual cortex (V1) is presented. The centerpiece of this model is an abstract hypercolumn model, derived from the Bayesian Confidence Propagation Neural Network (BCPNN). This model functions as a building block of the proposed laminar V1 model, which consists of layer 4 and 2/3 components.

The V1 model is developed during exposure to visual input using the BCPNN incremental learning rule. The connectivity pattern demonstrated by this correlation-based network model is similar to that of V1. In both modeled cortical layers local horizontal connections are dense, whereas long-range horizontal connections are sparse. Layer 4 local horizontal connections are biased towards the iso-orientation domain, whereas long-range horizontal connections are equally distributed between all orientation domains. In contrast, both local and long-range horizontal connections of the layer 2/3 are biased towards the iso-orientation domains. The layer 2/3 network is axially specific as well. Thus, this V1 model demonstrates how the recurrent connections can be self-organized and generate a cortex like connectivity pattern.

Furthermore, in both layers inhibition operates within a modeled hypercolumn. This is in line with what is found in the V1, i.e. inhibition is mainly local, whereas excitation extends far beyond the inhibitory network. Observe also that neither excitation nor inhibition dominates the network.

Based on this connectivity pattern the V1 model addresses several response properties of the neurons, such as orientation selectivity, contrast-invariance of orientation tuning, response saturation followed by normalization, cross-orientation inhibition. Configuration-specific

facilitation phenomena are explained by the axially specific layer 2/3 long-range horizontal connections. It is hypothesized that spike and burst synchronization might aid this process.

The main conclusion drawn is that it is possible to explain connectivity as well as several response properties of the neurons by a general V1 model, which is faithful to the known anatomy and physiology of the neocortex. Thus, when simplicity is combined with biological plausibility the models can give valuable insight into structure and function of cortical circuitry.

Erik Olsson, Diagnosis of Machines within Industry using Sensor Signals and Case-Based Reasoning, lic thesis

Machines are not perfect; they sometimes fail to operate as intended. Such failures can be more or less severe depending on the kind of machine and the circumstances of the failure. E.g. the failure of an industrial robot can cause the hold-up of an entire assembly line costing the affected company large amounts of money each minute on hold. This kind of situation can be prevented by equipping machines with automatic condition-monitoring systems that continuously monitor their condition and instantly report the detection of a failure or an incipient failure. The nature of machine-monitoring and diagnosis lends itself naturally to Case-Based Reasoning.

Case-Based Reasoning is a method in the discipline of Artificial Intelligence based on the idea of assembling experience from problems and their solutions as "cases" for reuse in solving future problems. Cases are stored in a case library, available for retrieval and reuse at any time. By collecting such sensor data as sound and vibrations from a machine and representing this data as the problem part of a case and consequently representing the measured corrective action as the solution to this problem, a complete series of the events of a machine failure and its correction can be stored in a case for future use. This thesis describes an innovative approach to this concept by using a combination of Case-Based Reasoning and wavelet analysis as a means of condition monitoring and diagnosis of primarily industrial machines. For evaluation purposes this novel approach is implemented as a prototype system for the diagnosis of the status of gearboxes in industrial robots.

Markus Nilsson. Classify and Retrieve. PhD Thesis.

Diagnostics based on time series are sometimes difficult to perform, particularly when the time series is continuous and non-stationary, i.e. they seldom contain recurring patterns which makes it difficult to identify similarities with other time series. This doctoral thesis presents an artificial intelligence approach to the analysis of continuous non-stationary signals for diagnostic purposes. One way to solve this kind of problem is to break down the series into new forms that are more easily interpreted, and to identify familiar patterns within them. The newly formed series is analysed, using the Case-Based Reasoning paradigm. Known problemsolution pairs are stored in memory and reused for solving problems by classifying new patterns occurring in time series obtained subsequently. Reasoning is conducted on the basis of the knowledge available and a best-guess solution obtained using the available knowledge is presented. The memory need not therefore contain a problem, which has been solved previously and is identical with the problem which is to be solved. This approach to problem solving has been applied to physiological time series as a clinical decision support system. The system provides decision support by classifying patterns of respiratory sinus arrhythmia from heart rate and capnography time series.

3.3.4 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.

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.

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.

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.

Markus Nilsson is an industrial Ph.D. student in artificial intelligence employed by PBM StressMedicine AB. His research interests are artificial intelligence methods and techniques for medical applications. He received his PhD in 2005. He is now working in industry (Ericsson).

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

3.3.5 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

3.3.6 Services to the Community

Peter Funk:
- was elected to the board 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 Special Issue of the Computational Intelligence Journal (case-based reasoning in health care), 2005. ISI Journal Citation Reports® Ranking: 2004: 18/78
- Review for Journal, Special Issue of Computational Intelligence special issue on CBR in the Health Sciences.
- was external examiner for one Ph.D thesis at Trinity College, Ireland
- was external examiner for one Ph.D thesis at Dublin University College, Ireland
- 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.

3.3.7 Interactions with society

Peter Funk organised the yearly Swedish Artificial Intelligence Seminar in Västerås, a three day event with over 80 participants. He was 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; 5graduate students; 2 licentiates and 1 PhD planned for 2006; focusing on communication for small embedded devices, and traffic measurement and analysis; funding from VR, Vinnova, KKS, CUGS, and MdH.

Scientific achievements 2005:
- Development of algorithms for the hierarchical scheduling of communication in layered sensor networks.
- Continued work on the characterization of network flow sizes and their impact on network performance. This is of importance for routing decisions in interior routing protocols.
- A light-weight measurement and analysis algorithm for active bandwidth measurements has been developed and implemented as an available tool.
- Initial measurements in wireless networks, where characteristics are fundamentally different from wired networks.
- Development of a new available bandwidth measurement method called BART that measures the available bandwidth in real time using filters in the estimation process
- BART was implemented in a tool and was also evaluated in testbed and Internet scenarios.
- The TOPP model for describing available bandwidth estimation was extended in order to explain measurement results obtained in wireless networks.
- A study of how available bandwidth measurement methods affect TCP was performed.

3.4.1   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.

3.4.2 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 2005, one licentiate thesis was defended by Adam Dunkels. 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. An architecture for sensor networks using existing infrastructure has been presented

Future plans:

During 2006, the techniques for addressing and power management will be addressed. Asymmetrical protocols for lower radio power consumption will be investigated further. One licentiate theses 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 2006, 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:

One licentiate thesis was defended by Andreas Johnsson. BART was further developed. BART is an end-to-end available bandwidth measurement method that uses filtering in the estimation process. BART was implemented as a tool and was evaluated in testbed as well as in Internet scenarios. Different parameter settings and their impact on the estimates were studied.

The TOPP model for describing available bandwidth estimation was extended in order to explain measurement results obtained in wireless networks.

Studies on cross-traffic effects on TCP performance were made

Future plans:

Studies on cross traffic effects on throughput and delay variance will be studied. Further studies of the use of advanced filtering in performance analyses will be performed.

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

Achievements:

Studies of the impact of cross traffic on estimation accuracy. Studies of the use of advanced filtering in the estimation process. A prototype tool for bandwidth measurements has been developed and evaluated in testbed as well as in Internet settings.

Future plans:

During 2006, further studies of the use of advanced filtering in performance analyses will be performed. More advanced tools for network bandwidth measurements will be developed and evaluated. A study on how the filtering is affected by wireless networks is also an open issue of interest.

Further, detailed analysis on how the measurement methods affect TCP performance will be made.

3.4.3 Theses

In 2005 COMPASS staff presented the following theses:
- Bandwidth measurements in wired and wireless networks.
- Towards TCP/IP for Wireless Sensor Networks.

Below, these theses are presented in more detail.

3.4.3.1 Licentiate Thesis

Andreas Johnsson, Bandwidth measurements in wired and wireless networks

Date: April 21

Opponent: Dr. Thomas Lindh

Examiner: Prof. Hans Hansson

Supervisors: Prof. Mats Björkman, & Dr. Bob Melander

Abstract:

In the Internet today, end-user applications cannot get bandwidth guarantees from the network. Instead, bandwidth measures, such as available bandwidth and link capacity, must be measured where after the application can adapt its send rate to the bandwidth measurement estimate. An example application that relies on bandwidth measurements is TV transmission in real time over the Internet.

To measure the available bandwidth between two nodes in a computer network, such as the Internet, active measurement methods are used. These methods do not require prior knowledge about the network topology. Measurement data, divided into probe packets, is injected into the network with an initial packet separation. The packets are time stamped on the receiver side. By deploying analysis methods the available bandwidth and link capacity can be calculated using the initial separation and the time stamps as input.

The work presented in this licentiate thesis studies bandwidth measurement methods with two foci: a) how can the interactions between probe packets and other traffic in the network be described? and b) how do existing measurement methods, designed for wired networks, behave in wireless networks?

A framework has been developed to describe the interactions between probe packets and other network traffic packets. This framework also describes the differences between using the statistical mean and median operator on time stamps in an analysis.

A simplified version of the TOPP measurement method, called DietTopp, has been developed and implemented. DietTopp is evaluated and compared to other bandwidth measurement tools in both wired and wireless scenarios.

Results obtained from measurements in wireless 802.11b networks show important differences compared to measurement results obtained from wired networks. The origins to some of the observed differences are explained whereas some are left to future research.

Adam Dunkels, Towards TCP/IP for Wireless Sensor Networks.

Opponent: Prof. Dr. Karl Holger

Examiner: Prof. Hans Hansson

Supervisors: Prof. Mats Björkman, & Dr. Thiemo Voigt

Abstract:

Wireless sensor networks are composed of large numbers-up to thousands- of tiny radio-equipped sensors. Every sensor has a small microprocessor with enough power to allow the sensors to autonomously form networks through which sensor information is gathered. Wireless sensor networks makes it possible to monitor places like nuclear disaster areas or volcano craters without requiring humans to be immediately present. Many wireless sensor network applications cannot be performed in isolation; the sensor network must somehow be connected to monitoring and controlling entities.

This thesis investigates a novel approach for connecting sensor networks to existing networks: by using the TCP/IP protocol suite in the sensor network, the sensors can be directly connected to an outside network without the need for special proxy servers or protocol converters.

Bringing TCP/IP to wireless sensor networks is a challenging task, however. First, because of their limited physical size and low cost, sensors are severely constrained in terms of memory and processing power. Traditionally, these constraints have been considered too limiting for a sensor to be able to use the TCP/IP protocols. In this thesis, I show that even tiny sensors can communicate using TCP/IP. Second, the harsh communication conditions make TCP/IP perform poorly in terms of both throughput and energy efficiency. With this thesis, I suggest a number of optimizations that are intended to increase the performance of TCP/IP for sensor networks.

The results of the work presented in this thesis have had a significant impact on the embedded TCP/IP networking community. The software developed as part of the thesis has become widely known in the community. The software is mentioned in books on embedded systems and networking, is used in academic courses on embedded systems, is the focus of articles in professional magazines, is incorporated in embedded operating systems, and is used in a large number of embedded devices.

3.4.4 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.

3.4.5 National and International research co-operation

The following is a partial list of national and international research co-operation by Compass staff in 2005:

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).

3.4.6 Services to the Community

Mats Björkman
- was scientific evaluator for the KK foundation.
- was on the grading committee at one PhD dissertation.
- was "opponent" at three licentiate presentations.
- is scientific advisor for a media technology educational program, Blekinge Tekniska Högskola.
- was reviewer for several conferences and workshops.

3.5 Mechatronics

3.5.1 Focus

The research in the mechatronics lab is governed by industrial applicability in three areas (power control applications, RF applications and embedded systems applications) as well as foundation research in robotics. The research in Robotics is on systems engineering mainly on sensors and electronic circuits, but also on platform design of robotic system.

3.5.2 Research projects

Stabilization of motor drives and traction converters

Project leader:	Lennart Harnefors
Members:	Lars Magnus Jansson
Partners:	ABB Corporate Research, Bombardier Transportation
Funding:	Banverket, ABB, Bombardier Transportation and MdH

Project description:

The project consists of two parts: A) Stable sensorless control of synchronous motor drives. Sensorless in the meaning of controlling an ac-engine without speed- or angle sensor on the engine axis. This kind of drive system has difficulties in start and reverse situations. Part A of the project consists of algorithm development, with the help of which permanent magnetized synchronous engines manages a stable start and reverse. The method has been further developed for induction magnetized synchronous engines in a report for ABB (Corporate Research). B) Stable train drive. Trains with converters have an active impedance, i.e. the phase lag can exceed 90 degrees. This implies the possibility for a nonstable condition even if the supply consists of solely passive components. In this part of the project focus is directed towards the development of regulators to guarantee stability of the drive system.

The project was finalized with the dissertation of Lars Magnus Jansson in 28 september 2005.

Power grid resilient and nondisturbing drivesystems

Project leader:	Lennart Harnefors
Members:	Kai Pietiläinen
Partners:	Royal Institute of Technology
Funding:	Elforsk/Elektra and MdH

Project description:

Voltage sags in the power grid happens frequently, mainly caused by lightning strikes. Modern society uses to a large extent computerized processing which requires fair grid quality. As little as a millisecond voltage loss (sag) suffice to cause millions of euro costs in power electronic drivesystems. Examples can be industrial mills, steel industries and other power consuming industries which rely on the power grid. Presumably 90% of all voltage sags can be handled by proper drive regulation without halt in production. In this project, financed by Elforsk/ELEKTRA-program, halt-prevention control of converters and converter fed asynchronous motors are studied.

The project was finalized with the dissertation of Kai Pietiläinen 20 october 2005.

Implementation of digital filters

Project leader:	Lennart Harnefors
Members:	Johnny Holmberg, Krister Landernäs
Partners:	Linköping University
Funding:	MdH

Project description:

Last ten years has seen an explosive increase in battery powered portable IT equipment. The power consumption is a crucial factor for these digital implementations. Power consumption is further an important parameter for system-on-chip solutions, where the large systems may be heated beyond reliable operating temperatures by power losses in the active transistors. In this project focus is maintained on digit serial filters with high computation capacity while maintaining low power consumption. Analyses are made on how to find the best compromise between area, power consumption and computation rate.

The project will be finalized by the dissertation of Krister Landersnäs in january 2006.

Frequency Synthesizer for Multi-Standard RF Communication Systems

Project leader:	Denny Åberg
Members:	Tord Johnson
Funding:	MdH

Project description:

Today we see an increase in multi-standard wireless communication devices, e.g. cellular phones with both GPRS and Bluetooth transceivers. The cost for these multi-standard devices is in principle linear with the number of standards, since one transceiver is needed per standard. Reducing the number of transceivers into one multi-standard transceiver would therefore dramatically reduce the cost and increase the functionality for radio frequency (RF) communication devices.

Frequency synthesizers are used to generate the oscillation signal in transceiver systems. The frequency of that signal determines which RF channel will be received and to which RF channel the base-band information will be transferred. The frequency synthesizer is in other words the transceiver's tuning system. Multi-standard communication devices sets extreme demands on the frequency synthesizers to achieve a lock on the vast difference in desired frequency, and to open selected bandwidths for different standards.

This project is focused on the design of a frequency synthesizer that can surpass the high demands of a future multi-standard RF front-end. Aspects such as spectral purity, tuning range and power dissipation are to be investigated for low voltage CMOS technologies.

The project resulted in the licentiate dissertation by Tord Johnson in april 2005. The project was finalized in october 2005.

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 will be finalized with the dissertation of Ali Fard in january 2006.

Microwaves in biomedicine

Project leader:	Denny Åberg
Members:	Tommy Gunnarsson and Peder Norin
Partners:	Arbexa, Supélec University
Funding:	KKS

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.

3.5.3 Theses

Two Ph.D. Theses and one licentiate thesis were presented by Mechatronics staff in 2005:

Lars Magnus Jansson, On Stabilization of Sensorless Synchronous Motor Drives and Traction Converters.

In this thesis we discuss and analyze aspects and methods for low-speed operation, startup, and-particularly-rotational reversal for sensorless control of non-salien permanent-magnet synchronous motors (MSMs), i.e. Stabilization in the low-speed region.

Furthermore, a speed and position estimation algorithm for speed-sensorless control of electrically excited synchronous machines (EESMs) with damper windings is developed. For ESM drives, an initial rotor position estimation algorithm is also developed.

Regarding the PMSM drives, it is shown that the sensorless drive synchronizes from any initial rotor position, recovers from initial rotation in the wrong direction, and also reverses rotation without lockup or instability phenomena.

The results regarding sensorless control and performance in the low-speed region are simulated and experimentally verified, which indicates that the proposed estimator is effective.

An additional subject in this thesis is control of traction converters. One major problem is that trains with pulse-width-modulation (PWM) converters have active input impedance; thus the phase shift between the input current and voltage is greater than +/- 90 degrees for a certain frequency region. This may result in poor damping and in worst case unstable operation. Here, it is shown that via sophisticated current control and improved feed-forward, one may stabilize the system with respect to passivity.

Kai Pietiläinen,Voltage Sag Ride-Through of AC Drives: Control and Analysis, PhD thesis.

This thesis focuses on controller design and analysis for induction motor (IM) drives, flux control for electrically excited synchronous motors with damper windings (EESMs), and to enhance voltage sag ride-through ability and analysis for a wind turbine application with a full-power grid-connected active rectifier. The goal is to be able to use the existing equipment, without altering the hardware. Further, design and analysis of the stabilization of DC-link voltage oscillations for DC systems and inverter drives are studied, for example traction drives with voltage sags in focus.

The proposed IM controller is based on the well known field-weakening controller of Kim and Sul, which is further developed. Applying the proposed controller to voltage sag ride-through gives a cheap and simple ride-through system.

The EESM controller is based on set point adjustment for the field current controller. The analysis also concerns stability for the proposed flux controller.

Analysis is the main focus, and concerns the impact of the different parameters involved. Proper parameter selection for the controller, switching frequency, and DC-link capacitor is given.

The impact of voltage sags is investigated for a power-grid-connected rectifier. Here, we analyze the impact of different types of voltage sags and phase-angle jumps. The analysis gives design rules for the DC-link capacitor and the switching frequency.

Experimental results and simulations verify the theoretical results.

Tord Johnson, Design and Analysis of Charge-Punp Based Frequency Synthesizers, licentiate thesis.

Most telecommunication systems employ modulation techniques that require the transceiver to be capable of accurately estimating the phase of the transmission signal. The frequency synthesizer is a key element and extensively utilized to synthesize frequencies for such radio-frequency communication systems. A common topology for the frequency synthesizer is the charge-pump based phase-locked loop. The development and design of frequency synthesizer is known to be a complex and time-consuming task, aggravated by the vast difference in frequencies between the output and the internal signals. It is often necessary to perform long transient simulations with short time steps to achieve reliable results. This thesis will treat these difficulties and propose solutions to some of the design issues that concern the frequency synthesizer.

In most modern frequency synthesizers the phase detection circuits are capable of detecting both the frequency and phase difference. Such phase detectors are collectively known as phase-frequency detectors and generally employ some kind of memory functionality. The inherent memory in the phase-frequency detectors rouses the need for new models

describing the synthesizer. Throughout this thesis the dynamic and noise behavior in the presence of phase-frequency detector are especially investigated. The derived theory and conclusions are validated through earlier presented research as well as simulations of both the phase-frequency detector and the frequency synthesizer.

A high reference frequency is often sought in frequency synthesizers, since it then becomes possible to lower the division ratio in the frequency synthesizer. This will in turn lower the close-in phase noise of the synthesizer as well as decrease the power consumption of the divider chain. Unfortunately, it has also been shown that the size of the phase-frequency detectors blind-zone is directly proportional to the reference input frequency. Consequently, frequency synthesizers, utilizing high reference frequencies, will also have to include the effects of the phase-frequency detector's blind zone to accurately estimate the frequency synthesizer behavior. The blind-zone effect will become even more important as the tendency for high reference frequencies is further pursued. This thesis, therefore, investigates the influence of the phase-frequency detector blind zone. The results from these investigations have shown that a larger blind zone is deteriorative for the settling time, but has little influence on the synthesizer noise performance. However, for an exceptionally large blind zone there is the possibility that noise, present in the circuit, will force the synthesizer out of the locked condition.

Nonlinear models are developed and utilized to fully capture the frequency synthesizer's dynamic behavior both in the locked and out-of-locked conditions. The models are presented in the state-space form to facilitate simulations and to describe the internal variables within the synthesizer. Two different closed formulas for the settling time are given for a synthesizer with and without a phase-frequency detector exhibiting blind zone.

For the phase noise performance in the frequency synthesizer the nonlinear state-space model has been expanded with time-domain noise sources correlated according to the input noise sources. The linearized phase-domain noise model is compared to the state-space model. The comparison shows that the phase-domain model describes the phase noise property of the synthesizer well below the loop bandwidth. However, for offsets larger than the loop bandwidth the linearized phase-domain is insufficient.

3.5.4   National and International research co-operation

In Sweden, Prof. Lennart Harnefors has held an associate professorship in Chalmers. His research is made in collaboration with researchers at KTH, Linköping and Chalmers as well as with industrial researchers and developers.

The research on RF circuits has been made in collaboration with researchers within the national SocWare (SocTrix) program. Further, Ali Fard has spent several months visiting Prof. Andreani at Denmark Technical University, with whom the research co-operation has been very fruitful. Furthermore, Prof. Henrik Sjöland at LTH has been kind to allow Fard and Johnson to measure in their eminent RF-laboratory in Lund.

During 2005 cooperation was initiated between the researchers in the microwave project with a world leading group in microwave imaging in Paris, led by Prof. J.-C. Bolomey at Supélec. In the beginning of 2006 this will result in one student spending time in the research facilities at Supélec.

3.6 Sensors and Biomedical Engineering

3.6.1 Focus

We have concentrated on wireless, wearable sensor systems for supervision of physiological data. So far, Bluetooth has been used as a communication standard but the same principle can be used in other standards as w-lan, RFID and Zigbee. Also, multisensor systems facilitates 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 (collaboration with the Mechatronic goup) as well as a novel way to measure CO_2 in expired air through a resonant sensor. These fields/contributions, are fairly new but very promising, and with a great potential and a good chance for Swedish industry to become competitive.

3.6.2 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, Anna-Christina Ek, Lars-Åke Malmqvist
Funding:	VR
	Faculty

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

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
	Mikael Svensson
	Maria Lindén
Funding:	Vinnova
	EU

Project description

The aim of the project is to develop reliable automatic wireless <u>distributed</u> (without central server) and centralized (Ethernet based) networks for <u>mobile</u> 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 <u>sensoring and/or routing capabilities.</u> A distributed Bluetooth-network has been established, enabling handovers as a Bluetooth-unit moves over distance larger than the range of one Bluetooth™-unit.

Wireless sensor systems for i.e. ECG-surveillance

Project leader:	Maria Lindén
Members:	Jens Lönnblad,
	Javier Garcia Castaño
	Mikael Ekström
	Mikael Svensson
Partners:	Linköping University, Lars-Göran Lindberg
Funding:	Vinnova

Project description

Alternative input devices to computers for disabled persons

This project aims to develop alternative input devices to computers for disabled persons, e.g. a gyro based head mouse to enabling steering a computer without any hand or arm movement.

Intelligent systems for diagnostics and treatment within stress medicine

Project leader:	Mia Folke
Members:	Peter Funk
	Ylva Bäcklund
	Shaina Begum
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
	Mikael Svensson
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.

3.6.3   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.*

3.6.4   Theses

Jens Lönnblad, Monitor the heart simply and smooth - with less artefact using Bluetooth™. Licentiate Thesis, February.

This thesis discus the possibilities for the development of a wireless ECG monitoring system. Great efforts have been made to make this system physically small and lighted, as this will give the patient a suitable and comfortable surveillance. It will also give advances in reducing the frequently occurring artefacts that affects the registration of the hearts electrical activity. The thesis comprises four papers. Three about how Bluetooth™ technology can be used in a patient monitoring system. The last paper is about the occurrence of artefacts in ECG supervision. Bluetooth™ has been chosen due to the standards robust and secure radio communication, its low power consumption and minimal size, which makes it an attractive solution for this type of system. My biggest interest in this work is the development of the part close to the patient in, and also the need of, such a system. The results show that it is possible to use Bluetooth™, and that it is well suited for wireless patient monitoring.

Mia Folke, Measurements of Respiratory Carbon Dioxide. PhD Thesis, September.

Carbon dioxide plays a fundamental role in the metabolism of all living organisms. In man, the carbon dioxide concentration is mainly regulated through respiration. Consequently, measurements and monitoring of respiratory carbon dioxide is important in physiological applications, i.e. sports medicine as well as in clinical practice, i.e. in emergency care. This requires appropriate techniques for measurements. The aims of this thesis were to critically review present methods and devices used for respiratory measurements, to suggest and evaluate improvements, and to suggest and evaluate possible new applications of carbon dioxide measurements using an electro acoustic sensor. Carbon dioxide measurement in expired air has the advantages over other suggested methods for respiratory monitoring in providing extra information about conditions in arterial blood in subjects with healthy lungs. The suggested technique is based on an electro acoustic sensor sensing the carbon dioxide in respiratory air, with a filter to reduce humidity and temperature variations. The sensor consists of an ultrasound transmitter and a reflector placed in each end of a perforated tube. The sensor measures the molecular mass in the gas mixture inside its cavity. The molecular

mass has a linear relationship to the carbon dioxide concentration. The fact that the partial pressure of end tidal carbon dioxide can be measured with the electro acoustic sensor system makes it useful in several clinical situations. The partial pressure of end tidal carbon dioxide has also been found to be a useful indicator of the lactate threshold. This indicates a new application for sports medicine. Whit this method it is possible to measure the variation in the lactate threshold for an athlete in a specific sport on a daily basis, a prerequisite for optimising the work intensity during training and competition. The electro acoustic sensor system has been shown to be an useful measuring equipment in this application, although it is not selective to carbon dioxide and thereby influenced by change in oxygen content in the expiratory air.

3.6.5 Staff

Ylva Bäcklund is a professor at MdH since 2000.

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.

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 PhD-student at MdH. 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.

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 will present her lic during early 2006. Her research interests are development of a new blood flow sensor for the prevention of pressure sores.

Maria Lindén is a Senior Lecturer at MdH since 1999. She is the head of ISS and holds a PhD in Biomedical Engineering from Linköping University. Here research interests are biomedical engineering with the focus of wireless patient surveillance.

Jens Lönnblad is a PhD-student at MdH and presented his lic during 2005. He focuses towards *Wireless sensor systems for ECG-surveillance*.

Michael Svensson is a research engineer at MdH. He is currently working with wireless ad hoc sensor network.

3.6.6 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)
- "Biomedical Engineering Knowledge Centre": 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).

3.6.7   Services to the Community

Ylva Bäcklund was a member of the scientific program and session chair of Eurosensors conference.

Ylva Bäcklund was on the grading committee for 3 PhD disseratations.

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.

Maria Lindén acted as a referee for the journal Medical and Biological Engineering and Computing (MBEC).

Maria Lindén 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.

Maria Lindén was a member of the Faculty Board of Mälardalen University.

3.6.8   Interactions with society

The Sensors and Biomedical Engineering 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 Biomedical Engineering group also takes an active role in the "Biomedical Engineering Knowledge Centre". Other members are Linköping University, City of Katrineholm, County Council of Sörmland, "Näringslivscentrum", Industry, Flodafors Lego, and Screenlab AB.

3.7 Safety Critical Systems for Embedded Systems

3.7.1 Focus

This area includes has had activities in hardware design as well as formal modelling and verification of safety critical systems. The research has been in cooperation with the department for Astro and Aeronautics at MIT, Boston.

The group is now longer active.

3.7.2 Research projects

Project leader: Lars Asplund
Project members: Johan Furunäs
                                    Gustaf Naeser

The research within the SafetyChip project, which has been as a co-operation between Mälardalen University and MIT, Boston. The project aimed at developing a framework supporting the development of safety critical systems at the highest safety level. A development process using this framework starts with a tool that can generate a formal model, Intermediate-Model, from source code. This Intermediate-Model is not intended to be used directly for verification, it is intended for further transformation into formally verifiable notations. It is, however, very important that the Intermediate-Model is highly readable by programmers, i.e. it should be easy to validate its source-code conformance. The generation of the Intermediate-Model is automatic, but to ensure the correctness of the transformation, human interaction is required. Currently the Intermediate-Model is transformed into timed automata and verified using the UPPAAL tool. This transformation from the Intermediate-Model to the target model is fully automated and does not require any human interaction. The correctness of this transformation should be by mathematical proofs.

3.7.3 Theses

One PhD Thesis

Gustaf Naeser, *A Formal Approach to Embedded High-Integrity Real-Time Systems*, Doctoral thesis ISSN 1651-4238, ISSB 91-88834-89-1, Mälardalen University Press, Sweden, October 2005.

This thesis is not about some obscure theoretic computer science secrets; this thesis is about making safer computer systems. Another view of it is that it tries to make hard to use methods, like formal verification, easier to use so that more programmers and system designer can benefit from it. There are loads of systems used daily that are believed to be correct, though they have never been proven so. Testing, the predominant choice for detecting faults and errors, can only find errors the tester is looking for, i.e., testing can discover the expected. Formal verification, a less used method for discovering errors, can be used to discover that which rise from unexpected sources.

As the number of high-integrity, safety critical, systems increases, so does the demands for their safe execution. However, the developers of the systems try to keep the development

and production costs down. The limited resources available often prevent the use of traditionally safe, but expensive, means of ensuring the systems safe operation.

The SafetyChip framework presented in this thesis proposes an approach which, using automatic modelling, both aids formal verification and reuses the effort invested in the verification during the life time of the system. The reuse is accomplished by using custom hardware to monitor and police the systems execution based on the results of the verification.

Several issues limiting the use of formal verification in high-integrity systems are explored and resolved, e.g., in a kernel for the Ravenscar tasking profile. The kernel has been modelled, verified and partly realised in hardware. Experiments to evaluate the usefullness of the framework in medium sized applications have been conducted with a promising outcome indicating the usefulness of the SafetyChip framework.

3.7.4 Staff

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.

Johan Furunäs is a Ph.D. Student at CAL. Finished his Licentiate thesis "Interprocess Communication Utilising Special Purpose Hardware" December 2001 and received a Licentiate of Philosophy in Computer Systems from Uppsala University. Received a Bachelor of Science in Computer Engineering from Mälardalens University, Sweden (1995). Have been working with operating system co-processors since 1995 at Mälardalen University and Realfast for Ericsson UAB. His main research interest is interprocess communication utilizing co-processors, and he joined the SafetyChip-project in 2003.

Gustaf Naeser is a Ph D student at MdH since March 2001. He is active in the SafetyChip-project, and his special interest is in translation of software into a formal description, and formal verification of integrated models of hard- and software.
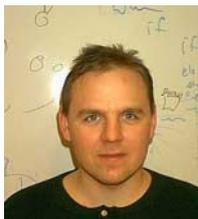
Peter Nygren is a postgraduate student at CAL since August 2000. His current research is focused on transparent interface between software and hardware communication with possibility to integration of custom specific hardware. However, his interest profiles cover much broad area in hardware software co-design.

Joakim Adomat has been working at Mälardalen since 1994. He started as a research engineer, and is currently a lecturer/Ph.D. student. Main areas of interest are SoC architecture, FPGA rapid prototyping, digital design and PCB. The future research ambition is to explore and improve systems for graphics rendering.

3.7.5   National and International research co-operation

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

3.7.6   Services to the Community and Interactions with society

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.

One important activity in Robotdalen is to create a larger interest for technology in general and robotics in particular. There will in the future be several external activities to achieve this goal. To mention a couple, there will be different robotics competitions for younger people. For children in the age between 10 and 16 there will be the First Lego League. "An international program for children ages 9-14 (9-16 in Europe) that combines a hands-on, interactive robotics program with a sports-like atmosphere. Teams consist of up to 10 players with the focus on such things as team building, problem solving, creativity, and analytical thinking." People at CAL have been involved in arranging one of the Scandinavian FIRST LEGO LEAGUE semi-finals. Sixteen teams participated and about 1000 spectators followed the competition that was held in Västerås.

4 National Grad 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 a six-year period 2004-2009. Matching efforts will be provided by participating industries. MRTC has the main responsibility for SAVE-IT. Additional partners include Linköping University (IDA/RTSLAB), KTH (DAMEK), Uppsala University (IT/UppAal), and currently the following industries: ABB Research, ABB/Robotics, Bombardier Transportation, Ericsson, Saab, and Volvo CEC.

The scientific focus of SAVE-IT is closely related to that of the research programme SAVE (design of software for safety-critical vehicular systems). SAVE-IT will organise graduate education for 15 graduate students employed by participating companies, as well as promoting increased co-operation and exchange between all participating organisations.

Main items on the SAVE-IT agenda are:
- Network activities, including industrial visits, training in non-technical skills, such as leadership and project management, international visits, and team-building.
- Graduate courses, consisting of both methodology oriented courses and courses on specific scientific topics.
- Research projects performed by the graduate students. These will be conducted in close co-operation with participating industries, and in association with SAVE.

In 2005 seven PhD students were accepted to SAVE-IT.

A massive campaign in order to recruit new PhD students was carried out, and as a result o this a number of new students will be admitted in 2006

Andreas Ermedahl was recruited as new co-ordinator for SAVE-IT, replacing Mikael Nolin.

In cooperation with ARTES++ seven different graduated courses were offered.

For further details on SAVE-IT please refer to :
http://www.mrtc.mdh.se/projects/save-it/activities.html.

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. MRTC 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. Currently, MRTC has two CUGS modules – one led by Björn Lisper, the other by Mats Björkman – with the following PhD students:

- Jan Carlson (High-level languages for hard real-time systems)
- Baran Cürüklü (Modelling and simulation of biological neural networks)
- 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 the ARTES++ graduate school. This school admits 20 students annually during a three year period 2004-2006. The following students from MRTC were admitted in January 2005 (in addition to the seven MRTC graduate students that were admitted in January 2004):

- Erik Olsson
- PengPeng Ni
- Ewa Hansen
- Christer Gerdtman
- Daniel Flemström
- Johan Lindhult (Eriksson)

ARTES++ will organise graduate courses, annual summer schools and PhD-student conferences. In addition, admitted students will be provided support for conference trips and a longer international visit, as well as for spending some weeks at a company. Funding for student employments are not provided by ARTES++.

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 a 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 students have been admitted to IRSED:
- Susanna Nordström
- Stefan Sjöholm
- Andreas Löfgren

5 Seminars, the Industrial day, and other events

A number of seminars and lectures were held at MRTC providing a forum for presentation and discussion of research within in MRTC as well as lectures by external scientists. Additionally, MRTC organised several workshops and schools with both external industrial and academic participation.

5.1 IDE Seminars and conferences

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.

5.1.1 Conferences and Seminars

5.1.1.1 SAIS

The yearly Swedish Artificial Intelligence Society's Seminar, SAIS, was held in Västerås 12-14 April 2005. The seminar attracted 80 participants and was organised and chaired by Peter Funk. Peter was also the program chair. SAIS attracted participants from mainly Sweden, both industry and academia (all major universities in Sweden where represented). This year Peter introduced a special industry day, appreciated and succeeding in bringing researchers and industry together www.idt.mdh.se/sais2005/. The event was also supported by some multinational Swedish companies.

5.1.1.2 E-CAP 2005, European Computing and Philosophy conference

E-CAP 2005, European Computing and Philosophy conference was organized 2- 4 June 2005 by IDE department with support from the MDH.
About 90 participants from 23 countries have taken part in the conference- among others representatives from several African countries, China and New Zealand. Conference materials will be published in a book, and in a special journal issue. Program chair and responsible organizer was Gordana Dodig-Crnkovic, with help from Local Organizing committee (Baran Curkulu, Harriet Ekwall, Ylva Boivie). The Conference has got excellent reviews from both professional organizations and participants. More information may be found at http://www.idt.mdh.se/ECAP-2005/

5.1.1.3 Open Seminar: Artificiell Intelligens och IT-säkerhet:

During 2005 IDE also arranged a seminar day in cooperation with Dataföreningen Sverige (Computer Association).

5.1.2 External Speakers

The following talks were given by external speakers at IDE in 2005:
- Wolfgang Weck: How is Eclipse Coming Along as a Component
- Martin Törngren: Challenges and approaches for integrated multidisciplinary development of embedded control system
- Pekka Abrahamsson: Researching into Agile Software Technologies
- Prof. Olof Lindahl: Kommersialisering av medicintekniska idéer - hur går det till?

- Raimund Kirner, TU Wien: Extending Optimising Compilation to Support Worst-Case Execution Time Analysis
- Lars Grunske : Safety in component-based systems
- Jacky Estublier: Challenges of Concurrent Engineering

5.1.3   MRTC Industrial Day

The MRTC Industrial Day is an annual event organised in spring each year. The purpose of the industrial day is to present and discuss our achievements, with a special emphasis on industry relevance and impact.

Our co-operation partners, other industry, national academia, and students are invited to participate in this event, which in addition to MRTC presentations features invited speakers, typically world-leading researchers or industrialists.

Since one day is not enough to present all the multitude of projects and activities at MRTC, each industrial day has a special focus corresponding to a specific research direction.

In 2005, MRTC did not arrange any public industrial seminar. The reason for this was the strong focus and intensive work on two major funding applications – PROGRESS and VinnMRTC – that were submitted during the year.

Industrial seminars 2005

On the other hand, as important elements in the preparation of these proposals a large number of meetings with industrial representatives and with groups of industrialists were held. During spring 2005 we had two seminars with industry to discuss the progress application to ensure the industrial relevance in the application. At both seminars several of our main-partners were participating including, Volvo CE, CC-systems, ABB, and Bombardier.

During the autumn we had specific seminars with all partners supporting the VinnMRTC proposal individually to both ensure the relevance in the proposal and form specific project proposals.

Industrial Day 2004

This years traditional Industrial Seminar focused on development of large complex embedded systems. Swedish industry has a tradition in being excellent in these systems with high reliability and availability requirements, such as telecom systems, automation systems, aero planes, and vehicles. The systems become increasingly complex, while at the same time the global competition becomes tougher and tougher. To remain competitive we must both understand where the complexity origins and how to handle it efficiently.

In this year's seminar these issues were addressed by providing talks from two world leading researchers, Kurt Wallnau Software Engineering Institute, CMU, USA and Jeff Voas, Cigital, USA. They both addressed design and verification issues when developing complex systems. Further, a talk addressing complexity issues in system development was given by Jakob Axelsson from Volvo Cars.

From the programme:
- Welcome and brief presentation of MRTC, Hans Hansson, MdH
- Softwares Inoperable Interoperability Problem, Jeff Voas, Cigital, USA

- Component-based architectural specifications that enhance predictability of quality-attributes, Kurt Wallnau, CMU, USA
- Complexity Issues in System Development: Examples from Automotive Electronics, Jakob Axelsson, Volvo Cars/MDH
- The day was finished with a panel discussion with Prof Christer Norström as moderator, and participation from the speakers and from Per Skytt (ABB Corporate Research).
- This year's edition also opened for further informal discussions after the panel while the participants enjoyed a beer and a sandwich.

Industrial Day 2003

The focus on 2003 years edition of MRTC Industrial Seminar was on Robotics, both from an industrial and academic perspective. One of the highlights was a talk by Erik Sandewall from Linköping University on "The WITAS Unmanned Aerial Vehicle Project".

Additional items on the agenda:
- Welcome and brief presentation of MRTC (Hans Hansson)
- Learning systems and autonomous robotics at AASS (Tom Ducket, Örebro University)
- Industrial Robotics – pas, now and in the future (Torgny Brogårdh, ABB Robotics)
- The Robot Valley Initiative and Robotics at MRTC (Lars Aspund)
- Panel: Robotics in Society (Panelists: Tom Duckett, Erik Sandevall, Torgny Brogårdh, Lars Asplund; Moderator: Christer Norström)

Industrial Day 2002

The Industrial seminar in 2002 had a focus on Safety-Critical Systems, with a much appreciated tutorial on "Safety-Critical System and Software Standards" given by Dr P.V. Bhansali, Associate Technical Fellow of The Boeing Company.

Additional items on the agenda:
- Welcome and brief presentation of MRTC (Hans Hansson)
- Automatic testing with fault injection (Håkan Edler, IVF)
- Poster Exhibit
- Multiprocess Application Monitor (Mohammed El Shobaki)
- Monitoring Hardware for Safety-Critical Systems (Lars Asplund)
- Componentization of industrial control systems (Frank Lüders)
- Research at Computer Science Laboratory 2001 (Ivica Crnkovic)
- Flexible Scheduling and Temporal Constraints in Embedded Control Systems (Gerhard Fohler)
- Enforcing Temporal Constraints (Kristian Sandström)

Industrial Day 2001

In 2001 the focus was on Industrial Software Engineering, with invited speaker Jeffrey Voas from Cigital, who gave the talk "Why Testing Under Expected Operational Scenarios is Not Sufficient".

Additional items on the agenda:
- Welcome and brief presentation of MRTC (Hans Hansson)

- Poster Exhibit
- Component-based Software Engineering - Promises and Challenges for Industrial IT (Ivica Crnkovic)
- Experience in Using Standard Technologies in Industrial Applications (Erik Gyllenswärd)
- Education goals at Department of Software Engineering and Mälardalen University (Elvy Westlund)
- Software Product lines – Flexible and Reusable Architectures (Anders Wall)
- Scalable Multiprocessor Platform for Industrial Control Applications (SARA) (Lennart Lindh, Leif Enblom)
- "Best Practice" of Academia & Industry Cooperation - Sveriges Verkstadsindustrier (Annita Persson Dahlqvist)
- Panel: Total global integration of real-time, safety-critical systems with non-real-time non-safety-critical information systems - utopia or reality? (Panellists: Jeffrey Voas, Hans Skoog, Christer Ramebäck, Annita Persson, Björn Lisper, Christer Norström; Moderator: Bengt Asker)

Industrial Day 2000

In 2000 the focus was on Real-Time Systems, with an invited presentation by Prof. Jack Stankovic from Univ. of Virginia: "Application Specific Operating Systems for Embedded Systems: A Component Based Solution".

Additional items on the agenda:
- Welcome and brief presentation of MRTC (Hans Hansson)
- Poster Exhibit
- Real-life Applications of Computer Science: Analysis of RT Systems and Industrial Software Engineering (Lisper/Crnkovic)
- Designing Safety Critical Embedded Systems (Hansson/Norström/Thane)
- Scalable Multiprocessor Platform for Industrial Control Applications (Lennart Lindh)
- Panel on "Real-Time Research for Industry" (Panellists: Bernt Ericsson, Hans Skoog, Peter Lidén, Göran Lundin, Christer Ramebäck, Jack Stankovic, Neeraj Suri, Jan Torin; Moderator: Bengt Asker)

6 Publications

6.1 Research publications

Books
1. George Heineman *(external)*, Ivica Crnkovic, Heinz Schmidt *(external)*, Judith Stafford *(external)*, Kurt Wallnau *(external)*: *Component-Based Software Engineering, 8th International Symposium, CBSE 2005*, Springer, Lecture Notes in Computer Science,, ISBN: 3-540-25877-9, August, 2005
2. Lennart Lindh, Tommy Klevin *(external)*: *Programerbara Kretsar - Utveckling av Inbyggda System*, Studentlitteratur, ISBN: 9144037139, 2005

Journals
1. Ning Xiong, Peter Funk: *Construction of Fuzzy Knowledge Bases Incorporating Feature Selection*, Journal of Soft Computing - A Fusion of Foundations, Methodologies and Applications, vol in print, nr ISSN: 1432-7643, Spring Verlag, , web version: http://dx.doi.org/10.1007/s00500-005-0009-7, December, 2005
2. *Game Ethics - Homo Ludens as a Computer Game Designer and Consumer*, International Journal of Information Ethics, to be published, vol Special Issue dedica, December, 2005
3. Gordana Dodig-Crnkovic, Thomas Larsson: *Game Ethics - Homo Ludens as a Computer Game Designer and Consumer*, International Journal of Information Ethics, vol 4, nr 12, p20-23, ICIE, December, 2005
4. Markus Nilsson, Peter Funk, Erik M. G. Olsson *(Dept. of Psychology, Uppsala University)*, Bo von Schéele *(PBMStressMedicine AB)*: *Clinical decision-support for diagnosing stress-related disorders by applying psychophysiological medical knowledge to an instance-based learning system*, Journal of Artificial Intelligence in Medicine, Elsevier, November, 2005
5. Andreas Ermedahl, Friedhelm Stappert *(Siemens VDO Automotive AG, Germany)*, Jakob Engblom *(Virtutech, Sweden)*: *Clustered Worst-Case Execution- Time Calculation*, IEEE Transactions on Computers, vol 54, nr 9, p1104--1122, September, 2005
6. Xavier Vera, Jaume Abella *(external)*, Josep Llosa *(external)*, Antonio Gonzalez *(external)*: *An accurate cost model for guiding data locality transformations*, ACM Trans. Program. Lang. Syst., vol 27, nr 5, p946-987, ACM Press, September, 2005
7. Thomas Nolte, Mikael Nolin, Hans Hansson: *Real-Time Server-Based Communication for CAN*, IEEE Transactions on Industrial Informatics, vol 1, nr 3, p192-201, IEEE Industrial Electronics Society, August, 2005
8. Christer Norström, Hans Hansson: *Editorial - Special Section on Factory Communication Systems*, IEEE Transaction on Industrial Informatics, vol 1, nr 3, p149-150, IEEE Industrial Electronics Society, August, 2005
9. Paul Caspi at al. *(external)*, Ivica Crnkovic: *Guidelines for a Graduate Curriculum on Embedded Software and Systems*, ACM Transactions on Embedded Computing Systems,, vol 4, nr 3, p587–611, ACM, August, 2005
10. *Artefacts in continuous ECG recordings - Provoking and preventing manoeuvres*, Scandinavian Cardiovascular Journal, vol 39, nr 3, p167-171, July, 2005
11. Damir Isovic, Gerhard Fohler, Liesbeth Steffens *(external)*: *Real-time issues of MPEG-2 playout in resource constrained systems*, International Journal of Embedded Systems, vol 1, issue 2, nr ISSN 1740-4460, Cambridge International Science Publishing, June, 2005
12. Weirong Wang *(external)*, Al Mok *(external)*, Gerhard Fohler: *Pre-Scheduling*, Real-Time Systems Journal, vol to appear, Kluwer, May, 2005
13. Pietro Andreani *(Technical University of Denmark)*, Xiaoyan Wang *(Infineon Technologies, Munich)*, Luca Vandi *(Technical University of Denmark)*, Ali Fard: *A Study of Phase Noise in Colpitts and LC-tank CMOS Oscillators*, IEEE Journal of Solid-State Circuits, vol 40, nr 5, p1107-1118, May, 2005
14. Fredrik Granstedt *(external)*, Mia Folke, Mikael Ekström, Bertil Hök *(Hök Instrument AB)*, Ylva Bäcklund: *Modelling of an electroacoustic gas sensor*, Sensors and Actuators B, vol 104, p308-311, Elsevier, May, 2005
15. Annika Jonsson, Maria Lindén, Ylva Bäcklund: *Evaluation of antidecubitus mattresses - a review*, Medical & Biological Engineering & Computing, vol Accepted 2005-05-03, May, 2005
16. Jens Lönnblad, Göran Nilsson, Mia Folke, Bertil Hök *(Hök Instrument AB)*, Maria Lindén, Ylva Bäcklund: *Artefacts in continous ECG recordings - provocing and preventing manoeuvres*, Scandinavian Cardiovascular Journal, vol Accepted, May, 2005

17. Björn Lisper: *Infinite unfolding and transformations of nondeterministic programs*, Fundamenta Informaticae, vol 66, nr 4, p415-439, April, 2005
18. Christina Björkman: *Feminist Research and Computer Science: Starting a Dialogue*, Journal of Information, Communication and Ethics in Society, vol 3, nr 4, March, 2005
19. Ivica Crnkovic, Heinz Schmidt *(external)*, Judith Stafford *(external)*, Kurt Wallnau: *Automated Component-Based Software Engineering*, Journal of Systems and Software, vol Volume 74, nr 1, Elsevier, January, 2005

Theses

20. Annita Persson-Dahlqvist: *Product Data Management and Software Configuration Management Integration*, Licentiate Thesis, Mälardalen University Press, December, 2005
21. Waldemar Kocjan: *Symmetric Cardinality Constraints*, Licentiate Thesis, MRTC, December, 2005
22. Daniel Sehlberg *(external)*: *Static WCET Analysis of Task-Oriented Code for Construction Vehicles*, Master Thesis, MRTC, October, 2005
23. Dag Nyström: *Data Management in Vehicle Control-Systems*, Ph D Thesis, Mälardalen University Press Dissertations, October, 2005
24. Radu Dobrin: *Combining Off-line Schedule Construction and Fixed Priority Scheduling in Real-Time Computer Systems*, Ph D Thesis, Mälardalens University Press, September, 2005
25. Tomas Lennvall: *Adapting to Varying Demands in Resource Constrained Real-Time Devices*, Ph D Thesis, Mälardalen Univerity Press, September, 2005
26. Markus Nilsson: *Retrieve and Classify*, Ph D Thesis, Malardalen University Press, August, 2005
27. Johan Andersson: *Modeling the Temporal Behavior of Complex Embedded Systems - A Reverse Engineering Approach*, Licentiate Thesis, Mälardalen University Press, June, 2005
28. Mia Folke: *Measurements of Respiratory Carbon Dioxide*, Ph D Thesis, Mälardalen University Press, June, 2005
29. Stig Larsson: *Improving Software Product Integration*, Licentiate Thesis, Mälardalen University Press, June, 2005
30. Jukka Mäki-Turja: *Engineering Strength Response-Time Analysis --- A Timing Analysis Approach for the Development of Real-Time Systems*, Ph D Thesis, Mälardalen University Press, May, 2005
31. Christina Björkman: *Crossing Boundaries, Focusing Foundations, Trying Translations: Feminist Technoscience Strategies in Computer Science*, Ph D Thesis, Blekinge Institute of Technology, May, 2005
32. Andreas Johnsson: *Bandwidth Measurements in Wired and Wireless Networks*, Licentiate Thesis, MRTC, April, 2005
33. Johan Fredriksson: *Transformation of component models to real-time models*, Licentiate Thesis, Mälardalen University Press, April, 2005
34. Tord Johnson: *Design and Analysis of Charge-Pump Based Frequency Synthesizers*, Licentiate Thesis, Mälardalen University Press, April, 2005
35. Baran Çürüklü: *A Canonical Model of the Primary Visual Cortex*, Ph D Thesis, Mälardalen University Press, March, 2005
36. Mikael Åkerholm: *A Software Component Technology for Vehicle Control Systems*, Licentiate Thesis, Mälardalen University Press, February, 2005
37. Jens Lönnblad: *MONITOR THE HEART SIMPLY AND SMOOTH - WITH LESS ARTEFACTS USING BLUETOOTH*, Licentiate Thesis, Mälardalen University Press, February, 2005
38. Anders Möller: *Software Component Technologies for Heavy Vehicles*, Licentiate Thesis, ISSN: 1651-9256, Mälardalen University Press, January, 2005

Articles in collection

39. Ivica Crnkovic, Heinz Schmidt *(external)*, Judith Stafford *(external)*: *Report of the International Symposium on Component-Based Software Engineering*, ACM SIGSOFT Software Engineering Notes, p 1-9, ACM, SIGSOFT, Editor(s): SIGSOFT, May, 2005
40. Christina Björkman: *Invitation to Dialogue: Feminist Research meets Computer Science*, The Gender Politics of ICT, p 237-250, Middlesex University Press, ISBN: 1-904750-46-X, Editor(s): Jacqueline Archibald et al, March, 2005
41. Gerhard Fohler: *Adaptive Real-time Systems (contribution)*, Embedded Systems Design - The ARTIST Roadmap for Research and Development, Springer, ISBN: 3-540-25107-3, Editor(s): Bouyssounouse, Bruno; Sifakis, Joseph, February, 2005
42. Jakob Axelsson, Joakim Fröberg, Hans Hansson, Christer Norström, Kristian Sandström, Björn Villing *(external)*: *A Comparative Case Study of Distributed Network Architectures for Different Automotive*

Applications, The Industrial Information Technology Handbook, p 57-1 to 57-20, CRC Press, ISBN: 0-8493-1985-4, Editor(s): Richard Zurawski, January, 2005

43. Hans Hansson, Mikael Nolin, Thomas Nolte: *Real-Time Systems*, The Industrial Information Technology Handbook, p 81-1 to 81-28, CRC Press, ISBN: 0-8493-1985-4, Editor(s): Richard Zurawski, 2005

44. Ivica Crnkovic, Magnus Larsson, Otto Preiss *(ABB CRC)*: *Concerning Predictability in Dependable Component-Based Systems: Classification of Quality Attributes*, Architecting Dependable Systems III,, p pp. 257 – 278, Springer, LNCS 3549, Editor(s): R. de Lemos et al. (Eds.):, 2005

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155. Markus Nilsson, Peter Funk: *A Multi-Modal Decision Support System for Respiratory Sinus Arrhythmia*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-174/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, April, 2005

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161. Ylva Boivie, Hans Hansson: *Annual Report 2004,* MRTC report ISSN 1404-3041 ISRN MDH-MRTC-172/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, March, 2005

162. Jukka Mäki-Turja, Mikael Nolin: *Fast and Tight Response-Times for Tasks with Offsets - Extended version*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-173/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, March, 2005

163. Jukka Mäki-Turja, Mikael Nolin: *Response Times in Hybrid Scheduled Systems*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-169/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, February, 2005

164. Kaj Hänninen, John Lundbäck *(external)*, Kurt-Lennart Lundbäck *(external)*, Jukka Mäki-Turja, Mikael Nolin: *Introducing Resource Efficient Event-Triggered Tasks in an RTOS*, MRTC report ISSN 1404-3041 ISRN MDH-MRTC-170/2005-1-SE, Mälardalen Real-Time Research Centre, Mälardalen University, February, 2005

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Technical reports

166. Jan Carlson: A Constant-memory Event Algebra with Intuitive Algebraic Properties, Technical Report, MRTC, December, 2005

167. Peter Funk: Artificial Intelligence for Industrial Applications– the ExAct-project, Technical Report, The fifth seminar in condition based monitoring, UTEK (in Swedish), September, 2005

168. Johan Fredriksson, Massimo Tivoli, Ivica Crnkovic: A component-based development framework for supporting functional and non-functional analysis in control system design, Technical Report, MRTC, June, 2005

169. Johan Lindhult: Licentiate Thesis Proposal: An Operational Semantics for Parallel Execution of Re-entrant PLEX, Technical Report, MRTC, June, 2005

170. Stig Larsson: Expected Influence of Ethics on Product Development Processes, Technical Report, MRTC, June, 2005

171. Filip Sebek: Excellence in teaching at Samford University, Technical Report, MdH, March, 2005

172. Baran Çürüklü, Anders Lansner (KTH): On the development and functional roles of the horizontal connections within the primary visual cortex (V1), Technical Report, MRTC, March, 2005

173. Markus Nilsson: Ph.D. Proposal: Retrieving physiological features in decision support systems, Technical Report, MRTC, February, 2005

174. Johan Fredriksson, Kristian Sandström, Mikael Åkerholm: Optimizing Resource Usage in Component-Based Real-Time Systems - Appendix, Technical Report, MRTC, February, 2005

175. Christer Sandberg: Licentiate thesis proposal:Improvements of the Flow Analysis in WCET Tools, Technical Report, MRTC, February, 2005

6.2 MSc Theses

The following MSc-theses have been presented at IDE in 2005:

1. Rebecca Nilsson; Niclas Persson: Utredning av ventilavledarindikator
2. Joakim Wennergren; Torkel Ödegaard: Designing and implementing a locally cached distributed file system with version rollback
3. Karwan Ghafouri; Mikael Mjölsnes: Implementering av databassystem för ölbryggeri
4. Amel Muftic; Ethics and safety-critical software systems
5. Henrik Bovin; Peter Sävström: Development of an Intelligent Support System using CBR and Ontologies
6. Daniel Gustavsson; Thomas Karlsson: File System for Mass Memory in Space
7. Hans Bokvist; Jörgen Stenmark: An Analysis of Test Improvements with Software Quality Rank
8. David Setherberg; Håkan Torseng: Continued development of an instantaneous value model of a classic SVC in SIMPOW
9. Anncharlotte Karsberg: Framtagning av prototyp för DSA-funktion (vinkelinstabilitet i kraftnät) i Network Manager-systemet
10. Jon Eskils; Robert Hjelm: Utveckling och analys av industriella positioneringssystem
11. Joakim Risberg: Development of an Object Oriented Tracker for ABBs Automation System 800 xA
12. Fredrik Dahlberg: Collision Determination Benchmarking
13. Tony Valcic: Funktionsövervakning och styrning av simulatorsystem
14. Andreas Blomqvist: Design av e-handels system
15. Jonas Lorenzson; Anders Strand: Wireless Human Health Monitoring
16. Mathias Wall: Software design and implementaiton of a fualt isolation scheme for robot controllers
17. Hanna Lindblom: Simulatorer för undervisning i formella språk och automatteori; testning, utvärdering och analys
18. Tommy Lundberg; Henrik Karlsson: Växelriktarmoduler för solcellsanläggningar
19. Tommy Hamplin; Markus Larsson: DuPaD - A Dual-paradigm drawing tool
20. Mats Gustafsson: COMET MiniLine - The design and implementation of a database for small embedded real-time systems
21. Anders Karlström: Datainsamlingskort för anslutning till USB
22. David Albertsson; Peter Sandberg: An Evaluation Model for Selecting Test Tools
23. Jessica Malm; Karin Karlsson; Charlotte Nilsson: Self-improving Questionnaire System with a Classification Function
24. Mathias Strandberg: Nomadic video streams
25. Moris Habib Behnam: Flexible Scheduling for Real Time Control Systems based on Jitter Margin
26. Marcus Tönnäng: Produktuvteckling av USB I/O
27. Jens Nielsen; Peter Westling: Universal Telematic Gateway Remote access to a vehicle´s communications network

Appendix A Evaluation of the MRTC profile

During autumn 2005 an evaluation of the results and impact of the MRTC profile grant was performed by Faugert & Co and Technopolis on the behalf of the KK-foundation. The evaluation consisted of two main parts:

- An evaluation performed by Faugert & Co based on a self-evaluation and other documents provided by MRTC, and on interviews with MRTC and MdH staff and with industrial and other cooperation partners
- A scientific peer-review conducted by the internationally reputed scientists Wolfgang Halang, Leo Motus, and Joseph Sifakis

The full evaluation report is available at the KK-foundation web-site www.kks.se. We will here report some of the main conclusions from the evaluation.

Excerpts from the evaluation by Faugert & Co

Translated from Swedish by us.

The overall picture is that MRTC in six years has accomplished to build a well-profiled research environment with strong industrial relevance. In short time MRTC has not only managed to establish itself as nationally leading in real-time research, but also become internationally recognized. For a relatively small country, such as Sweden, this is a remarkable accomplishment. The research has its starting pointy in already existing contacts or cooperation with industry. At the same time many entirely new contacts have been established within the profile framework.

The management of the centre has been very successful, from a more traditional academic perspective and from an administrative and project management perspective. MRTC has in an extraordinary way established close contact with regional industry, and developed efficient and in some cases unique cooperation strategies.

MRTC managers have also in a successful way established international cooperation with prominent research institutions and Networks of excellence within the research community. According to the Peer-review report this has lead to a faster development of certain projects by import of technologies and knowledge on a very advanced technological level and it has also evidently increased MRTC´s visibility.

MRTC has followed a strong and clear policy when building a strong research environment by strategic recruitment of recognized academic personnel, such as professors and senior researchers. This has contributed to a sustainable research environment. The Peer-review report states that the future plans for the centre are realistic and well focused, and regards the merge with the Department of Electronics rather as a measure of expansion in order to create more volume and momentum.

Most PhD students that we have spoken to are positive to the Graduate education at MRTC, even if some would like to see more common activities. The industrial connections are regarded as solely positive, and in the research environment it is regarded to be a good qualification to have industrial experience. The Industrial Graduate students seem to be made use of as strategic resources and as "border-crossers", and not only as a source of information between industry and academia. This is most likely because of the high industrial relevance of MRTC, but maybe also because of the big number, both in absolute

and relative figures of industrial graduate students. In this profile, it is rather the normal condition to spend time outside academia. This is possibly unique among all KK-funded profiles.

The different forms of cooperation with long-term undertaking of industry generate new relevant projects, which actively contribute the cooperating industry's development. MdH and MRTC seem to play an important role for the regional development, and we want to specially point out the research group´s active and urging role in the Vinnova funded project "Robotdalen". MRTC also plays an important role in the regional economy since it forms the basis for recruitment of competent personnel for local industry.

MRTC has developed an impressive scope of activities for its industrial contacts, and the solid industrial back-ground that many of the senior researchers possess is one of the keys to this. Project portfolios that are built enterprise-wise, with continuous assessment and job-rotation are worth to be noticed. There are examples of spin-off companies from MRTC, as well as research projects that have been consolidated in industry to be developed further. There are also examples where the original contacts have been broadened and now involve many persons from both academia and industry. It is noticeable that many of these cooperations seem to be very solid, and not depending on the external funding from the KK-foundation.

The long-term funding from the KK-foundation seems to have come at a strategic point and has had a decisive role in order to render the described development. The funding from the KK-foundation, together with funding from other founders have made possible for MRTC to create the necessary critical mass and infra-structure that makes it possible to develop the centre. MRTC has in a similar way to other profiles considered the KK-funding as support for the environment in large, which has given the centre greater flexibility and freedom when allocating resources internally. The MRTC managers chose not to see the 36 MSEK from the KK-foundation as funding for some specific projects. The funding was incorporated in a structure of cooperation which was enabled with the funding, and that consciously was let to grow outside the direct KK-funded frame-work. This makes it more difficult to specifically present and show the profile and its projects.

The MRTC managers point out that the present financial situation does not admit support for basic research at an appropriate level, which also the Peer-review points out. The experts mean that this situation could be aggravated without the funding from the KK-foundation: "Whilst MRTC activities are to a large extent sustainable, to secure its longer-term viability, the centre urgently needs additional resources to strengthen basic research activities. In a long run, the insufficient attention to basic research could harm the sustainability of the MRTC as a truly influential institution in the region." They point out that EU-funding is an underused source of funding, and that that together with other research funding and long-term engagement from industry there is a way of budgeting for long-term research for MRTC.

It should be noted that MRTC has been very successful in attracting other sources of funding, and that MRTC is very active in applying for new funding. Apart from the KK-foundation, MRTC also has funding from Vinnova and SSF, amongst others. In some ways this funding can be seen as a spin-off effect from the KK-profile, since MRTC would not be what it is today without the profile-funding.

Our impression is thus that MRTC may well serve as role model when it comes to building a profiled research environment that attracts regional industry and thus stands for industrial relevance in research. The combination of scientific excellence and unusually strong industrial support emphasizes the importance of such environment to live on. This is not only important for the industry and the academia, but also for the region itself. As a conclusion, future success for MRTC depends on

- "management skills" – these have to be good in order to lead and manage the initiative
- technological content – it is important not to become too small and diversified. The rapid growth during this period does not necessarily become a problem, as long as the management can keep up focus and vision.

Excerpt from the peer-review report

"Overall, the panel found that, despite the short space of time the MRTC has had to establish itself as one of Sweden's leading contributors to real-time research and its limited funding for basic research, it has been very successful in implementing its three-pronged vision, albeit to varying degrees. It has demonstrated

International leadership and impact through relevant and innovative research, as attested by publications, international collaborations and services to the scientific community. The quality and volume of publications and other signs of recognition show that the visibility of MRTC has significantly increased over the six-year period. Nevertheless, research is mainly driven by problems and applications, and there are not enough basic research activities. More journal publications could reasonably have been expected.

Transfer of state-of-the-art competence to industry, through joint R&D projects and education activities. MRTC has been successful in establishing collaborative projects with industry and attracting industrial funding. Industrial and application-oriented aspects of the profile are exemplary and appear to have exceeded expectations.

Development of curricula for training and education in real-time systems, including a nationally leading Licentiate School in real-time systems and a research-oriented MSc Program, with increased industrial involvement. Training has been internationally relevant. The centre's involvement in national initiatives such as ARTES and SAVE-IT and its openness to industrial Ph.D.s are very strong.

Over the last six years the MRTC has become an internationally leading research centre in real-time systems, and has become the largest research centre in real-time systems in Sweden. For a relatively small country, the resources in this niche area are high. The KK grant, together with the industrial and regional funding that this has helped to leverage, has established the necessary critical mass as well as the infrastructure and potential for attracting the resources needed for the centre's continued development.

However, current funding structures do not permit support for basic research activities to an adequate level. The situation is likely to become even worse without the Profile money (20% of the budget), which - unlike the industrial money - is not allocated to specific projects. Whilst MRTC activities are to a large extent sustainable, to secure its longer-term viability the centre urgently needs additional resources to strengthen basic research activities. In a long run, insufficient attention to basic research could harm the sustainability of the MRTC as a truly influential institution in the region.

Management has been very successful, as attested by the results and achievements of the project. It did an excellent job in establishing a strong industrial network with local industry. It explored and promoted effective collaboration strategies. This is a major achievement that has considerable impact on development, through resources from contracts and transfer of people to and from industry. Such strong interaction with industry ensures the relevance of the R&D work of the Centre. Management has done an excellent job in attracting and hiring professors and researchers with recognized competences, contributing to the sustainability of the Centre."

Management has also been very successful in establishing international collaboration with distinguished Centres in the area, and Networks of Excellence. This allowed - for some projects - faster development by importing state-of-the-art techniques and know-how. It has also drastically improved the visibility of the Centre."