CERES

Centre for Research on Embedded Systems

Presentation and Activity Report 2013

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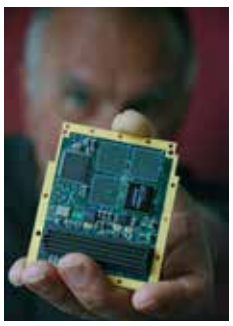


Cover Photo

A development board of a 16-core manycore processor named Epiphany from Adapteva is seen in the picture. The researchers at CERES are involved in developing tools and APIs for completing the design flow from high-level data flow languages to the native language of the said architecture. The developed tools will be used for high-performance embedded streaming applications.

CERES

Centre for Research on Embedded Systems

Knowledge Foundation

Preface

Internationalization, more than anything else, is what currently characterizes the development of CERES. During 2013, three new professors came from abroad to join CERES, bringing loads of international influences, contacts, networks and collaborations into our centre. New postdocs and PhD students, as well as a vivid stream of international visitors further amplify this. Many were the outstanding scholars who came to give talks in the Halmstad Colloquium distinguished speaker series. The lectures in this series are recorded and made available on Youtube, attracting thousands of views.

Our scientific production, measured in number of publications in international journals and peer-reviewed conferences, has increased significantly from 2012 to 2013. Two best-paper awards in scientific conferences were obtained. Our annual Halmstad Summer School on Testing is growing every year and is now an established international event.

The impact of the research, not only in the scientific community but, even more, in industry and society, was praised by the international evaluation panel in the ARC13 assessment of all research at the university. The analysis and advice provided by the panel are highly appreciated and will be extremely useful for the further development of CERES.

Funding with a long-term perspective from The Knowledge Foundation, ELLIIT and SSF, as well as from the university's own sources, gives us excellent opportunities. Additional project funding for co-production with industry is provided by Vinnova and EU. The generous support from The Knowledge Foundation in the form of the "excellence profile" funding CERES+ during 2012 and 2013, has helped us position CERES internationally and sustain it as a strong research partner for industry.

A large part of the research is co-produced with partners in academia and business. We are highly grateful to all our partners in Sweden and worldwide. An important step for further developing industry collaboration was taken when the industrial graduate school EISIGS was started in 2013. The large increase in PhD student recruitment is important to CERES and to industry.

Halmstad University celebrated its first 30 years in 2013. The Information Technology Open Day, which was part of the celebrations, highlighted the university's proven importance for creating new businesses and reshaping the industrial landscape. We are proud to have many of these companies as our partners in research and advanced education today.

A deeply felt thanks to all our employees, partners and friends! The future is bright!

Bertil Svensson,
Director of CERES

CERES – The Centre for Research on Embedded Systems

With a scientific focus on cooperating embedded systems, and in close relationship with industry, the Centre for Research on Embedded Systems (CERES) was initiated more than ten years ago (2003) and built up with support from The Knowledge Foundation. CERES is part of the School of Information Science, Computer and Electrical Engineering (School of IDE) at Halmstad University.

Cooperating embedded systems are of vital importance for the continued development of new products and services, improving society, human life and the environment. The industrial applications are manyfold, and CERES has given priority to areas such as health care, traffic and transport, and advanced sensing and communication systems. The research of CERES provides knowledge (solutions, theories, methods and tools) to bridge the gap from basic enabling technologies to application domains. As an arena for industrially motivated, long-term research, CERES is intended to increase the competitiveness of Swedish industry. It serves as a partner for industry's own research and development, as a recruitment base for those who seek staff with cutting-edge knowledge, and as a competence resource for industry and society. CERES hosts research education and profiled master and bachelor studies.

CERES plays an important role in the profile and strategic development of Halmstad University, for example by hosting a major part of the PhD education in Information Technology and by being a leading player in the University's strategic research initiative, Research for Innovation. Also, with its strong record of spin-off companies from the embedded systems area, CERES is considered vitally important for the University's profiling as the university of innovation.

Four main research areas of CERES

Currently, there are four main research areas within CERES. However, there is no clear border line between the areas; rather, collaboration between the areas is greatly encouraged. The four areas are: *Real-time and wireless communication, Embedded parallel computing, Modelling and simulation of cyberphysical systems, and Model based testing and verification.* Many research activities cannot easily be sorted into one of the four areas. This goes particularly for projects that have a strong focus on applications, such as in health care or traffic and transport. Additionally, an important part of CERES is its electronics research in collaboration with another lab of the School of IDE (MPE-lab).

CERES research focus in a broader context

Within the School of IDE, CERES is part of a larger, coordinated research arena within information technology, covering the entire spectrum from basic, enabling technologies to end usage and business models, see Figure 1. The right-going arrows can be understood as "enables" and the left-going as "demands". The core expertise of CERES is mainly used in the two circles meeting in "systems solutions". In projects performed in cooperation with industry it is a great asset to CERES to have access to this wide-ranging expertise.

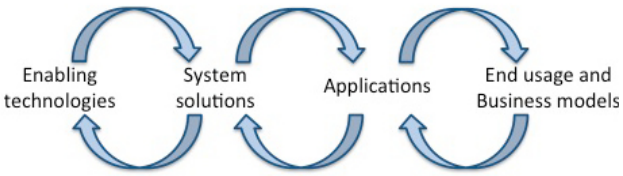


Figure 1. Embedded and intelligent systems research, ranging from enabling technologies, via systems solutions and applications, to business models.

CERES position as a leading actor in embedded systems has attracted national cooperation in the ELLIIT consortium, consisting of the universities in Linköping, Lund, Halmstad and Blekinge. This consortium was selected by the Swedish Government (in 2009) to achieve long-term extra funding of research that is considered to be of particular strategic importance to Sweden. Since 2010 CERES has been performing joint, strategic research projects together with the other ELLIIT partners. To Halmstad University it is strategically important that CERES continues to develop additional strength in order to qualify to maintain this role in the national investment in information and communications technology.

> Cooperating embedded systems are of vital importance for the continued development of new products and services, improving society, human life and the environment.

Funding

The funding of the research at CERES during 2013 came – in almost equal parts – from four sources; between 4 and 5 million SEK from each made a total of 18.2 million SEK. The four sources are: Profile+ funding from The Knowledge Foundation, Other funding from The Knowledge Foundation, Other external funding and, finally, Internal funding from Halmstad University. Figure 2.

Figure 2. CERES funding sources 2013

CERES Funding 2013	KSEK
Profile+ funding from The Knowledge Foundation	5 000
Other funding from The Knowledge Foundation	4 063
Other external funding	4 360
Internal funding, Halmstad University	4 788

The main external funding sources are: The Knowledge Foundation, The Foundation for Strategic Research (SSF), ELLIIT, the European Union (Artemis program), and VINNOVA.

The development of the funding for CERES since the year 2003, when CERES started as a so called KK Platform, is shown in Figure 3.

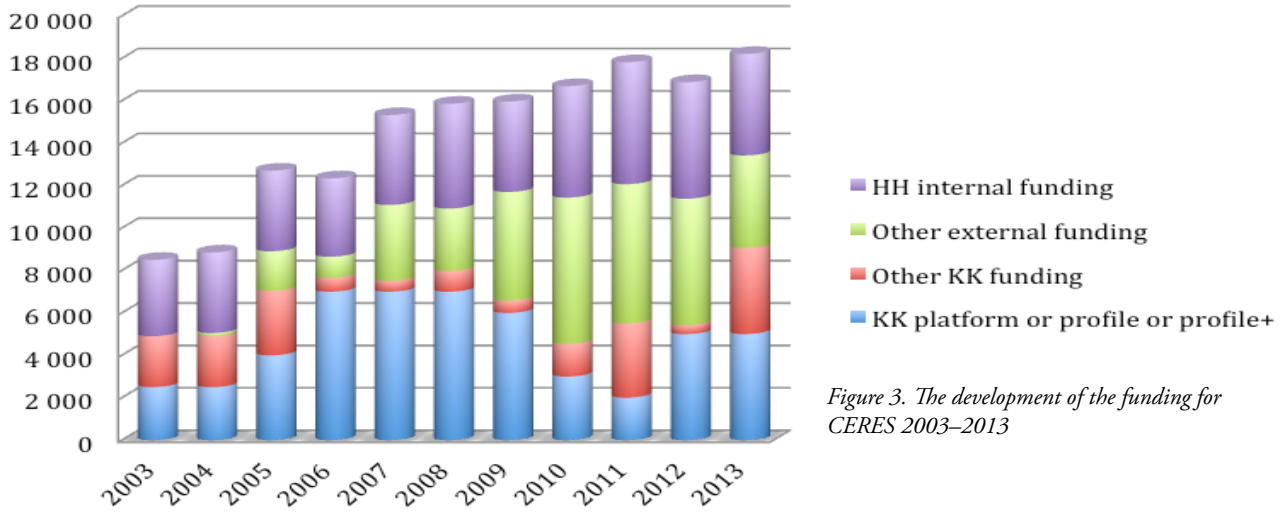


Figure 3. The development of the funding for CERES 2003–2013

The CERES-team gathered for kick-off, August 19th. Purpose with the meeting was to update ourselves regarding ongoing research in CERES, as well as on new projects starting or being in the final planning phase.

Two Years as "Excellence Profile"

Following up on its six-year support of CERES in the form of "profile funding", The Knowledge Foundation in 2011 offered CERES to qualify for two-year "profile+ funding" during 2012 and 2013. The goal would be to further develop the centre's international research edge and its international research network, while at the same time maintaining its focus on industrially relevant research and industrial collaborations. CERES had already reached significant national recognition as a research centre for co-operating embedded systems; CERES was also already asked for and participated as international partner in, e.g., European research projects.

Starting from this position, the ambition with CERES+ was to further establish CERES as an internationally well known research centre for *co-operating smart embedded systems,* with particular emphasis on *smart co-operation and communication and smart programming and execution*. These two specializations correspond to two of the informal sub-groups of CERES: the group for real-time communication and the group for embedded parallel computer architectures and languages, respectively.

During the CERES+ period and after, the research edge was shown through participation in international projects and through increased international visibility within the profile areas. This was promoted by, e.g., research in co-production with the strategically most important partners of CERES and connecting this research to international contacts; further, international collaboration and visibility through joint projects and distinguished researcher visits and talks (The Halmstad Colloquium); and, finally, international recruitment of professors and supporting their research as an integral part of CERES

Scientific and operational outcome of CERES+

In the project plan of CERES+, the scientific goals were expressed as "establishing ourselves as a leader in the international scientific community in dependable real-time communication, programming of embedded parallel computers as well as modeling and simulation of embedded systems and cyberphysical systems". The project plan specified indicators in terms of publications in top-ranked journals and conferences as well as developed tools that have been spread to and used to the research community. In both respects – and most clearly in terms of publications – the trend is very positive, indicating a successful work towards these goals.

The operational objectives of CERES+ were expressed as increased visibility, increased international cooperation, strengthened industrial cooperation and increased research capacity. Increased visibility can be seen in the large numbers of applicants for doctoral student positions (between 30 and 150 applicants per opening in the last four announcements) and good attendance at open seminars, including the Halmstad Colloquium – which also receives many visitors afterwards online (so far over four thousand views). Locally and nationally CERES has been exposed by its own, well-attended, recurrent event (CERES Open Day, Information Technology Open Day) and, for example, Embedded Conference Scandinavia in Stockholm. CERES is offering an annual international summer school and is increasingly hosting national and international conferences. Guest researcher visits have increased significantly, as has the number of international co-publications. During the CERES+ funding period we have also recruited two visiting professors (one during 2013, the second during 2013-2014), one in each area of strength. The funding comes from the Knowledge Foundation and the University, with companies in the CERES network as co-actors. Industrial cooperation has also been strengthened by an industrial graduate school (EISIGS – common to the entire EIS and in cooperation with CIEL – the centre for innovation, entrepreneurship and learning research).

Results and effects for the co-producing companies

The research financed by CERES+ during 2012 and 2013 was conducted in the form of a number of projects. Three of the projects involve close cooperation and co-production with CERES' major Swedish industrial partners: Volvo, Saab and Free2move as well as with SP Technical Research Institute of Sweden. These industry-related projects also include international collaborations, which has been assessed as very important.

Through the cooperation within CERES+ the co-producing companies have strengthened their position in the technology areas that are key to their business. For Volvo, this includes the emerging field of collaborative vehicles, with demands for secure, wireless real-time communication. A significant

Katrin Sjöberg former PhD student at CERES, now working as an expert at Volvo Technology.

contribution is that one of the doctoral graduates of CERES, Katrin Sjöberg who graduated in 2013, is now working as an expert in this particular area at Volvo Technology. Having access to researchers who are willing to migrate between university and industry (”gränsgångare”) is highly attractive for the CERES partners; also the cooperation with Saab has had such an arrangement.

A very marked effect in the partner companies is thus their obtained ability to maintain close contact with the research frontier and be active in research cooperation and in international projects. Even the smaller companies that CERES has or has had affiliation with, have developed this ability.

CERES contributes to the strategic development of Halmstad University

CERES is part of the university-overarching research programme ”Research for Innovation” which has a paramount role in the focused development of the entire Halmstad University.

The goals of Research for Innovation are expressed in terms of *positioning, branding, quality and relevance*. The development of CERES contributes to the positioning of Halmstad University in that it becomes internationally known for being a leading research environment in cooperating smart embedded systems. Partnerships with other centres at the University help positioning the university further. Such cooperation is now focused in the continued development of CERES. Examples are: digital security and critical infrastructure; electronics for internet-of-things; health technology.

CERES is a good example of an environment that integrates research, education and innovation, thereby contributing to the *profiling and branding* of the university as ”the university of innovation”. The new industrial graduate school in embedded and intelligent systems, targeting innovation, is one of the latest concrete examples of this. CERES+ has lifted the *quality* of the university’s research and education one step further, including through high quality recruitment, recruitment of international visiting professors and a strong development of international contacts. This already gives positive effects on the quantity and quality of scientific results and publications, and it should, within one or a few years, also result in increased funding and increased number of externally funded graduate students.

Relevance: Cooperating with industry is at the centre of all CERES operations. In CERES+ it has been particularly stressed to, together with industry, engage in international projects to position the industry-relevant research in an international context, thereby further strengthening the competitiveness of the participating companies.

> The ambition with CERES+ was to further establish CERES as an internationally wellknown research centre.

Cooperative Systems Demand **Dependable Communication**

CERES sub-area Real-Time and Wireless Communication

Data communication is an important enabler for cooperation within and between embedded systems. For example, the different processors within a smart phone need to communicate with each other to coordinate different tasks and to collectively contribute to the execution of the different applications running on the phone. Another example is that of platooning, i.e. road trains of trucks, buses and cars driving more or less autonomously with short distances between them. Platooning can increase the efficiency of road usage, decrease the fuel consumption and improve traffic safety. However, it requires dependable wireless communication between the vehicles to, e.g. coordinate braking. New solutions are needed to meet the tough requirements. Other application where dependable communication with, e.g. real-time and reliability support, is important include avionics, health, manufacturing, surveillance, radio base stations, radar signal processing systems, and multimedia communication.

Research challenges tackled by CERES researchers within Real-Time and Wireless Communication normally arise from important industrial problems where the goal is to be able to meet the combination of several different tough requirements. Specifically, we study how communication methods, network architectures, analysis tools etc. can be designed to meet the requirements on both *real-time* performance and one or several of the following:

- *reliability*, especially for wireless communication with high error probability
- *energy efficiency*, especially when having battery-driven units
- *scalability*, e.g. to support many concurrently communicating units
- *dynamics*, e.g. caused by high mobility

From another perspective, we also study how to create wireless networks and communication methods that act in a *context-aware* and *application-demand oriented* way. One important approach is to do this in a cross-layer oriented way. Traditionally, we have had the goal to develop methods being able to give strict guarantees. However, with more dynamics and the often error-prone wireless communication, probabilistic guarantees are needed instead. With probabilistic guarantees or predictions of the performance, the systems can take appropriate actions depending on the currently available performance of the communication.

The group has contributed extensively to the communication area, especially real-time communication. The results are on, e.g., communication methods and protocols, channel coding and diversity, timing analysis as well as network architectures for communication within and between embedded systems, utilizing either wired or wireless communication. We were among the first groups in the world to contribute with results on wireless industrial real-time communication already in the late 90s. We founded the concept of deadline-dependent coding, and later a framework for reliable real-time communication, later adapted for, e.g. multi-channel networks using IEEE 802.15.4 leading to the best paper award at a big international conference, ETFA 2010. The research on deadline dependent coding continued extensively with a lot of results and a best paper award. Within the field of wireless communication for cooperative traffic safety applications, we have contributed with results on both centralized and decentralized solutions improving the real-time performance compared to standard IEEE 802.11p. The results have even attracted ETSI (The European Telecommunications Standards Institute) to contract us to lead a special task force on medium access control in vehicular communication. We were among the first in the world to present results on how to support hard real-time traffic over switched Ethernet – work since early 2000, with the first publications in 2002. Moreover, we have shown better results than the well-known Network Calculus with our real-time analysis for packet-switched networks. DSL communication is another field with a number of publications. On the application level, we have published results on both wireless sensor networks and vehicular communication. Recently, the group has also published on video transfer and misbehaviour/denial-of-service detection in vehicular networks. The group is active in arenas like Vehicle ICT Arena, Safer, and NFITS.

Real-Time and Wireless Communication

Research within Real-Time and Wireless Communication is performed by the following staff (including industrial PhD students). Professors: Magnus Jonsson, Tony Larsson, Tomas Nordström (mainly another field), Alexey Vinel (Guest Prof.). Associate Professor: Elisabeth Uhlemann. Assistant Professor: Kristina Kunert. PhD/Lecturer: Urban Bilstrup. Postdocs: Annette Böhm, Shih Yang Lin. PhD Students: Hoang Le-Nam, Marcus Larsson, Mahboobeh Parsapoor, Hawar Ramazanali, Benjamin Vedder. Research Engineer: Nikita Lyamin.

Examples of current or recent industrial collaborators: Emwitech, Ericsson, Free2move, HMS Industrial Networks, Kapsch TrafficCom, Mentor Graphics (former Volcano), Qamcom Research and Technology, Saab Group, Scania, SP Technical Research Institute of Sweden, Volvo Cars, and Volvo Group Trucks Technology. Examples of international collaborators include: University Mediterranea of Reggio Calabria (Italy), Simula Research Laboratory (Norway), Tampere University of Technology (Finland), Vienna University of Technology (Austria).

The Acumen to Innovate

CERES sub-area Effective Modeling Group (EMG)

It is widely anticipated that future innovations will be predominantly in the form of Cyber-Physical Systems (CPSs), that is, systems where embedded cyber components interact closely and in complex ways with their physical environment. Such systems pose significant challenges when it comes to design, analysis, testing and certification. The Effective Modeling Group (EMG, www.effective-modeling.org), led by Professor Walid Taha, develops and studies better technologies for supporting model-based development of Cyber-Physical Systems. The group addresses the various challenges through novel support for mathematical modeling, rigorous simulation, visualization, and immersive interaction. The methods developed by the group are evaluated in a wide variety of contexts, including bipedal and exoskeleton robotics, vehicle dynamics, advanced driver assistance systems, assisted living devices, and others.

EMG is the principal developer of an open source modeling and simulation environment called Acumen (www.acumen-language.org). According to the New Oxford American Dictionary, the word Acumen means the ability to make good judgments and quick decisions, typically in a particular domain. The development of this language began around 2007 as part of a close collaboration with researchers at Schlumberger in Sugarland, TX. While centered on a small mathematical modeling language, Acumen comes with a graphical user interface that provides lightweight support for 3D visualization and human-in-the-loop simulation. Most recently, Acumen introduced experimental support for rigorous simulation, whereby, instead of computing approximate simulation results, we compute rigorous bounds on the exact mathematical result. Preliminary experience with this method has revealed that not only is it feasible, but it has two additional advantages. First, there are many cases where it provides a faster way to run the same model with a large number of inputs. Second, the same methods provide a powerful mechanism for a modeling and simulating system in the presence of uncertainty about model parameters and/or inputs.

EMG comprises principal investigators at multiple institutions, including Halmstad University, Rice University, and Texas A&M University. It has been principally involved in the following projects.

Professor Walid Taha with the humanoid "Jonson".

CERES+ Project "Core Enabling Technologies for Acumen" (2012-2013)

This project was focused on two core research questions: First, how can we formalize the semantics of mathematical equations (with discontinuities) in a computable manner? Second, how can we apply this to interesting practical problems? A key result of the project was bringing the team up to speed on the state of the art, and then adding to it. The addition was in the form of showing that enclosure methods (that is, basically, rigorous simulation methods) can be used to enclose solutions for Zeno systems (that is, bound by the behavior of hybrid sys-

tems around Zeno points). This contribution shows that it is possible for rigorous simulators to go past a Zeno point in a sensible manner. The work won the 'Best Paper' award for the conference that it was presented at.

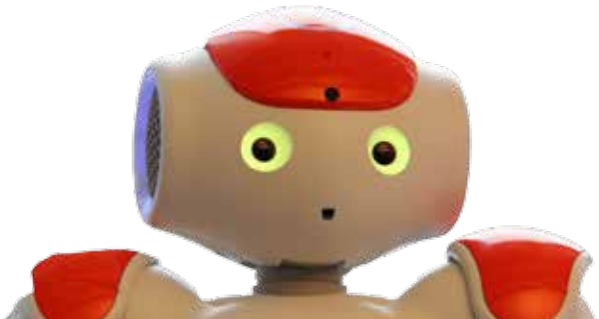
Another important result for this project was having mechanical engineers use the tools being developed by the group, to study concrete scenarios of vehicle collisions . This was done in collaboration with the NG-Test project, and provided valuable input regarding both positive and negative aspects of the usability of the technology and the tool being developed by the group.

US NSF Project "A CPS Approach to Robot Design" (2010-2015, ongoing)

This project focuses on robotics as an important, archetypical class of CPSs, and consists of four key tasks: 1) Compiling and analyzing a benchmark suite for modeling and simulating robots, 2) Developing a meta-theory for relating cyber-physical models, as well as tools and a test bed for robot modeling and simulation, 3) Validating the research results of the project using two state-of-the-art robot platforms that incorporate novel control technologies and will require novel programming techniques to fully realize their potential, and 4) Developing course materials incorporating the project's research results and test bed.

With the aim of accelerating innovation in a wide range of domains including stroke rehabilitation and prosthetic limbs, the project is developing new control concepts and modeling and simulation technologies for robotics. In addition to new mathematical foundations, models, and validation methods, it will also develop software tools and systematic methods for using them.

> The group addresses the various challenges through novel support for mathematical modeling, rigorous simulation, visualization, and immersive interaction.



A Database-Centric System Architecture for Ambient Intelligence and Smart Environments

Smart homes integrate heterogeneous network-enabled home-based technologies for a better quality of living of residents. Early research on smart environments focused on the integration and interoperation of technologies and on the understanding of user's behaviors to improve comfort and safety as well as reduce energy costs. Lately, research and application projects explore smart homes to support disabled and old individuals living alone with services to enhance independence and medical care. Smart homes can also support care workers and healthcare professionals. At CERES, research on smart and intelligent environments aims to overcome challenges associated with development and deployment of such systems. To this extent, a database-centric system architecture has been proposed and exploits mechanisms provided by database management systems, other than data storage, to address requirements for security, privacy, dependability, personalization, extensibility, and scalability in smart homes. The Centre for Health Technology in Halland (HCH) at Halmstad University hosts a permanent exhibition and demonstration of an "Intelligent Bedroom", which has been implemented to evaluate the proposed database-centric architecture.

Wagner Ourique De Morais working with a Database-Centric System Architecture for Ambient Intelligence and Smart Environments.

Jumping into the **Parallel Future**

CERES sub-area Embedded Parallel Computing

The embedded future is parallel. In the devices and infrastructure around us, be it for communication, transport, health, security, manufacturing or entertainment, high performance computers for signal processing do a critical job – often with very low power budgets. Increased parallelism is the only way ahead for providing significant performance improvement while keeping the energy use and heat dissipation under control. Manycore processor architectures offer scalable parallelism and the performance needed for implementation of the required functionality. However, the increasing programming complexity of such highly parallel devices is a challenge. Industry need to take a jump in terms of re-targeting from existing software development solutions to solutions compatible with evolving manycore platforms, i.e., not just one parallel platform but a sequence of ever more parallel architectures.

In the world after the jump-to-parallelism, software portability, program correctness and programmer productivity demand that programs are written in a high-level language capable of expressing application-level parallelism, while abstracting away platform dependent physical parallelism.

Five projects within the CERES sub-area Embedded Parallel Computing have been set up to address these challenges.

The KK-funded project Jump to Manycore Platforms (JUMP) (local project leader, Hoai Hoang Bengtsson) was run during 2012-2013, jointly with two industrial partners, Saab and Free2move. A US company, Adapteva, Inc., also contributed to the project with its new manycore architecture, the Epiphany.

The project identified the future challenges in advanced signal processing systems, analysed how they match with future hardware development and which programming methods and tools need to be developed to bridge the gap to the expected future. Examples showing that high-level tools can become efficient were developed. Concrete experience of how existing and emerging software development approaches fit the industrial application areas was gained, and comparative knowledge on both emerging manycore architectures and emerging software development tools was created

The project Smart Embedded Multicore Systems (SMECY) (2010-2013) (local project leader Bertil Svensson, followed by Tomas Nordström) was run with 30 partners from nine European countries as part of the European strategic research programme ARTEMIS. Multi-core technologies are seen as strategic for industry in all areas of embedded systems. The joint goals of SMECY were to develop new parallel architectures and, in particular, associated supporting tools in order to master complete system design.

The project has developed two "intermediate representations" (IRs) and integrated most of the partners' tools around these IRs, providing paths from several programming models and languages to two very different platforms. The three application clusters (radar, mobile multimedia, video surveillance) have defined a complete tool chain each, representing a small subset of all possible tool combinations, and demonstrated them in a wide set of case studies. The tools are complemented by a runtime environment providing fault tolerance.

The project High Performance Embedded Computing (HiPEC) (local project leader, Verónica Gaspes) is funded by the Foundation for Strategic Research (SSF) and is run jointly with the two ELLIIT partners Lund University and Linköping University during 2011-2016. The project addresses reconfigurable array processor architectures as well as software tools for their programming. Two massively parallel execution platforms with powerful computing nodes and hierarchical interconnection structures suitable for streaming applications are developed and studied. The software development approach is based on using CAL language for application programming as well as the development and use of tools for timing and energy analysis at early design stages. Combining both hardware and software experts in the same project provides a strong basis for covering the whole spectrum of this new technology. The group from CERES works on developing the code generation parts of the tool-chain, starting from the CAL actor machine intermediate representation and creating backends for the developed architectures but also for commercial architectures. The work usually ends up generating code that the native tools of the target architectures can handle, in general this is C code for each individual core and using special libraries for communication and coordination of the cores. Working with IRs on several levels is one way to increase portability of the tools.

The project Streaming Applications on Embedded High-Performance Commercial Platforms (STAMP) (local project leader, Zain-ul-Abdin) is an ELLIIT-sponsored project in collaboration

with Computer Science at Lund and can be seen as a spinoff of the HiPEC project. While the HiPEC project has a focus on the design of new hardware architectures and efficient mapping of applications on these, STAMP has a focus on the efficient use of architectures that are emerging on the commercial market at an increasing pace. The STAMP project aims to complete the design flow for compiling and executing CAL applications targeting selected emerging commercial architectures, thus leveraging the tool-chain developed in HiPEC. Currently we have developed backends for Adapteva's Epiphany and Ambric manycore architectures.

The recently started project Embedded Streaming Computations on Heterogeneous Energy-efficient aRchitectures ESCHER (project leader, Tomas Nordström) is a KK funded project run in collaboration with the companies SAAB EDS, Xcube, ImaComp, and Adarate. It aims to develop a tool framework that can support programmer productivity and program portability for streaming applications running on heterogeneous manycore architectures while maintaining state-of-the-art performance and power efficiency. The design and implementation of such framework needs a coordinated effort to co-develop both the hardware architectures and the application development environment. With regard to hardware, the focus will be on how parallel heterogeneous architectures should be organized, designed, and evaluated, as well as how they should interface with the application development tools and frameworks. The software aspect will focus on how to develop real-time streaming applications at a high level of abstraction, develop a single application source that can target a multitude of heterogeneous architectures, utilize domain knowledge to better target a diverse set of architectures, and support an efficient design process taking into account resource efficiency and real-time aspects.

> Industry need to take a jump in terms of re-targeting from existing software development solutions to solutions compatible with evolving, ever more parallel architectures.

Quest for **Quality**

CERES sub-area Model-Based Testing and Verification

Testing and debugging account for more than half of the software development costs and are becoming serious bottlenecks in the software development process. The problem is intensified in embedded systems due to the tight coupling between software and its hardware platform; hence, embedded software is often tested too late and too little and in an ad-hoc and unstructured manner. Concurrency faults are particularly difficult to find and are extremely difficult to reproduce. Due to their critical application areas, faults in embedded systems may turn into failures with very severe consequence.

A promising solution to testing issues is found in automated Model-Based Testing (MBT) processes, which provide a structured approach to testing from high-level behavioral models. Our vision is that MBT is instrumental in mechanizing and integrating the test process in the development cycle. Moreover, embedded software is particularly suitable for MBT, because operational (behavioral and reactive) aspects play a prominent role in its correctness.

Our research goal is to provide practical industrial strength MBT solutions, that can deal with product lines of embedded systems. The first project towards this goal is Model-Based Testing for Software Product Lines (MBT4SPL), which has been funded by a strategic investment from the Vice Chancellor of Halmstad University. Software product lines (SPLs) have been proposed as a response to the ever-increasing demand for mass production and mass customization of software. Since their introduction, SPLs have gained popularity and have been increasingly used in the practice of software development. Briefly, an SPL consists of a variety of computer systems (products) that are built upon a common base (platform). The products share several core features, but also differ from each other in some features, commonly referred to as variability points.

Testing such SPLs is known to be very challenging due to the large spectrum of variability and the complexity of products. There have been several attempts to provide a structured discipline for testing SPLs. However, it appears from the recent surveys that several fundamental approaches to model-based testing are not yet fully adapted to and adopted in this domain. In this project, we aim to bridge this gap by providing notions of conformance testing that take the structure of a product line into account.

A major challenge in testing software product lines is efficiency. In particular, testing a product line should take less effort than testing each and every product individually. In this project, we address this issue in the context of model-based testing. We aim at minimizing the test effort by taking the commonalities and differences of various products into account and structure the test-suites and coordinate their executions so that commonalities are tested once and for all and then the focus of the testing on specific product is shifted into the specifics of each product.

> Embedded software is often tested too late and too little and in an ad-hoc and unstructured manner.

Professor Mohammad Mousavi leads the research on testing

Electronics Centre in Halmstad

Electronics Centre in Halmstad (ECH) is an arena for regional cooperation in the field of electronics, where small and medium-sized companies with common technical challenges are forming a regional knowledge/resource cluster in collaboration with Halmstad University and the public sector. ECH is a shared R&D entity with resources such as advanced electronics labs, EMC testing facilities and an arena for building "know how" in terms of research and education. The focus of ECH is integration of electronics in everyday products to make them "smart", which provides a substantial added value and competitive advantages, and represents an important innovation potential of traditional Swedish manufacturing industry. The potential growth of the electronics field is huge, it is estimated that the development of the "Internet of things" means that there will be over 50 billion connected electronics units in 2020. Applied research, innovation and knowledge-building in the field of electronics integration is a prerequisite to be successful within the global ecosystem that is emerging around these new "smart" products. Identified research subjects in focus at ECH are, next generation electronic building practice, electromagnetic compatibility (EMC), and low power design. Cross-fertilization with the Centre for Health Technology in Halland (HCH), and the Centre for Digital Security Studies (CDSS) under formation, will "enable interesting and potentially ground breaking intellectual combinations" leading to new research as well as development of innovative education programs.

Thomas Lithén, research engineer at e-lab.

> It is estimated that the development of the "Internet of things" means that there will be over 50 billion connected electronics units in 2020.

Halmstad Colloquium

In February 2012, Halmstad University launched the Halmstad Colloquium, a distinguished speaker series. By mid-2014, more than twenty renowned researchers had visited the university through this series, and enthusiastically shared their knowledge with our researchers and students, as well as with representatives from industry. Talks in the series are recorded and made available online through the university's YouTube channel.

The primary benefit of the Colloquium has been to give our researchers and students the opportunity to attend lectures by distinguished researchers from all over the world, and to meet with them. The theme of the series is embedded and intelligent systems, Cyber-Physical Systems, and related topics. These are all areas where Halmstad University is building up strong research environments and has an interest in increasing international collaborations. Most Colloquium speakers spend multiple days at the university to learn about the research happening here and to explore opportunities for collaboration.

A secondary benefit of the Colloquium has been to encourage industry engagement in the university's research. This engagement plays a critical role in facilitating the process of transferring the research results developed at the university to industry, thus completing the innovation process and benefiting society in a direct manner. Successful and effective technology transfer is of great importance not only to the university itself, but also to one of its key benefactors, namely, the KK Foundation.

One of the noteworthy features of the series has been recording the talks and making them available online through YouTube on the Halmstad University channel. Links have been provided to the recordings from the Colloquium series website (http://www.halmstadcolloquium.org/). At a time when distance learning and massive open online education are popular, it is surprisingly relatively rare to find openly-available online recordings of talks by distinguished speakers. By mid-2014, each of the six most viewed recordings of Halmstad Colloquium talks had attracted between 393 and 794 views. With such numbers one can be sure at least that a significant number of viewers is now aware of, and has access to, this excellent series of lectures. In addition, the recordings are available for use (and in fact are already being used) to supplement research education at our university, as well as any other educational institution around the world.

Walid Taha is the principal developer and inaugural director of the Halmstad Colloquium concept, and Bertil Svensson is the program manager for CERES. They both stress the importance of continuing the Halmstad Colloquium beyond the CERES+ initiative. With improving communications, the research community is constantly getting closer, and the pace of progress only gets faster. Initiatives like the Colloquium improve the quality of our research environment in many ways, including increasing awareness of the most important developments in a wide range of research areas and increasing opportunities for successful international cooperation.

The Halmstad Colloquium was supported by both CERES and CAISR centres. The executive team of the colloquium included Walid Taha, Roland Thörner, Stefan Gunnarsson, Eva Nestius, Adam Duracz, and Harsh Beohar.

You can receive email announcements about upcoming talks by signing up on the colloquium website.

Speakers during 2013 invited by CERES are found on next page. Besides those guests, Halmstad Colloquium has also had the pleasure to invite a number of other speakers, selected by other research groups:

Marcia O'Malley, Rice University
Mechatronic Systems for the Repair and Training of Human Sensorimotor Control

Karl H. Johansson, Royal Institute of Technology
Event-based control and estimation

Janos Sztipanovits, Vanderbilt University
Model-based Design of Cyber-Physical Systems

Karl Iagnemma, Massachusetts Institute of Technology
Autonomy is overrated: Towards shared human-machine control of vehicles and other mechanical systems

Magnus Egerstedt, Georgia Institute of Technology
Interacting with Multi-Robot Networks

All Halmstad Colloquium talks are available on Youtube! www.halmstadcolloquium.org

Marcia O'Malley, Rice University

Invited Speakers 2013

Validated Numerics

Warwick Tucker
University of Uppsala

The Actor Model: Foundations, Languages and Open Problems

Gul Agha
University of Illinois at Urbana-Champaign

To type or not to type ...

Robert Cartwright
Rice University

Decentralised Constraint Satisfaction

Doug Leith
National University of Ireland Maynooth

A Linear Adaptive Control Approach to Congestion Management in Cooperative ITS

John Kenney
Toyota InfoTechnology Center

Kahn Process Networks in Silicon for Real-Time Embedded Systems

Mike Butts
Synopsys

The Human Heart An Ultimate Cyber-Physical System

Radu Grosu
Vienna UT / Stony Brook

The Future of Embedded Computing; a DARPA Perspective

Dan Hammerstrom
DARPA

Stochastic Petri Nets

Kishor S. Trivedi
Duke University

Vehicular Channel Characterization for Dependable Intelligent Transport Systems

Christoph Mecklenbräuker
Forschungszentrum Telekommunikation Wien

PhD Education

Research Education

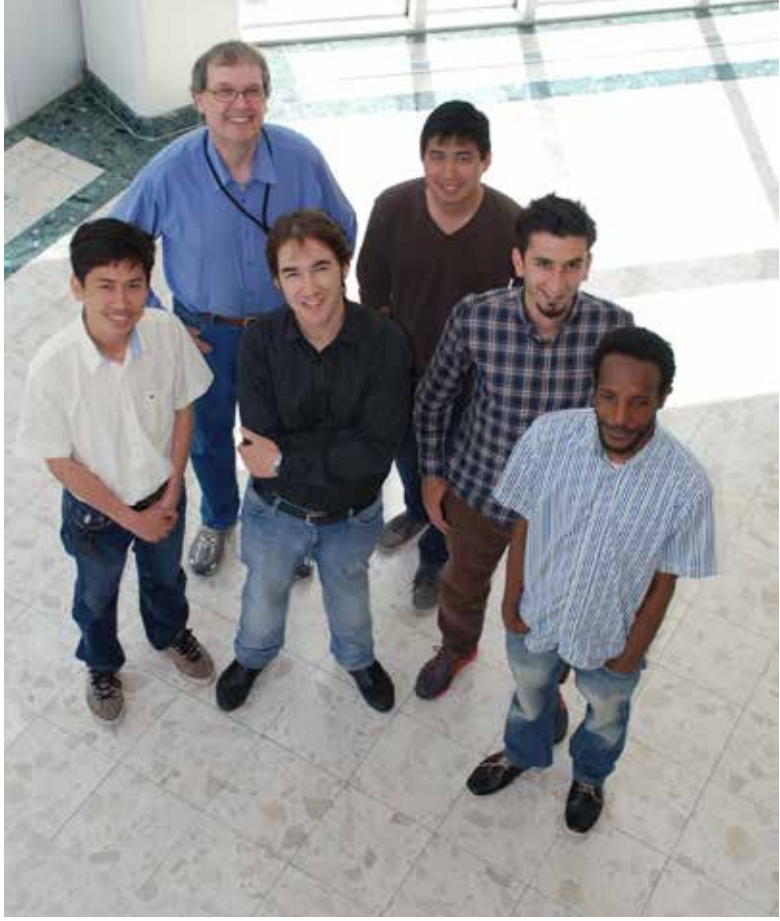
Halmstad University has, through the research environment Halmstad Embedded and Intelligent Systems Research (EIS), PhD education rights within the research area of Information Technology. There are two research subjects within Information Technology; Computer Science and Engineering (in Swedish "Datateknik") and Signals and Systems Engineering (in Swedish "Signal- och systemteknik"). At present date (2014-05-20) there are a total of 24 PhD students enrolled in Information Technology, of which 12 are in Computer Science and Engineering and 12 in Signals and Systems Engineering. In the EIS research environment there are another 14 PhD students enrolled at other universities (mainly in nanophysics and informatics). The EIS research environment thus has a total of 38 PhD students involved in research.

What is special about HH PhD education?

One of the unique aspects of the EIS research environment is that it does not only contain computer scientists, there are also research labs in areas such as nanophysics and informatics. This contributes to make the research environment more diverse and cross-disciplinary thus providing PhD students with opportunities to interact with researchers from different fields.

Support committees

In addition to the supervisors (one main supervisor and one or more co-supervisors), each doctoral student in the research environment has a follow-up committee as a support during the research studies. The committee shall meet annually with the student and the main supervisor to monitor the progress, to offer advice, to identify problems and to support the student to set goals. When forming a follow-up committee it is advisable to have one "specialist" and one "generalist" within the committee. The specialist is someone with knowledge of the technical area in which the student works, whereas the generalist has broad experience of research education but is typically (and intentionally) not too close to the student's and the main supervisor's research group.



Some of the PhD students at CERES: Le-Nam Hoang, Erik Hertz, Wagner Ourique De Morais, Maytheewat Aramrattana, Süleyman Savas and Essayas Gebrewahid.

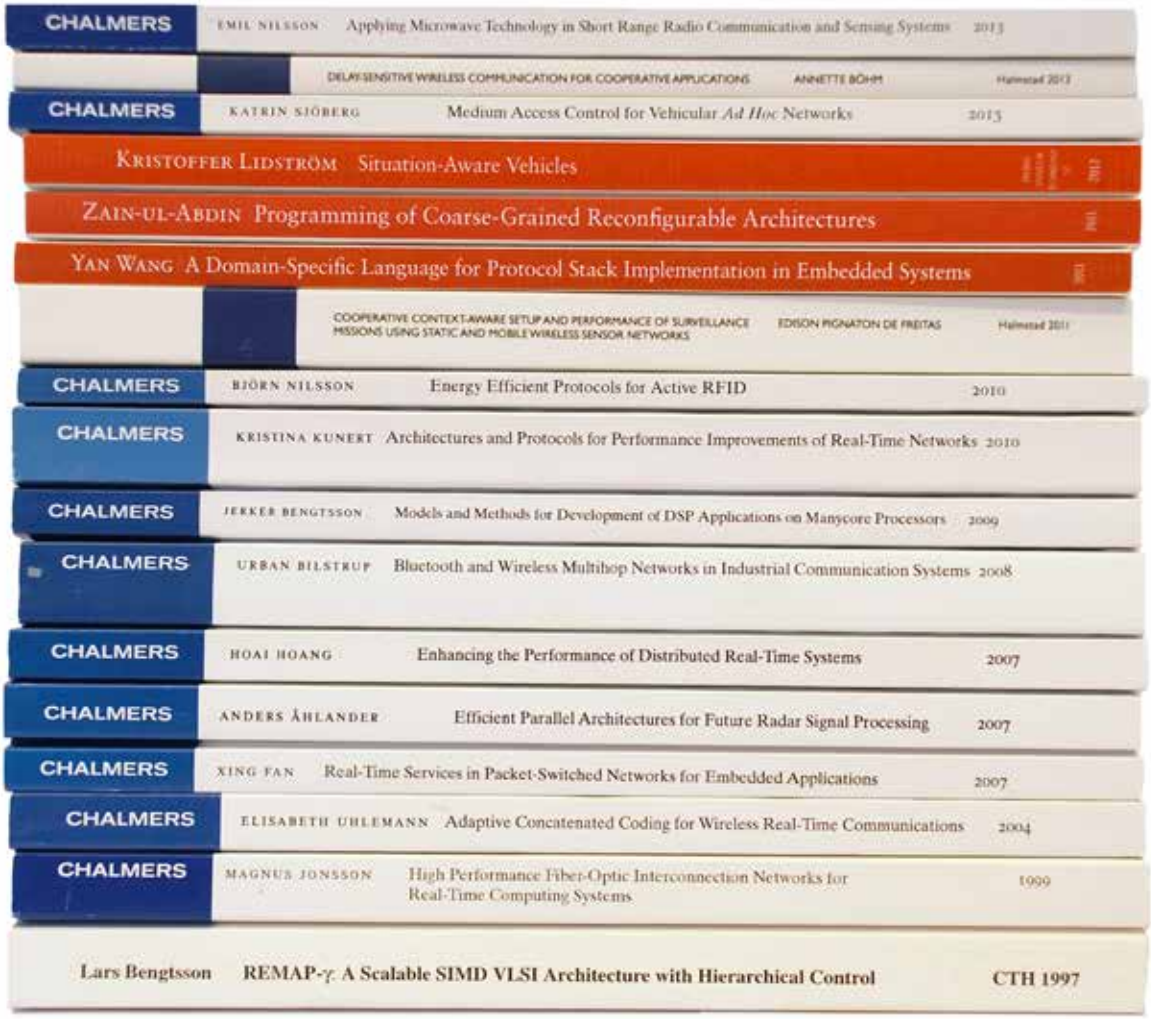
Obligatory courses

All PhD students at Halmstad University are required to take the course "Introduction course for PhD students". This course contains three modules; "Research ethics", "Theory of science" and "Pedagogics". For PhD students at the EIS research environment, there is an additional requirement to take three small courses that introduce the PhD student to research topics or tools within the EIS area. These courses can provide a useful introduction and perspectives on EIS related research and/or inspire to use tools that can be useful for the student's future research career.

Yearly PhD conference

Each year, the PhD students of the EIS research environment arrange a PhD conference which PhD students from all the different areas are expected to attend. This is typically a two-day activity where the PhD students make presentations of their work and listen to invited speakers (such as former PhD students who tell about their experiences during and after PhD studies). In the evening there are also social activities for the PhD students and supervisors.

A pile of knowledge. The PhD theses in Embedded Systems at Halmstad University



Name	University	Year
Emil Nilsson	Chalmers University of Technology	2013
Annette Böhm	Halmstad University	2013
Katrin Sjöberg	Chalmers University of Technology	2013
Kristoffer Lidström	Örebro University	2012
Zain-ul-Abdin	Örebro University	2011
Yan Wang	Örebro University	2011
Edison Pignaton de Freitas	Halmstad University	2011
Björn Nilsson	Chalmers University of Technology	2010
Kristina Kunert	Chalmers University of Technology	2010
Jerker Bengtsson	Chalmers University of Technology	2009
Urban Bilstrup	Chalmers University of Technology	2008
Hoai Hoang	Chalmers University of Technology	2007
Anders Åhlander	Chalmers University of Technology	2007
Xing Fan	Chalmers University of Technology	2007
Elisabeth Uhlemann	Chalmers University of Technology	2004
Magnus Jonsson	Chalmers University of Technology	1999
Lars Bengtsson	Chalmers University of Technology	1997

Industrial Graduate School

Collaboration in postgraduate education strengthens competitiveness

At Halmstad University's industrial graduate school: "Embedded and Intelligent Systems Industrial Graduate School - EISIGS", employees from industry are undergoing postgraduate education. The idea is that, in the long term, this will strengthen the competitiveness of the involved companies through the newly gained research skills and knowledge by applying it in key areas. At the same time, the industrial graduate school contributes to Halmstad University´s profile and the development of the research- and educational environment.

Over the next few years, the aim is that eight persons from within the industry will undertake the postgraduate education with collaboration with companies, Halmstad University and the Knowledge Foundation; who help with the funding. The postgraduate students will share their time between their regular work and the university. The University is responsible for the education and tutors, the companies are responsible for, among other things, the students' salary, and the students themselves are responsible for work effort and input.

Collaboration within the University

Halmstad University has the rights to award doctoral degrees in three areas. Procedures and focus within the education depends largely upon funding. Parallel with the industrial graduate school, a more regular postgraduate education is carried out where postgraduate students are employed by the university and spend most of their time at the institution. The industrial graduate school implies additional postgraduate students within research environments which benefits the university.

-Having more postgraduate students from industry is very positive for research environments and contributes to strengthening joint productions. Together with these postgraduate students, we can conduct further research in close cooperation with industry, says Professor Magnus Jonsson, head of the industrial graduate school.

The education is conducted in collaboration between the University's research environments EIS - Halmstad Embedded and Intelligent Systems Research and CIEL - Centre for Innovation, Entrepreneurship and Learning Research.

- It is good that these two strong research environments collaborate in the industrial graduate school, and we see how the University's innovation profile is strengthened by the venture, says Magnus Jonsson.

Companies contribute strategically

It is seen what it means for the companies by looking at just how much they contribute in terms of resources. All participating companies agree to cover part of the their student's salary costs. Furthermore, they take part in supervision and mentoring, as well as being involved in the research projects that the students are active in.

Magnus Kilian

-We want to further strengthen our profile as a research company, and having a postgraduate student within the business feels like a natural part of the profiling. The expertise that our company gains will help strengthen us in general for the future, says Magnus Kilian CEO at Qamcom Research & Technology in Gothenburg, one of the companies participating in the venture.

- The company works with, among other things: product development in signal processing, communication systems, embedded systems, software testing, and system security. We operate both our own projects and assignments for clients.

- Initially, the student will work in-house by finding research questions within our line of business. This raises the level of what we do both on the long and short term; irrespective of whether it is a client´s assignment or our own, says Magnus Kilian.

A Challenge for the students

For those who go the postgraduate programme, it is an opportunity to acquire one of the most qualified educations available. However, it does not come easily. The education takes four to five years and involves a lot of work and travelling for the students. Hawar Ramazanali from Saab Training & Simulation was the first industrial research student to accept this challenge. He specialises in power efficient and flexible radio communications.

- For me personally, the start has been extremely fun, instructive and interesting, not least that as a post graduate student I now have a different focus than I've had before. To put things simply, I can say that my job now is less about what is tried and tested, and more about what is unexplored and new and how things can be done better.

The industrial graduate school involves major commitment from all parties. It is clear that companies are willing to invest in this; not only to enhance competence at different companies, but also as an investment in key skills.

- It feels really good that the company wants and has the ambition to specialise in my field, and I feel even better that they do it by investing in me. I think there's a difference between being a "regular" postgraduate student and an industrial postgraduate student. I work with two main targets: to complete my PhD and to keep the company's vision clear to me; therefore, matching it with the academic requirements so that it will be good for both parties, says Hawar Ramazanali.

> We want to further strengthen our profile as a research company, and having a postgraduate student within the business feels like a natural part of the profiling.
> *Magnus Kilian, Qamcom Research & Technology*

Presentation PhD Students in EISIGS

Marcus Larsson

Qamcom Research and Technology

After spending five years at Chalmers University of Technology at the Automation and Mechatronics program with focus on mechatronics, I ended up in the automotive industry at the Swedish west coast (2008). The coming five years I spent developing and implementing embedded software, e.g. software for exhaust after treatment control and Human Machine Interface. In 2013 I joined Qamcom Research & Technology and Halmstad University and began my PhD studies aiming for a PhD in Information Technology with focus on communication. My main interest lies within vehicular communication (V2X), Intelligent Transportation System and Functional Safety. Currently I am working in the RelComm-H project that aims to investigate reliable Vehicle-to-Vehicle communication for heavy duty vehicles.

Benjamin Vedder

SP Technical Research Institute of Sweden

In 2007 I started studying at Chalmers University of Technology in the programme Automation and Mechatronics. I got my bachelors degree in 2010 and in 2012 I got my masters degree in the masters programme Communication Engineering at Chalmers. As my masters thesis I made the major part in the construction of a miniature autonomous vehicular platform with 1:8 scale cars. In 2012 I started working at SP Technical Research Institute of Sweden and in 2013 I started my industrial PhD studies at SP together with Halmstad University in the area of computer science and testing. In my spare time I spend a lot of time on the construction and programming of embedded intelligent systems. I have published many hardware and software designs on my personal homepage. I have also won the Swedish national robot competition several times and got second place in one of Europe's biggest competitions for self-made, autonomous and mobile robots.

Hawar Ramazanali

SAAB AB

I received my MSc in Electronics Engineering in 2006 and after different work experiences I started to work at Saab Training & Simulation in 2008 with various assignments, ranging from developing a software defined radio platform to on-site technical support around the world. I started an Industrial PhD position at EISIGS research school in 2013 which is a cooperation between Halmstad University and Saab amongst other participating companies. The aim of my research project is to study and propose solutions for a flexible software defined radio framework fulfilling future requirements within the military training domain. I will start with the area of radio resource handling with differentiated QoS requirements for different traffic types in a radio network. The requirements of providing more bandwidth in the training radio network combined with requirements for many nodes(thousands) supporting mixed traffic types and services like data, voice and video will be studied and solutions will be proposed.

Maytheewat Aramrattana

The Swedish National Road and Transport Research Institute (VTI)

I received the BSc degree in Electrical Engineering from Kasetsart University, Thailand in 2010. My bachelor thesis was about prototyping an agricultural system monitored and controlled by a wireless sensor network. I spent about a year working as a hardware engineer in a company during 2010 and 2011. After that I pursued my education by entering the MSc program in Embedded and Intelligent Systems at Halmstad University in 2011. I graduated in October 2013 and got accepted to the Embedded and Intelligent Systems Industrial Graduate School (EISIGS) working in a project called "Vehicle ICT Innovation Methodology" together with VTI.

Presentation **PhD Students**

Mahboobeh Parsapoor

I have a master degree in artificial intelligence; my master thesis is entitled 'Predicting the Price of Virtual Supply Chain Management Using Emotional Methods'. I am currently an early stage researcher of CC-lab at Halmstad University, focusing on developing bio-inspired methods for spectrum management in wireless networks, in particular cognitive radio networks. I am also conducting research on presenting a new type of data-driven model that is referred to as brain emotional learning inspired models; these are developed by taking inspiration from the underlying neural structure of brain emotional learning. I am testing them on space weather and geomagnetic storms prediction and improving them in order to propose a high generalization model. In addition to computational intelligence and wireless communication, my research interests include cognitive science and space weather phenomena.

Süleyman Savas

Since my childhood I had an interest in computers, well actually mostly in computer games. That is how I started my computer related studies. I got my bachelor degrees from Halmstad University and Karadeniz Technical University (Turkey) in Computer Science and Computer Engineering respectively (2008 and 2009). Later I got my masters degree on Embedded and Intelligent Systems in Halmstad University. After the bachelor studies I had five weeks of internship in Halmstad University and after getting the master's degree I first worked three months as a research engineer in the university and then, for two years in industry, mostly with embedded systems using bluetooth communication. Then I got the opportunity to start PhD studies in my interest area which is parallel computer architectures. The focus of my research is heterogeneous manycore architectures.

Erik Hertz

After receiving my MSc degree in Electrical Engineering from Lund University I worked in industry for a few years. My research career started with the Swedish Defense Research Agency (radar), continued with Ericsson Research (mobile phones), and then Cargine (within Koenigsegg) (combustion engines). In my spare time when I worked at Cargine I was pursuing my PhD on a self-developed methodology for performing approximations of unary functions in digital hardware. The advantages with the methodology are high chip area efficiency, very fast computation, very low power consumption, and a favorable error behavior compared to comparable methodologies. Possible applications for the methodology are applications where high computation rates and high resolution are needed, such as signal and image processing, robotics and so on. My status today is that I have received my Licentiate degree from Lund University and am now at Halmstad University to finish my Doctor degree.

Essayas Gebrewahid

I have done my BSc in Computer Science and Information Technology in Haramay University, Ethiopia. I got my MSc in Embedded and Intelligent Systems from Halmstad University. After graduation I joined CERES as Research Engineer. As Research Engineer I contributed in the ELLIIT national research initiative and the SMECY European Artemis project. Currently, I am a PhD student at Halmstad University under supervision of Bertil Svensson, Veronica Gaspes and Zain-ul-Abdin. My PhD focus is on developing compilation tools for massively parallel, high-performance, low-power course-grain reconfigurable platforms. My research interests are mainly in compilers, parallel and reconfigurable computer architecture and embedded systems.

Presentation **PhD Students**

Wagner De Morais

I received my BSc in Computer Science from Federal University of Santa Maria, Brazil, and my MSc in Embedded Systems, with emphasis on wearable computing, from University of Nice Sophia Antipolis, France. Before joining CERES as PhD student in 2007, I worked as software developer during six years at one hospital and three software companies in Brazil. From 2009 to 2012, I worked as Research Engineer at the Centre for Health Technology Halland (HCH) at Halmstad University. My work at HCH involved the development of serious games, measurement systems and smart environments for healthcare. Currently, under supervision of Prof. Bertil Svensson and Assoc. Prof. Nicholas Wickström, my research focuses on a database-centric software architecture for smart environments supporting Ambient Assisted Living.

Le-Nam Hoang

I studied my BSc in Electronics and Telecommunications at Hanoi University of Technology, Vietnam. In 2008, I started my M.Sc in Electrical Engineering, with specialization on Radio Communications, at Blekinge Institute of Technology, Sweden. I graduated in late 2010 by defending my thesis named “On the Performance of Two-Way Amplify-And-Forward Relay Networks”. After graduation, I went back to Vietnam and later joined Research Centre of Vietnamese Post and Telecommunications Institute of Technology. From February 2012, I have been pursuing my PhD at Halmstad University under the supervisions of Assoc. Prof. Elisabeth Uhlemann and Prof. Magnus Jonsson. Currently, my main research interests include wireless communications, vehicular communications and communication theory.

Adam Duracz

I studied Mathematics and Computer Science at Stockholm University and obtained my MSc with a thesis on the ”Derivation of Probability Distributions for Risk Assessment”. Following my university education I spent four years as a consultant at IBM, working on projects involving all aspects of software delivery, including development, design and requirements elicitation. I joined CERES at Halmstad University in 2012, where I am working on the development of a high-performance rigorous semantics for the Acumen language, under the supervision of Prof. Walid Taha and Assoc. Prof. Verónica Gaspes.

Annette Böhm defended her thesis at a dissertation last summer. The photo was taken at the academic ceremony in November, when her doctoral degree was conferred according to tradition. Among other things she received the laurel wreath, a symbol of freedom, from promotor Bertil Svensson.

PhD Graduation

Annette Böhm

Delay-sensitive wireless communication for cooperative driving applications

PhD thesis, Halmstad University
Main supervisor: Prof. Magnus Jonsson, Halmstad University
Co-supervisor: Dr. Elisabeth Uhlemann, Halmstad University and Mälardalen University
Opponent: Prof. Javier Gozálvez Sempere, University Miguel Hernández, Spain
Grading Committee: Professor Paul Davidsson, Malmö University, Professor Ulf Körner, Lund University, Professor Christer Åhlund, Luleå University of Technology

Cooperative driving holds the potential to considerably improve the level of safety and efficiency on our roads. Recent advances in in-vehicle sensing and wireless communication technology have paved the way for the development of cooperative traffic safety applications based on the exchange of data between vehicles (or between vehicles and road side units) over a wireless link. The access to up-to-date status information from surrounding vehicles is vital to most cooperative driving applications. Other applications rely on the fast dissemination of warning messages in case a hazardous event or certain situation is detected. Both message types put high requirements on timeliness and reliability of the underlying communication protocols. The recently adopted European profile of IEEE 802.11p defines two message types, periodic beacons for basic status exchange and event-triggered hazard warnings, both operating at pre-defined send rates and sharing a common control channel. The IEEE 802.11p Medium Access Control (MAC) scheme is a random access protocol that does not offer deterministic real-time support, i.e. no guarantee that a packet is granted access to the channel before its deadline can be given. It has been shown that a high number of channel access requests, either due to a high number of communicating vehicles or high data volumes produced by these vehicles, cannot be supported by the IEEE 802.11p MAC protocol, as it may result in dropped packets and unbounded delays. The goal of the work presented in this thesis has therefore been to enhance IEEE 802.11p without altering the standard such that it better supports the timing and reliability requirements of traffic safety applications and provides context-aware and efficient use of the available communication resources in a vehicular network. The proposed solutions are mapped to the specific demands of a set of cooperative driving scenarios (featuring infrastructure-based and infrastructure-free use cases, densely and sparsely trafficked roads, very high and more relaxed timing requirements) and evaluated either analytically, by computer simulation or by measurements and compared to the results produced by the unaltered IEEE 802.11p standard. As an alternative to the random MAC method of IEEE 802.11p, a centralized solution is proposed for application scenarios where either a road side unit or a suitable dedicated vehicle is present long enough to take the coordinating role. A random access phase for event-driven data traffic is interleaved with a collision-free phase where timely channel access of periodic delay-sensitive data is scheduled. The ratio of the two phases is dynamically adapted to the current data traffic load and specific application requirements. This centralized MAC solution is mapped on two cooperative driving applications: merge assistance at highway entrances and platooning of trucks. Further, the effect of a context-aware choice of parameters like send rate or priority settings based on a vehicle's position or role in the safety application is studied with the goal to reduce the overall number of packets in the network or, alternatively, use the available resources more efficiently. Examples include position-based priorities for the merge assistance use case, context-aware send rate adaptation of status updates in an overtaking warning application targeting sparsely-trafficked rural roads and an efficient dissemination strategy for warning messages within a platoon. It can be concluded that IEEE 802.11p as is does not provide sufficient support for the specific timing and reliability requirements imposed by the exchange of safety-critical real-time data for cooperative driving applications. While the proper, context-aware choice of parameters, concerning send rate or priority level, within the limits of the standard, can lead to improved packet inter-arrival rates and reduced end-to-end delays, the added benefits from integrating MAC solutions with real-time support into the standard are obvious and needs to be investigated further.

PhD Graduation

Katrin Sjöberg

Medium access control for vehicular *ad hoc* networks

PhD thesis, Chalmers University of Technology
Main supervisor: Professor Erik Ström, Chalmers University of Technology and Halmstad University
Co-supervisor: Dr. Elisabeth Uhlemann, Halmstad University and Mälardalen University
Opponent: Dr. John Kenney, Toyota InfoTechnology Center, California, USA
Grading Committee: Professor Anna Brunström, Karlstad University, Dr. Stefan Parkvall, Ericsson Research, Kista, Professor Petar Popovski, Aalborg University

Cooperative intelligent transport systems (C-ITS), where vehicles cooperate by exchanging messages wirelessly to avoid, for example, hazardous road traffic situations, receive a great deal of attention throughout the world currently. Many C-ITS applications will utilize the wireless communication technology IEEE 802.11p, which offers the ability of direct communication between vehicles, i.e., ad hoc communication, for up to 1000 meters. In this thesis, medium access control (MAC) protocols for vehicular ad hoc networks (VANET) are scrutinized and evaluated. The MAC protocol decides when a station has the right to access the shared communication channel and schedules transmissions to minimize the interference at receiving stations. A VANET is a challenging network for the MAC protocol because the number of stations in is unknown a priori and cannot be bounded. Therefore, the scalability of the MAC method has a major influence on the performance of C-ITS applications. Two different MAC protocols are studied: carrier sense multiple access (CSMA) of 802.11p and self-organizing time division multiple access (STDMA). These two MAC methods are examined with respect to the communication requirements and protocol settings arising from C-ITS standardization. Based on these constraints, suitable performance measures are derived such as MAC-to-MAC delay and detection distance, where the former catches both the delay and reliability. In STDMA, the channel access delay is upper-bounded and therefore known before transmission, since regardless of the number of stations within radio range, all stations are always guaranteed timely channel access. In CSMA, the channel access delay is not upper-bounded and it is unknown until transmission commences, as it is based on the instantaneous channel load and stations can experience a random delay when in backoff. The evaluation of CSMA and STDMA is performed through extensive computer simulations, modelling a 10 km highway with six lanes in each direction. Vehicles travel along the highway and broadcast position messages periodically with different update rates. Two different channel models have been used during the evaluations, one distinguishing between a receiver being in line-of-sight (LOS) or obstructed LOS (OLOS) from the transceiver, while the other does not consider this. The simulation results, for both channel models, show that CSMA has on average a smaller channel access delay than STDMA. However, the results also reveal that STDMA always achieves a better reliability than CSMA, especially for distances of 100-500 meters between transmitter and receiver. The distance, at which approaching stations receive the first messages from each other, is up to 100 meters longer for STDMA than CSMA. This thesis therefore concludes that STDMA is a very suitable MAC method for VANET-based C-ITS applications.

Dr. Elisabeth Uhlemann, Dr. Katrin Sjöberg and Professor Erik Ström.

PhD Graduation

Emil Nilsson

Applying microwave technology in short range radio communication and sensing systems - theory and design

PhD thesis, Chalmers University of Technology
Main supervisor: Peter Linnér, Chalmers University of Technology
Co-supervisor: Professor Håkan Pettersson, Halmstad University
Opponent: Professor Eric A.M. Klumperink, University of Twente, The Netherlands
Grading Committee: Professor Henrik Sjöland, Lund University,
Dr. Jan Svedin, FOI, Linköping, Dr. Stefan Andersson, Ericsson, Lund

Microwave technology continues to reach new areas and applications. Microwave based sensors create the possibility to sense objects in remote and hostile environments, while miniaturization makes the merge of radios, sensors, and computing into new small devices possible. Bridging the communication of the last 10 meters from numerous physical devices to a global network must be done wireless. Short range radio communication technology represents the most realistic untethered technology at hand. Advanced digital control and processing electronics enable realization of sophisticated functionality and sophisticated communication protocols, also in low cost small size radio nodes. The high level of integration today common for digital electronics is increasingly utilized in analog electronics. The need for small low power transceivers in many new applications is motivated by limited physical space and maintenance cost. The energy source for the device (usually a battery) sets the life time, the cost, and in some cases the physical dimensions of the final product. Low power electronics enable the use of more agile energy sources and longer lifetime with smaller batteries and energy harvesting techniques. In this thesis a low power transceiver hardware and MAC protocol are proposed and investigated. A theory estimating noise in an envelope detector subject to a blocking signal is developed and used as a knowledge base for implementation of a Wake-up radio. The small Wake-up radio consumes 2.3 and is designed in 130 nm CMOS using no other external components than the carrier substrate its mounted on. A survey of recently published low-power receivers is compared with estimation of lowest power consumption with optimized receiver topologies. Finally, the design of a low output-power radar interferometric sensor for industrial applications is presented together with measurements and simulations.

Some Highlights

Wagner De Morais - Winner of Doctoral Colloquium award at the 9th International Conference on Intelligent Environments 2013 with his paper a “Smart Bedroom” as an Active Database System. The conference was held in Athens, Greece.

Adam Duracz, Walid Taha, Jan Duracz together with Michal Konecny and Aaron Ames, won Best Paper Award on the 1st IEEE International Conference on Cyber-Physical Systems, Networks, and Applications, in Taipei, Taiwan in August 2013. Their paper is entitled “Enclosing the Behavior of a Hybrid System up to and Beyond a Zeno Point”.

CERES was also during 2013 an important actor in the Embedded Conference Scandinavia in Kista. CERES personnel gave three talks and our guest professor Dan Hammerstrom gave a keynote speech. The joint CAISR and CERES stand had a focus on health technology. More than 1500 visitors attended the conference, a meeting place that covers all the hot topics in the world of embedded.

EISIGS kickoff. Embedded and Intelligent Systems Industrial Graduate School at Halmstad University is a graduate school with high industrial relevance focusing on cooperating embedded systems for intelligent applications.

The humanoid Jonson, had during 2013 a medially breakthrough on TV, first in a dance show and then as moderator in a Swedish scientific show for kids “Hjärnkontoret”. Here together with his friend Lorentzon. Students from the school of IDE did the programming work.

More than 200 visitors from academia, industry and other parts of the society attended the Information Technology Open Day, which was organized in November 2013 as part of the one week long celebrations of Halmstad University's 30 year anniversary. Besides presenting and demonstrating research activities, one of the aims of the day was to draw attention to the many successful enterprises within the information technology area that have grown in symbiosis with the research at Halmstad University. Lena Norder, CEO of The Swedish Electronics Trade Association gave a talk about the need for further efforts within innovation and research. She also led a panel discussion about future opportunities and challenges with electronics and ICT. The other panel members were, from left to right: Jörgen Palmhager, COO, HMS Industrial Networks AB; Maria Åkesson, associate professor and MI-lab leader, Halmstad University; Johan Karlsson, CEO, Advanced Electronic Systems AB; and Bertil Svensson, professor and CERES director, Halmstad University.

The Halmstad Summer School on Testing provides an overview of the state of the art in testing, including theory, industrial cases, tools and hands-on tutorials by internationally-renowned researchers (photo from 2014).

CERES Staff

Jonsson, Magnus
Professor, PhD
Prof., Real-time Computer Systems, Vice Director of CERES
magnus.jonsson@hh.se

Taha, Walid
Professor, PhD
Prof., Computer Science
walid.taha@hh.se

Larsson, Tony Ingemar
Professor, PhD
Prof., Embedded Systems
tony.larsson@hh.se

Cartwright, Robert
Professor, PhD
Guest Prof.

Mousavi, Mohammad
Professor, PhD
Prof., Computer Systems Engineering
m.r.mousavi@hh.se

Hammerstrom, Dan
Professor, PhD
Guest Prof., Computer Architecture

Nordström, Tomas
Professor, PhD
Prof., Computer Engineering
tomas.nordstrom@hh.se

Vinel, Alexey
Professor, PhD
Guest Prof., Data Communications
alexey.vinel@hh.se

Svensson, Bertil
Professor, PhD
Prof., Computer Systems Engineering, Director of CERES
bertil.svensson@hh.se

Uhlemann, Elisabeth
PhD, EE
Associate Prof., Communication Systems
elisabeth.uhlemann@hh.se

CERES **Staff**

Bilstrup, Urban
PhD, CE
Lecturer, Computer Engineering/Wireless Communication
urban.bilstrup@hh.se

Hoang Bengtsson, Hoai
PhD, CE
Assistant Prof., Computer Systems Engineering

Carlsson, Jörgen
PhD
Senior Lecturer, Head of department
jorgen.carlsson@hh.se

Kunert, Kristina
PhD, CE
Assistant Professor
kristina.kunert@hh.se

Gaspes, Verónica
PhD, CS
Associate Prof., Computer Science
veronica.gaspes@hh.se

Sant'Anna, Anita
PhD, Signals and Systems
Assistant Professor
anita.santanna@hh.se

Nilsson, Emil
PhD, EE
Research Engineer and Lecturer, Electronics
emil.nilsson@hh.se

Ul-Abdin, Zain
PhD CSE
Assistant Professor, Computer Science & Engineering
zain-ul-abdin@hh.se

Wickström, Nicholas
PhD CE
Associate Prof., Computer Systems
nicholas.wickstrom@hh.se

Atkinsson, Kevin
PhD, CS
Post-doctoral Fellow
kevin.atkinson@hh.se

CERES Staff

Beohar, Harsh
PhD
Postdoctoral Researcher,
Model-based Testing
harsh.beohar@hh.se

Böhm, Annette
PhD, CSE
Postdoctoral Researcher
annette.bohm@hh.se

Duracz, Jan
PhD, CS
Postdoc Computer Science

Masood, Jawad
PhD, Mechanical Engineering
Postdoctoral Researcher,
Cyber-physical Systems

Sjöberg, Katrin
PhD, Signals and Systems
ITS Research Engineer, Volvo
GTT

Erlandsson, Stella
BSc, Innov. Eng.
Project manager, Liaison officer
stella.erlandsson@hh.se

Lithén, Thomas
Engineer
Research engineer
thomas.lithen@hh.se

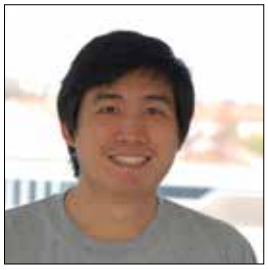
Thörner, Roland
MSc, Informatics
Project coordinator
roland.thorner@hh.se

Wiberg, Per-Arne
Lic. Tech., CE
Lecturer
pelle.wiberg@hh.se

Bornhager, Malin
BSc CE
Lecturer
malin.bornhager@hh.se

CERES **Staff**

Eldemark, Hans-Erik
MSc, EE
Lecturer, Computer Engineering and Innovation Engineering
hans-erik.eldemark@hh.se



Aramrattana, Maytheewat
MSc, CSE
PhD Student, Computer Science and Engineering
maytheewat.aramrattana@hh.se

Heimer, Philip
BSc
Lecturer
philip.heimer@hh.se

de Morais, Wagner
MSs, CE
PhD Student, Computer Science and Engineering
wagner.demorais@hh.se

Månsson, Nicolina
MSc
Lecturer
nicolina.mansson@hh.se

Duracz, Adam
MSc, CS
PhD Student, Computer Science and Engineering
adam.duracz@hh.se

Torstensson, Olga
MSc
Lecturer
olga.torstensson@hh.se

Gebrewahid, Essayas
MSc, CSE
PhD Student., Computer Science and Engineering
essayas.gebrewahid@hh.se

Wecksten, Mattias
Lic.Tech.,CS
Lecturer, Computer Engineering
mattias.wecksten@hh.se

Hertz, Erik
Lic.Tech., Eng.
Research Engineer
erik.hertz@hh.se

CERES Staff

Hoang, Le-Nam
MSc
PhD Student, Computer Science and Engineering
le-nam.hoang@hh.se

Ramazanali, Hawar
MSc EE
PhD Student ,CSE,Wireless communication
hawar.ramazanali@hh.se

Larsson, Marcus

PhD Student, Computer Science and Engineering
marcus.larsson@hh.se

Savas, Süleyman
MSc, CSE
PhD Student, Computer Science and Engineering
suleyman.savas@hh.se

Parsapoor, Mahboobeh
MSc CE
Research Engineer
mahboobeh.parsapoor@hh.se

Vedder, Benjamin
MSc, EE
PhD Student, Computer Science and Engineering
benjamin.vedder@hh.se

Application Areas

Advanced Sensing and
Communication Systems

Health Technology

e-lab, Enabling Technologies

Traffic and Transport

CERES Publications 2012-2013

International full-paper reviewed journal papers

Accepted during 2013 for publication during 2014

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Doctoral and Licentiate theses

2013

Nilsson, E. "Applying Microwave Technology in Short Range Radio Communication and Sensing Systems - Theory and Design," Ph.D. Thesis. *Chalmers University of Technology,* Göteborg, Sweden, Dec. 2013.

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2012

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Accepted during 2013 for publication during 2014

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2012

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Internal reports

2013

Ourique de Morais, W. and N. Wickström, "Sleep and night activities of care beneficiaries at the "Trygg om Natten" (Safe at Night) Project," *Research Report, School of Information Science, Computer and Electrical Engineering (IDE)*, Halmstad University, Sweden, 2013.

2012

Bergenhem, C. and M. Jonsson, "Two Protocols with heterogeneous real-time services for high-performance embedded networks", *Research Report, School of Information Science, Computer and Electrical Engineering (IDE)*, Halmstad University, Sweden, 2012.

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2013

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HALMSTAD UNIVERSITY

Visiting Address: Kristian IV:s väg 3
P O Box 823, SE 301 18 Halmstad
Telephone: +46 35 16 71 00
E-mail: registrator@hh.se
www.hh.se

Halmstad University, Information Department, June 2014.