CAISR

Center for Applied Intelligent Systems Research

Annual report 2015

HALMSTAD UNIVERSITY

CAISR

CAISR, the Center for Applied Intelligent Systems Research, is a long-term research program on intelligent systems established by Halmstad University. The program is funded by the University and the Knowledge Foundation with support from Swedish Industry.

The subject expertize in the center is in signal analysis, machine learning and mechatronics. The center also has an emphasis on cooperating systems, in line with the research focus for the larger EIS environment. Several industrial partners are collaborating with researchers from the University in joint projects, and take an active part in the development of CAISR. The key application areas that the center does research in are intelligent vehicles and health technology. The industrial partners include multinational companies as well as research-based growing companies.

The mission of CAISR is to serve and promote the development of industry and society. It is a center for industrially motivated research on the future technologies for and application opportunities with aware intelligent systems. CAISR will serve as a partner for industry´s own research and development, as a recruitment base for those who seek staff with state-of-the-art knowledge in intelligent systems technologies, and as a competence resource for industry and society. All research is conducted within different research projects.

Cover photo:

Maria Luiza Recenta Menezes and Siddhartha Khandelwal are two of the doctoral students with CAISR.

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Annual Report 2015

Knowledge Foundation

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CAISR

Annual report 2015

The Director's statement

2015 was a very eventful year. We performed and passed the halftime evaluation of CAISR, we had intensive workshops that laid the foundation for the coming four years for CAISR, we had three PhD dissertations, we recruited new young staff, and we published more scientific journal papers than ever before.

The halftime evaluation, described in detail later in this report, was very positive regarding CAISR's achievements but highlighted some important challenges for the continued development. One particular thing that was pointed to as really excellent was CAISR's ability to coproduce scientific results with industry. This is what Knowledge Foundation Research Profiles are about and the experts on the evaluation panel were all well acquainted with doing research in collaboration with industrial partners. However, the expert panel also commented that it is a challenge how to grow further from where we are. We worked a lot with this challenge during the last quarter of 2015.

We published 18 scientific journal papers in 2015, which was a good step towards meeting our publication goals for CAISR. We devoted a considerable effort during 2015 to review our publication strategy and scientific goals onwards. The result of this work is summarized later in this report, in the section on the CAISR scientific agenda.

We contributed to Halmstad University's research theme in health innovation, with research results and application writing. The work resulted e.g. in two granted large research projects funded by the EU regional funds. We also started two new SIDUS projects, AIR and BIDAF, in collaboration with the Swedish universities in Örebro and Skövde, and the industrial research institutes SICS and Viktoria.

All in all, 2015 was a year packed with results, with positive feedback on our achievements but also a good critical review of where we are heading.

Thorsteinn Rögnvaldsson
Director of CAISR

CAISR **Scientific Agenda**

Aware systems research

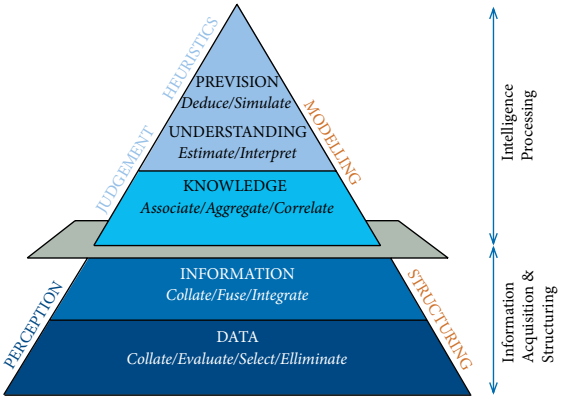
Awareness is a broad concept and has many connotations. Endsley[1] (1995) describes awareness, from a psychology perspective, as knowledge created through interaction between an agent and its environment, and "knowing what is going on". In awareness computing, Zhao[2] (2013) describes awareness as "a mechanism for obtaining information or materials which are useful for human users, for other systems, or for other parts of the same system, to make decisions". Inspired by this we define aware systems research as:

Research on the design of systems that, as autonomously as possible, can construct knowledge from real life data created through the interaction between a system and its environment. This data necessarily includes streaming data. Such systems should be able to handle events that are unknown at the time of design.

The construction of knowledge can be represented by the knowledge pyramid (Ackoff[3] 1989; Rowley[4] 2007), see Figure 1; the higher a system reaches on the pyramid, the more aware it can be. A fully aware system will have interaction both upwards and downwards in the pyramid.

Interestingly, Ackoff[3] (1989) speculates "that wisdom-generating systems are ones that man will never be able to assign to automata", i.e. that it is impossible to build machines that autonomously reach the wisdom level.

Most research on machine learning (ML) and artificial intelligence (AI) does not consider the knowledge creation aspects of intelligent systems. The usual approach is to have humans define the problem in significant detail, for example the data characteristics, the representations used, the model used, etc. and the ML/AI task is to construct an algorithm that replicates the human decision. There are therefore several open research challenges for each of the levels in the knowledge pyramid:



The knowledge pyramid, adapted from Ackoff (1989). "From Data to Wisdom". Journal of Applied Systems Analysis 16: 3–9.

The bottom level, *data*, relates to collecting and representing data. A pertinent question here is how to autonomously select what data to collect. With data coming from all sorts of sources, how can an intelligent system tell what data are (or will be) relevant? This decision is mostly done by humans today, which simplifies the learning problem immensely, but it is clearly one of the most relevant questions for autonomous learning. A related but more researched question is how to construct general features that apply to many problems. Furthermore, with endless streams of data (i.e. in the "internet of things" era) it is impossible and uninteresting to save all data. It should be possible to save snapshots, compressed, or aggregated representations of the data. These representations should be learned and general so that they apply to many different tasks. Also, the working environment of a system may change; features that look unimportant today may end up being important tomorrow. An aware system therefore needs to be curious and never stop exploring.

1 Endsley, M.R. (1995), "Toward a Theory of Situation Awareness in Dynamic Systems", Human Factors, **37**, pp. 32-64.

2 Zhao, Q. (2013), "Computational Awareness: Another Way towards Intelligence", Computational Intelligence (Eds. Madani et al.), Book Series Studies in Computatio nal Intelligence, Springer-Verlag, **465**, pp. 3-14.

3 Ackoff, R.L. (1989), "From data to wisdom", Journal of Applied Systems Analysis, **16**, pp. 3-9.

4 Rowley, J. (2007), "The wisdom hierarchy: representations of the DIKW hierarchy", Journal of Information Science, **33**, pp. 163-180.

The *information* level relates to questions that begin with "who, what, when and how many", creating "events" from the data in the layer below. Examples of operations that are required for this are classification, rearranging/sorting, aggregating, performing calculations, and selection. Much ML research (including that on deep learning models) has been devoted to this stage, and also AI research for e.g. text and language parsing. Important open research questions here regard autonomous clustering and categorization of events. How can events be autonomously grouped into categories for later use?

The *knowledge* level is about creating "rules" from the information. This requires combining information from different sources. Is an observed "event" from one set of data sources associated with some other "event"? Can such associations be formulated into rules? One obvious example is the supervised learning setting, where "events" (input) are matched to correct responses (target) provided by a human expert and encoded into a rule (model). A relevant research question here is how human generated knowledge, e.g. in the form of text comments in human curated data bases or models of the environment, can be combined with machine generated information to create rules. Another question deals with knowledge representations (knowledge structures); how can knowledge be represented so that it can be used for reasoning and prediction? A set of well-defined, highly-organized yet dynamic knowledge structures is a prerequisite for achieving awareness. A knowledge structure should evolve over time from experience, thus allowing for learning from data and human experts and be capable of taking into account different kinds of initial domain knowledge.

The top level, often denoted the *wisdom* level, relates to the question "why" or "what will happen"? It is about the ability to project into the future and reason back into the past. An aware system should be capable of extrapolating information into the future, and be able to estimate and evaluate the consequences of actions based on previous observations. This can e.g. be predicting paths in robotics, it can be input sensitivity analysis in ML, or it can be ontology-based reasoning. An active research field here is the autonomous creation (learning) of ontologies that can be used for reasoning (Zhou[5] 2007; Barforush & Rahnama[6] 2012).

5 Zhou, L. (2007), "Ontology learning: state of the art and open issues", Information Technology Management, **8**, pp. 241-252.

6 Barforush, A.A., and Rahnama, A. (2012), "Ontology learning: revisited", Journal of Web Engineering, **11**, pp. 269-289.

CAISR contributions

Our focus is on research questions that are general across application areas, across research groups and relevant for our external partners.

On the *data* level we pursue how to select what data to collect and how to find general and robust representations of data. This can be by learning representations, by designing representations, or by searching through sets of representations and estimating how good (interesting) they are. This means research on how to autonomously engineer features, or ways to learn representations. It also means research on the generality of representations. It means research on measures for determining how interesting a particular representation is. There are many practical issues related to e.g. missing, flawed or erroneous data. Handling this corresponds to feedback from higher levels in the knowledge pyramid; what data are expected based on the type of event? Another important issue is how human expertize can be combined with machine work, i.e. how the machine data exploration can be done in interaction with humans.

On the *information* level we explore how to do (semi-)autonomous deviation detection and clustering of events, as well as the maintenance of such categorizations, e.g. dealing with concept drift, seasonal variations, application changes, and so on. Clustering is something of an art and certainly a challenge to do well in an unsupervised manner and for general types of problems. It is also important to incorporate humans in the loop; to provide initial suggestions for categories, to give feedback on suggested categorizations, and so on.

On the *knowledge* level we explore how to associate events from different data sources, including human generated data. An important question is how this knowledge should be represented. Real-life data are inevitably connected with some uncertainty, and a question is how to handle the combination of information sources that may be uncertain. Again, it is important to explore how a human can be incorporated to build this knowledge in a semi-supervised way.

On the *wisdom* level, we predict the progress of observed events, and explain why certain things have happened. We do this through motion planning (for robots) and through sensitivity analysis (in the ML setting). We also intend to use ontologies.

The research questions are described above on the individual levels. However, one must remember that aware systems

is a systems science, it needs to address several parts and tie them together. To illustrate this, we build demonstrators to showcase what it means. One demonstrator setting is the intelligent home environment. Another one is the self-aware vehicle fleet for increased uptime. A third one is the mobile based decision support system for persons diagnosed with a chronic condition. A fourth possible one is the aware fork-lift truck in a warehouse.

Rafik Bouguelia and Anita Sant'Anna at the aware systems research workshop in late November 2015.

Aware systems and the health challenge

Aware systems will be very important enablers to meet the challenge of health, demographic change, and well-being; for improving individual health patterns, and for promoting healthy and active ageing.

The development in wearables has inspired a vision of using self-tracking for personalized health. Wearable devices that log our activities and interact with us, in order to help us improve our lifestyle and, with time, decrease the load on the health care system. To do life-long learning from this data requires methods for autonomous knowledge creation (i.e. aware systems research).

Wearables also apply to healthy and active ageing, but here ambient assisted living (AAL) is at least equally important. AAL promises a decreased cost for elderly living services while maintaining a high quality of service. Aware systems research is about developing methods for autonomously analyzing such streams of data and construct knowledge about individuals' living patterns. The perhaps most important challenge for ambient intelligence to become a useful technology is to construct knowledge systems that are simple, that can cope with the diversity and unpredictability of human needs, and that learn to ask and value the unknown (Reddering & Scholten, 2003)[7]. Aware systems research is about developing methods for this.

Aware systems and the urbanization challenge

The last 200 years have been the urbanization era. For example, 10% of the population in Sweden lived in urban areas in the turn from 18th to 19th century; today 85% live in urban areas . The development is similar in the rest of Europe. Worldwide, the number of people living in cities almost doubled between 1990 and 2014 . This growth happened in cities of all sizes, although large cities tend to grow a bit faster (e.g. megacities with more than 10 million inhabitants, or large cities with 5-10 million).

Urbanization is closely connected to development and economic growth. Less urbanized regions tend to be less prosperous, and highly urbanized regions (like Hong Kong) tend to be very prosperous. Unfortunately, other things also increase in urbanized regions. Geoffrey West at the Santa Fe Institute has demonstrated that when you double the size of the city, you get more than double the amount of good as well as bad socioeconomic quantities (patents, aids cases, wages, crime, litter, traffic, etc.) . However, it seems that the good outweigh the bad (at least we continue to move into urban areas).

The Smart City is a concept that brings a hope for breaking up this connection between good and bad, i.e. a promise to get the good in a city without having to accept the bad. This is enabled by, e.g., development in wireless communications, sensor networks, and data analytics. With an "internet of things" approach, where the city provides streaming data of all its different operations, it should be possible to mine this data to better optimize the operation, to detect problems, to better plan maintenance, to make sure that transport, energy and water supplies operate satisfactorily. Doing this city-wide requires automated knowledge creation and aware systems. This is not an issue only for megacities but for cities of all sizes worldwide.

7 Reddering, K., and Scholten, L., "Understanding Human Cultures", Chapter 1.2 in The New Everyday: Views on Ambient Intelligence (Eds. Aarts, E., and Marzano, S.), 010 Publishers, Rotterdam (2003)

Halftime evaluation

The halftime evaluation of CAISR took place during 2015 and was coordinated by Halmstad University's Board for Research and Education together with the Knowledge Foundation. The evaluation was based on a halftime report (partly a self-evaluation of the current status, partly a summary of achieved goals, and partly a plan for the coming four years) and a site visit by the external reviewers. The five external reviewers were:

- Professor Xin Yao[1], University of Birmingham, Director of CERCIA[2], IEEE Fellow and former President for the IEEE Computational Intelligence Society (2014-2015).
- Professor Maria Lindén[3], Mälardalen University. Leader of the Knowledge Foundation funded research profile Embedded Sensor Systems for Health (ESS-H)[4] .
- Jörgen Appelgren[5], Vice President R&D Automation, Atlas Copco Rocktec division. Atlas Copco have been an industrial partner in a Knowledge Foundation funded research profile at Örebro University (Applied Autonomous Sensor Systems), and they are industrial partner in an ongoing Knowledge Foundation profile at Örebro University (Semantic Robots).
- Marianne Treschow[6], chairman for the Knowledge Foundation evaluation group for research profiles. Former Director General for the Swedish Post and Telecom Authority.
- Professor Per Stenström[7], Chalmers University. IEEE and ACM Fellow. Member of the Royal Swedish Academy of Engineering Sciences (IVA).

The first three (Yao, Lindén and Appelgren) were appointed by the Halmstad University's Board for Research and Education, and the last two (Treschow and Stenström) were appointed by the Knowledge Foundation. The reviewers visited Halmstad in September 2015, for a full day of interviews and discussions with CAISR staff and Halmstad University management.

The reviewers' impressions of CAISR were generally very positive. They considered CAISR's focus on awareness to be "forward-looking and very appropriate for a long-term research agenda", but they recommended a more focused scientific agenda. They deemed the research quality and productivity to be good to very good, the environment itself and the networks and academic collaborations as very good, and the research impact and strategies to be very good. The reviewers emphasized the successful collaboration with industry as a particular strength and that "CAISR has done an excellent job in both establishing research value and advancing coproduction with their industrial partners". In their opinion is the excellent coproduction "a real strength of CAISR and should be carefully fostered and grown into a unique selling point".

The reviewers opinion was that "CAISR has really gone a long way and achieved a great deal to be a highly research active centre". Some of the reviewers had long time experience with research centers where there is close collaboration between academia and industry, and they acknowledged the pros and cons for CAISR as a profiled applied research center. It brings the strong advantage of working with real data and relevant problems, but it can also mean that the scientific productivity is lower. In this context they considered the scientific productivity in CAISR to be very good.

The reviewers provided several recommendations for the continued development. One was to focus more in the scientific agenda, and try to broaden the industrial participation with more companies that share the scientific agenda goals. Another was to be more specific in the choice of publication venues. A third was to diversify the external funding sources even more. A fourth was to increase the number of PhD students.

One of the most important advices was to recruit more senior staff, at least one more professor. This is in line with the plans set out in CAISR before, but the reviewers emphasized this. This is also one of the most important things to do during 2016.

Halftime evaluation panels. From left: Prof. Per Stenström, Dr. Malin Henningsson, Susanne Andersson*, Jörgen Appelgren, Prof. Maria Lindén, Prof. Xin Yao, Dr. Marianne Treschow, Dr. Stefan Östholm*. * The Knowledge Foundation*

1 http://www.cs.bham.ac.uk/~xin/
2 http://www.cercia.ac.uk/
3 http://www.es.mdh.se/staff/114-Maria_Linden
4 http://www.mdh.se/forskning/inriktningar/2.4200/ess-h
5 https://se.linkedin.com/in/jorgen-appelgren-7668009
6 https://se.linkedin.com/in/marianne-treschow-a155021b
7 http://www.cse.chalmers.se/~pers/

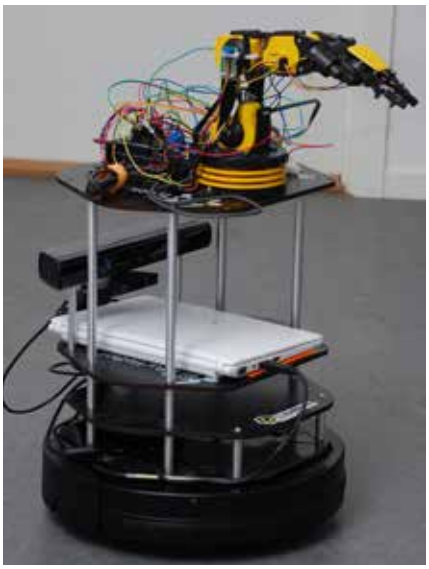
Data collection in the HMC² -project. The subjects had accelerometers positioned on the wrist, waist, knee and ankles. The shoes were instrumented with force sensors.

Application areas

Health Technology

We envision a future where wearable sensors and smart environments are commonplace, where we can gather information about our activities, sleep patterns, social interactions, medical care, and many other sources of health-related data. The monitoring, analysis and use of such information require new aware intelligent systems that can - based on the available data - assess a given situation, learn and adapt overtime, and provide relevant and timely information.

Our mission is to support healthy and active lifestyles, safe and independent aging, as well as effective care services by developing intelligent systems that are aware of a person's situation, health, and well-being using affordable, unobtrusive, and ubiquitous sensors. At CAISR, we develop technologies that support the acquisition and analysis of health-related data for monitoring and decision-support. We work with both mobile technologies and intelligent environments, and focus on movement analysis, behavior modeling and deviation detection techniques.



Above: You hear the words "Are you okay?" spoken in a mechanical voice and look down: there is a small robot intended to one day be capable of helping in healthcare emergencies. Healthcare robotics lies at the crossroads of CAISR's focuses on health and autonomous vehicles, and will be advanced by new methods designed in machine intelligence, mechatronics, and signal processing.

Intelligent Vehicles

The intelligent vehicles project portfolio within CAISR builds on our strengths in machine learning on the one hand and autonomous systems on the other. This is reflected in our expertise in data-driven modeling, knowledge representation, anomaly detection, localization, mapping, and motion generation.

Within machine learning, we develop methods and tools to analyze and exploit the wealth of data that can be collected on modern vehicles. The aim of this line of research is to detect and model behavior patterns in fleets of vehicles (self-awareness), and to leverage these models for increasing efficiency, predicting failures and improving diagnostics. Concerning autonomous systems, our focus is on next-generation driver assistance and automation, with an emphasis on keeping the human in the loop. This ranges from interactive semantic mapping as well as multi-vehicle motion planning and plan adaptation, especially in semi-structured environments shared with humans and under shared control (situation and human awareness), to understanding and improving the modalities and interfaces that are most appropriate for bringing technological advances to the end user (human awareness).

Above: A fork-lift as a part of an intelligent warehouse environment, there the fork-lift truck autonomously builds up a map of environment and do inventory of stock while working safely together with people as in the AIMS Project.

To the right: Rafael Valencia and the Volvo FH Autonomous Truck employed in Cargo-ANTs and ANTWaY projects.

CAISR **organization**

CAISR is organized in a matrix structure, with academic research and application areas as the two dimensions. The academic management group consists of the three professors in CAISR plus the head for the school of information technology. One of the professors is also manager for CAISR and another is heading the lab where CAISR is placed, with overview of teaching, administration and research duties in the lab. This provides a complete overview of teaching and research. The two application areas are coordinated by two younger researchers, who each head discussion groups for their respective application areas. Also projects that are outside CAISR but within the application areas are invited to these groups. These groups meet biweekly to discuss the project portfolio and progress from the perspective of their application area. CAISR also has a project coordinator who oversees details regarding reporting, coproduction and information.
The academic management group, the application area coordinators, plus the CAISR project coordinator meet monthly to discuss general CAISR issues. Many of the issues are also raised and discussed during weekly meetings where all the lab staff members are present.
The CAISR management is supported by the industrial advisory board (IAB), where each industrial partner in CAISR is represented, and a reference group. The IAB give advice on the progress and activities from the industrial partners' perspective and they take decisions when new industrial partners want to enter or old partners need to leave. Jonas Rahm from Kollmorgen was the chairman during 2015 for the CAISR IAB. The IAB meet approximately semiannually.

Industrial Advisory Board

Malte Ahrholdt	Volvo Group Advanced Technology & Research
Jacob Arvidson Klint	Toyota Material Handling Europe AB
Emil Hällstig	Optronic Partner dp AB
Peiman Khorramshahi	DaraLabs AB
Lars Nyström	Neat Electronics AB
David Johansson	Tappa Service AB
Jonas Rahm (chairman)	Kollmorgen Automation AB
Per-Arne Viberg	Swedish Adrenaline AB

Jonas Rahm, chairman of IAB

CAISR Reference Group

Robert Evans	Senior software engineer at Google, Mountainview, California.
Charlotta Falvin	Chairman of the board for the Faculty of Engineering at Lund University and for the Lund research park Ideon. Member of the board for several companies.
Christer Fernström	Director and consultant at Fernstrom et Associates in Grenoble, France and the CTO of CommuniTeams in Copenhagen, Denmark.
Lars Niklasson	Pro vice chancellor for Jönköping University. Professor in computer science.
Misha Pavel	Professor of Practice jointly appointed between College of Computer and Information Sciences and the Bouvé College of Health Sciences at Northeastern University, Boston, Massachussetts.
Bertil Svensson	Professor in computer systems engineering. Leads the Knowledge Foundation-environment "Research for Innovation" at Halmstad University.

Christer Fernström

Chairman of The Reference Group

Christer Fernström has worked with computer architecture for more than 30 years. Today he is the chairman of CAISR's reference group. According to him, the close cooperation with health professionals, patients and the industry has given CAISR a unique position within health technology and intelligent vehicles.

The reference group consists of representatives both from academia and industry from around the world and has an advisory role to CAISR's management team. The group meets at least once a year to go through current projects and is led by chairman Christer Fernström.

–We try to emphasise the importance of broadening the horizons, the researchers cannot just work on their own projects. What connections has CAISR established with European projects? What is CAISR's position compared with other research labs around the world? These are questions that we try to raise.

Christer Fernström

Christer Fernström did a Phd in computer architecture in Lund in the mid-1980s. During the last 30 years he has been active in France. Among many things, he has been the strategic manager at Xerox' European research centre. Today he lives in Grenoble, where he runs his own consulting firm, Fernström et Associates, helping research-intensive startups to develop.

–I came to Paris in the 1980's to be part of a newly established research team. The team moved to Grenoble and we quickly became engaged in various European research projects. Among other things I looked at new programming languages for computer systems operating in parallel.

Christer Fernström's role in CAISR's reference group is to set the agenda, consolidate comments from the members, and follow up with the management team.

How to take care of students and postgraduates is one of the issues that the group tries to emphasise.

–Beside the actual research projects, PhD work is supposed to lead the way to continued research. Therefore it is very important with supervisors who support and give guidance in matters relating to for example publications and how to keep in contact with research projects around the world.

Another task on the reference group's agenda is to raise the importance of cross-border cooperation between various research groups.

–We have worked with the CAISR team to find different ways to establish cooperation both between the university and with industry partners. I think this is one of the areas where we have made a substantial contribution.

Regularly, the reference group hold separate meetings with CAISR's industrial partners to reconcile their perception of the research being conducted.

–We usually get very good response. As for intelligent vehicles, the university is strongly linked to the industry, which is very positive. One can hardly imagine a better position than getting real research problems to solve.

Health technology and intelligent vehicles are two current application areas that are very important in today's society, says Christer Fernström.

–CAISR in general has made important contributions, building new features and implementing them into existing products. It is extremely stimulating to see the result of CAISR's research work on the market.

According to him, there is a huge need for technology that is smart and that can also be accepted by the users.

–It is important that the knowledge of technology is coupled with the needs and processes of potential user groups. Halmstad has a unique position thanks to the Health Technology Centre, where research groups have the opportunity to work together with both health professionals and patients.

Goals and **achievements** 2012-2015

CAISR has had a strong development during the first four years, in research as well as education. We list some of our achievements here, grouped into research, education (PhD, Master and Bachelor), and infrastructure for research and education.

The quality of research produced by researchers in CAISR is high. This was established in Halmstad University's external ARC13 evaluation that took place 2013, and corroborated in the CAISR halftime evaluation experts' reports 2015. During the period 2012-2015 we published 111 peer reviewed scientific papers. Of these were 37 Journal papers and 74 conference papers. All Journal papers were published in Journals at least level 1 in the Norwegian DBH ranking[1] (three are level 2). Eight of the conference papers were presented at conferences ranked as "A*" or "A" in the Australian CORE system[2] , i.e. were presented at "highly visible and well known" conferences in the field of computing research and education (CORE). This is, on the total, in line with our plan but we aim to increase the ratio of Journal papers to conference papers.

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Conference papers with full paper review 2012 - 2015

Fernando Alonso-Fernandez has been the most cited researcher in CAISR during 2012-2015. His work with iris segmentation, together with Josef Bigun, and quality measures in biometric images has received considerable attention worldwide. His papers published during 2012-2015 have so far gotten about 200 citations in Google Scholar. Fernando currently heads the health technology application area within CAISR.

Fernando Alonso-Fernandez

The total research turnaround of CAISR was almost 19.5 MSEK in 2015, up from 15 MSEK in 2012. The competitive funding from external sources constituted about 73%. Approximately 13% of the external funds came from the Swedish Research Council (VR) or EU FP7 during 2015.

1 https://dbh.nsd.uib.no/publiseringskanaler/Forside

2 http://portal.core.edu.au/conf-ranks/

At the end of 2015 CAISR had 13 PhD students. We have had five PhD dissertations and three Licentiate seminars (e.g. halfway seminars) in the period 2012-2015. Three of the students who have finished their PhD are continuing within academia and one in the industry; the fifth is currently enjoying some time off after the thesis work. Halmstad University started the EISIGS industrial PhD school in 2013, with a focus on embedded and intelligent systems and innovation. Three PhD students in CAISR are enrolled in EISIGS.

13
PhD students

Staff members in CAISR currently teach ten courses on PhD level. Five of these were developed in the period 2012-2015: Introduction to research on embedded and intelligent systems; Data mining; Non-linear optimization; Robotic manipulation; and Multi-scale and multi-dimensional signal analysis.

The CAISR volume of teaching, on basic and advanced levels, equaled 6.4 full time equivalents 2015, up from 4.5 in 2011 (the year before CAISR started). This is in line with our plan on how to grow the teaching basis. About 88% of the courses given by CAISR staff are rated "good" or "very good" (the highest possible rating) by the students. CAISR staff supervised 33 Master theses during 2012-2015, of which six led to scientific publications, and 54 Bachelor theses.

CAISR members were very important for Halmstad University to get the right to award "civilingenjör" degrees (corresponding to, e.g., the German Diplom Engineer). This was granted by the Swedish Higher Education Authority in 2013 and the first students were accepted in 2014. CAISR members are also co-developing the new Master program in IT-Forensics and Information Security, as well as participating in leading the Halmstad University Health Innovation education track.

We have established the Halmstad intelligent home: an environment equipped with sensors, actuators and robots to support education, research, and innovation activities in ambient assisted living. The intelligent home provides a platform for demonstrating and showcasing CAISR research, for implementing and testing new technologies in a realistic environment, and supports data collection. It also fosters

Funding

collaborations with other researchers, with the municipality and local industry. The intelligent home is a 50 square meter realistic home environment on campus, placed next to the Halmstad electronic test center[3].

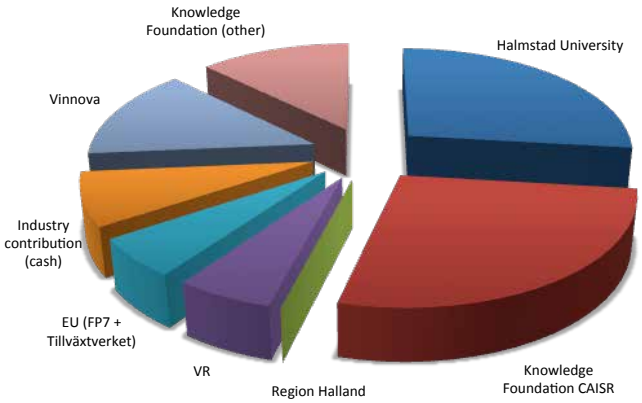
The Halmstad electronic test center

Several student and thesis projects are organized around the intelligent home; it has so far supported six completed Master theses and three Bachelor theses, with many more ongoing. It served as a demonstrator at the Halmstad Health Technology Workshop 2014. The intelligent home is a research platform for the new SIDUS-AIR project and a PhD student funded by the Brazilian Science without Borders program (presented later in this report).

3 http://www.hh.se/akademinforinformationsteknologi/samverkan/echelektronikcentrumihalmstad.65440615.html

Our original plan was to reach a total research turnaround on the university side of more than 17 MSEK (million Swedish kronor) for 2015. We ended up with a research turnaround of about 19.5 MSEK. However, the university overhead was decreased in 2015 so the research effort (measured in man hours) was considerably higher than our original plan. About 5.3 MSEK of the research funds came from the CAISR KK funds and 5.2 MSEK from Halmstad University. The remainder came from different external sources (see the pie diagram). The level of external funding reached almost 3/4 and we do not expect to be able to sustain much higher levels than this in the long run.

CAISR is an industry-guided research center with coproduction between industry and academia. The industrial matching funding was almost 5 MSEK for 2015. During the period 2012-2015 has the industrial (mostly in-kind) funding equaled almost 30 MSEK.



Funding for CAISR research on the Halmstad University side

18

published scientific journal papers in 2015

Financer	Budget 2015 (SEK)	Actual 2015 (SEK)
The Knowledge Foundation	5 537 069	5 283 179
CAISR Industrial partners (in kind)[1]	4 624 980	4 917 860
Other external funding[2]	8 800 000	8 941 537
Halmstad University	5 500 000	5 222 642
Sum total	24 462 049	24 365 218

1 All in kind contribution have been computed using the standard tariff of 800 SEK per hour (the actual company costs are sometimes larger than this and sometimes less).

2 Funding from other sources (VR, EU, Vinnova, companies…) not matching the Knowledge Foundation CAISR funding

Industrial Partners and Coproduction

DaraLabs AB

DaraLabs is a multidisciplinary team who share a vision of providing innovative, cost effective, and user-friendly medical devices by leveraging the growing power of smart-phones, to be used by healthcare professionals and consumers world-wide. DaraLabs are developing a platform with the purpose of minimizing the time-to-market of mobile health products. Today, the Mobile Health Platform has a powerful architecture that offers end-to-end communication and data storage possibilities with a cloud system that can perform computer-intensive calculations and analysis when needed.

> Our experience in production, testing, design and user interaction are an important complement to the technical expertise of CAISR

Dara Labs

NEAT Electronics AB

Neat Electronics AB develops and sells advanced alarm systems for elderly care on the world wide market. The global approach of the project is to increase efficiency in the care of elderly people, and at the same time enable them to live independently longer, with an increased sense of security and less intrusion in their privacy. The idea is to achieve this by monitoring behavior with passive sensors and by applying algorithms and alert staff at various predefined conditions and events.

> NEAT's ambition is to provide more added value than the competitors, to transform the data produced by sensors into useful information for the caregivers.

neat

Kollmorgen Automation AB

Kollmorgen Automation is a world leading company in development of control systems for AGV's. Innovation defines our future and by combining expertize in CAISR with our business focus and experience in the development of autonomous vehicles, this collaboration increases our ability to develop new features that benefit our customers.

> Other concrete results are that cooperation between companies becomes easier. We have started a project together with Volvo as a direct result of us meeting in CAISR.

KOLLMORGEN®

8 Industrial partners

Optronic AB

Optronic is a leading service provider in the field of optical sensors and is continuously looking for new application areas for these sensors. Within the CAISR project several interesting applications within logistics are discussed. This provides Optronic with a better understanding of how the sensors can be used in combination with state-of-the-art algorithms provided by the researchers. The project is also a good meeting place to together with other companies in the field discuss different technical topics. The opportunity to get all this information is very important to Optronic.

> Cooperating around research issues enables us to increase our understanding of our customers' challanges and better understand what their driving forces are.

OPTRONIC

Swedish Adrenaline AB

Swedish Adrenaline is a team and network of engineers and designers with the goal to provide athletes and companies in the sports arena with the most innovative and cool products possible. Road cycle power meter, lactate measuring device, new radar devices are the beginning of products and product ideas that come out of this innovation lab in cooperation with CAISR. We will continue to provide new cool products to meet user needs on the sports and life science markets.

> In summary: the impact of this research is very big and likely to change the direction of the company.

SWEDISH ADRENALINE

Tappa AB

Tappa aims to be a natural first choice for organizations wishing to strengthen the health of their employees. We do this by giving reasons for increased physical activity, and focus on healthy living that reflects healthier and happier employees.

> Also, the CAISR participation have given us close contacts with companies where there seems to be great potential in working together and draw advantages by understanding different aspects of the health business.

tappa.se

Toyota Material Handling Europe AB

Toyota Material Handling is the global leader of supplying fork lifters and material handling equipment. We also deliver Automated Guided Vehicles (AGVs) and solutions for all kinds of material handling purposes. The business benefit calculation is simple for our customers; by replacing a manual fork lift with an automated vehicle they get a more effective, safer and reliable material handling for a lower total life time cost.

> Toyota Material Handling is in a phase where we have special interest in methods for sensor performance evaluation and the project has helped us in this work.

TOYOTA
MATERIAL HANDLING

AB Volvo

The Volvo Group is one of the world's leading manufacturers of trucks, buses, construction equipment and marine and industrial engines. Inside the CAISR centre, Volvo collaborates with Halmstad University and other programme partners in the research fields of fuel efficiency, traffic safety, vehicle automation and predictive maintenance. This common work makes an important contribution for more intelligent embedded automotive systems in the Volvo Group.

> The mixed set-up with both concrete projects and colocation and general connection in a broader scope with the CAISR partner has shown to be quite fruitful.

VOLVO

Patents

- Method and apparatus for encoding and reading optical machine-readable data codes. US patent 8,757,490 B2. (2014).
- Remote diagnosis modelling. US patent 8,543,282 B2. (2013).
- A method for monitoring the operation of a sensor. Patent application number PCT/EP2013/002983. (2013).
- A method for detection of muscle fatigue during dynamic work in EMG signals and means for obtaining and processing said signal. Swedish national patent application number 92562 20141204. (2014).
- Power assisting system and method. EP2248501 (B1). (2014).

Cristofer Englund (see article to the right) and Thomas Rosenstatter in the GCDC2016 car, inspecting the sensor signals in the trust system. Thomas is a master student in a Double Degree Programme between Halmstad and Salzburg universities.

Cristofer builds links between academia and industry

As a research manager at Viktoria Swedish ICT, Cristofer Englund is involved in projects concerning automated and cooperative vehicles. Since 2015, he is also an adjunct lecturer at CAISR. Here he is working to forge stronger links between academia and the industry.

–My main mission is to increase the industrial relevance within the education at CAISR and contribute with more elements of real industrial problems. This can hopefully inspire and make the students see the benefits of their studies and what they can contribute.

Cristofer Englund

Cristofer Englund studied electrical engineering at the University of Halmstad in the late nineties. Subsequently, he took a master's degree in computer systems engineering which included a semester of studies in Australia, before he became a graduate student in Halmstad. Here he developed a system that automatically ensures the right amount of paint going on the paper in newspaper printers.

–In 2007 I started working with 3D imaging and MicroCT-scanning at Albany International in Halmstad. But after a couple of years I felt that I wanted to work with long term research projects, and that was how I ended up at my current employer.

Since 2010, Cristofer Englund works at Viktoria Swedish ICT located in Lindholmen Science Park in Gothenburg, a research institute focusing on sustainable mobility where automated and cooperative vehicles is an enabler.

–Right now we are running two projects in data mining together with Volvo Cars. In addition, we are part of an EU project on eco-navigation systems that instead of choosing the shortest route suggests the most fuel efficient routes.

Currently, Cristofer Englund works as a research director and researcher at Viktoria Swedish ICT. He is also working 20% as an adjunct senior lecturer at CAISR, in a KK-funded exchange project between industry and academia that aims to improve the scientific quality and industrial benefits of the education.

At CAISR he teaches data mining, holds lectures and supervise thesis work. He is also active in developing the engineering program at the university.

–Since I'm working at an institute focusing on the automotive and transport industries – cars, vessels, air and rail, I can impart knowledge about the problems and challenges that exist within the transportation industry. This will hopefully give students inspiration and an insight into their career options after graduation.

Viktoria Swedish ICT is one of four partners who are involved in organizing the Grand Cooperative Driving Challenge, GCDC2016, a European competition for self-driving cars that were first held in 2011 and where Halmstad University is participating with a team.

–One of our task is to help the Swedish teams when it comes to coordinating meetings where they can meet and network with each other as well as test their vehicles and communication. Developing automated vehicles and cooperative systems means that the vehicles need to communicate, but also that those who develop them must communicate with each other. This is partly what GCDC is about. First the teams collaborate – then they meet each other as competitors in the race itself.

–Among the Swedish students who participated in the very first challenge in 2011, 95 percent were recruited to the automotive industry within three months after they had finished their degree, including some from the University of Halmstad.

–For example, some of them got work at Volvo Cars and Scania, and we have further developed the collaboration with these persons.

Working in this way I believe we can help the university to educate students who are attractive to industry. We can participate and push them to move on after their studies.

CAISR in a **University Perspective**

For every university wishing to play a prominent role both nationally and internationally, it is necessary to focus on quality regarding research, on recruitment of faculty with excellence as well as on recruitment of ambitious students. It is also necessary to focus on positioning itself in strategic international knowledge networks, and to develop cooperation with the surrounding community, nationally and internationally. A university that succeeds in these aspects and becomes internationally acclaimed within its fields of success has a larger, international catchment in terms of students, at the same time as its importance for regional development increases. Halmstad University aims at further manifesting itself as such a university. And, this has actually taken place during the last years.

In 2013 the University governing board adopted a new vision and a new research and education strategy for Halmstad University. The guidelines described therein indicate the direction of the University until 2020. Halmstad University was established some 30 years ago as a higher educational institution without specific resources for research. Through external and some additional government funding, research has now gradually grown to be close to one quarter of the University's turnover. This trend needs to continue so that there is a better volume balance between teaching and research. This requires a purposeful process with effective uses of research resources and strategic partnerships, as well as focusing on and prioritizing strong and developable research environments.

Halmstad University's research and the education programs more and more reflect the University's profile. The University has chosen three areas where we offer education from undergraduate to doctoral level. These areas are information technology, innovation sciences, and health and lifestyle. Most of the University's research and much of the education fits within these three areas and thereby constitutes a base for the University's activities.

Halmstad University is to be known as the Innovation Driving University. This means that our research and education, in addition to having good quality and providing academic knowledge, is characterized by stimulating creativity, innovation and a clear involvement and responsibility within the community and society – locally, regionally and globally. We are an independent university that has alliances with other universities, both nationally and internationally. Our autonomy creates openness and responsibility as well as flexibility to meet the demands of the outside world. Togetherness, collaboration and co-production with external parties are the hallmark of our work and contribute to the University's profile. Results from research and education often lead to innovations.

As mentioned, focusing on and prioritizing strong and developable research environments is emphasized in our strategy. CAISR, focusing on aware intelligent systems, is such an environment. It is part of the larger information technology area, whose research comprises nearly half of the research activities of Halmstad University.

A good balance between research and education creates possibilities that all education is research-related and all research has contacts with undergraduate and graduate studies. This means that the choices of research topics and fields of study are not separated from each other. The University has chosen to build strong research environments and endeavors that together have good links with the overall education on offer. In this context, the research at CAISR is critical not only for our PhD education in the information technology area, but also for the success of our international masters programmes in Embedded and Intelligent Systems and our new Master in Computer Science and Engineering ("Civilingenjör").

As a result of CAISR being a KK research profile since 2012, it has become one of the two most developed centers within the EIS (embedded and intelligent systems) research environment (and of the entire university). CAISR has developed clear goals and strategies in order to reach scientific excellence, high co-production ability and international recognition. In doing so it serves as a role model for other research groups at the University.

Halmstad University has a ten-year contract with The Knowledge Foundation to develop as a "Foundation Research Centre" (KK-miljö). The name of this long-term research venture is "Research for Innovation" and it is expected to have a major influence on the development of the entire university. Also the goals of Research for Innovation are expressed in terms of positioning, branding, quality and relevance.

The positioning of our research is done through a set of research themes, one of which is aware intelligent systems, represented by CAISR. Thus, the development of CAISR contributes to the positioning of Halmstad University in that it becomes internationally known for being a leading research and study environment in aware intelligent systems. Partnerships with other centers at the University help positioning the university further. CAISR takes an active and creative role in such cooperation, most notably in the field of healthcare technology and health innovation.

CAISR 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 innovation-driving university”. The university's industrial graduate school in embedded and intelligent systems, targeting innovation, is one of the latest concrete examples of this. CAISR plays an important role as one of the environments hosting this graduate school.

CAISR is making important contributions to further lifting the quality of the university's research and education, for example through high quality international recruitment of PhD students, young faculty members and visiting professors, all contributing also to the strong development of international contacts. We see positive effects on the quantity and quality of scientific results and publications, as well as increased research funding. Clearly, the operations of CAISR, including its recruitments of international guest professors, have had the effect of dramatically increasing the international cooperation and visibility, including an increased in-flow of international guest researchers, post-docs, PhD students and Master students. The university's education at the research level and at the advanced level benefits a lot from this.

Cooperating with industry is at the center of all CAISR operations. This includes an ambition 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. Some of the strategically most important industrial partners of Halmstad University are among the CAISR partners. It is with satisfaction that we observe that the cooperation with these has been continuously strengthened during the profile period and that the collaboration also has been extended further on the international scene in the form of joint EU project participation.

Halmstad University works hard to spread its sources of research funding on several agencies. Both before and during the profile period, CAISR has been successful not only with the Knowledge Foundation but also with, e.g., VINNOVA, VR and EU. We expect this ambition and ability to spread over larger parts of the University, not the least through interdisciplinary collaborations.

During 2015 CAISR was halftime evaluated with an overall very good result. It is one thing to initiate a profile, but another thing to develop it; to organize research activities; to maintain and develop partnership collaboration; and to foster a creative an innovative environment that constantly set out new goals. All this is challenging when striving to be an internationally successful research milieu. The expert group has much positive to say about CAISR's abilities in all these areas. Quality of research, productivity, the research environment, networks and collaboration, impact and strategy work for future development, are all graded ”very good”. Industry collaboration is graded ”excellent”. What is the secret to this success?

The ability to generate appropriate and innovative research that addresses societally relevant areas is important. CAISR's two focus areas within the research theme aware intelligent systems, health technology and intelligent vehicles, are two such areas. It is also important that the output of research is well received by peers, which is obvious given inflow of international guest researchers. Productivity measures the ability to stay in focus on the selected target areas for the research centre. CAISR has three competence areas, signal analysis, mechatronics, and machine learning, that the research evolve around. The research environment is also inclusive, generous and demanding, focused on the core and open for networking with international research communities as well as coproducing with industrial partners and connected to education on all levels.

But the parts do not make the whole. The success of CAISR is the ability to blend and balance all these challenges in a good way. and to be aligned with the University's overall goals. Halmstad University's strategy is to profile research in two target areas: health innovation and smart cities. CAISR's two areas for future development, intelligent vehicles and healthcare technologies are very well aligned with this profiling strategy and will have an important role in the future development of both the KK-environment and the University's international profiling and positioning. CAISR is also well prepared for the second half of development to be an even more important actor in the future development of the University.

Awareness for **Autonomous Vehicles**

In this area we aim at making vehicles aware of their surroundings. The research questions we focus on are how vehicles can perceive and survey their surroundings, label them semantically (using prior information provided by human experts), and from this construct and maintain maps that can be used for navigation and obstacle detection. There is also a research strand looking into how situational awareness impacts the future industrial safety standards for autonomous vehicles.

AIMS

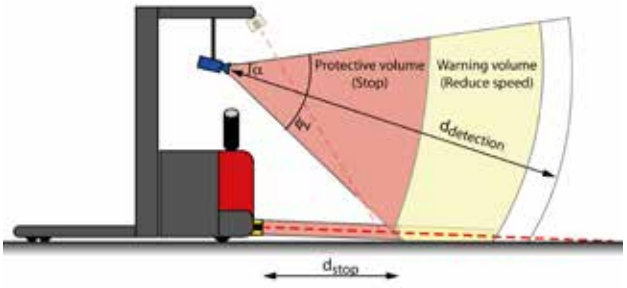
The purpose of AIMS is to make autonomous systems and AGV:s operating in a warehouse setting more intelligent, by extending their functionality with a system for automatic inventory and mapping of goods. A crucial ingredient for effective management of logistics and inventory is a map combining metric and semantic information of the warehouse as foundation for addressing the articles. Objects that are augmented into the semantic map can be both goods and objects belonging to the warehouse infrastructure, e.g. pallet rack and pallets.

The objective behind semantics is to elevate a robot's understanding by linking its model of the world to human related meanings. In general, a robot cannot acquire semantics unless there is a link between human knowledge and the robot's understanding, i.e. human semantics must be introduced to robots. One challenge is to find the right level of abstraction before linking the human knowledge and the robot world model. Another is to maintain a spatial semantic map of an environment with static, semi-static as well as dynamic objects.

In AIMS we have developed tools for surveying the robot's environment, tools that can be used to speed up the process of AGV system installation. The scientific results include a semi-supervised approach for semantic mapping, introducing human knowledge after unsupervised place categorization, in combination with adaptive cell decomposition of an occupancy grid map. We also contributed with a setup for evaluating sensors for obstacle detection and a system for tracking people in industrial settings. This project is collaboration between the CAISR, Kollmorgen, Optronic and Toyota Material Handling Europe.

Klas Hedenberg
Doctoral Student

My thesis work is focused on a safety system that better can handle the increasing complexity in the environments where driverless trucks operate. The approach is to use 3D perception along with methods for detect, track and identify objects in the environment. The goal is to develop an adaptive warning field based on the state of the truck and the state of other objects so that trucks are more efficient in terms of less stops.



Adding a 3D perception system makes it possible to detect objects in a larger volume and allows for increased functionality, thereby improving the truck's performance.

Saeed Shahbandi Gholami
Doctoral Student

Studying the problem of environment modeling for AGVs, I have focused on semantic mapping of warehouses. The semantic map is expected to be layout-like and support semantics of both open spaces and infrastructure of the environment. In our work, the process of semantic mapping is desired to lean toward full-autonomy, with minimum input requirement from the human user.

Jennifer David
Doctoral Student

My research area is on multi-vehicle path planning. I treat this problem as a centralized multi robot task scheduling problem and trajectory planning of individual vehicles. The goal of the research is to exploit the global nature of the task scheduler to avoid local conflicts between the trajectories of all vehicles.

CargoANTS

The continuous growth in global trade justifies the expectation that transport will continue to grow in the future. Thus, the handling of freight has to become significantly more effective across the range, from the smallest individual scale to voluminous container flows. Cargo-ANTs project (Cargo Handling by Automated Next Generation Transportation Systems for Ports and Terminals) envisions to bring cutting-edge insights from autonomous robotics research to bear on the above challenges.

Cargo-ANTs project aims to create smart Automated Guided Vehicles (AGVs) and Highly Automated Trucks (AT) that can co-operate in shared workspaces for efficient and safe freight transportation in main ports and freight terminals. The emphasis of the project is on increased performance and throughput; high levels of safety; development of automated shared work yards; planning, decision, control, and safety for AGVs as well as environment perception and grid-independent positioning.

The CargoANTS project team and project truck on a meeting in Halmstad

In this project CAISR is working on multi- and single-vehicle path planning for automated trucks and autonomous cargo transportation vehicles as well as planning the interaction between moving entities and adaptation of the planned path to changing conditions.

Cargo-ANTs is a 3-year project that began in September 2013. It is funded by the European Union under Framework Programme FP7. The partners of this project include TNO, Netherlands; AB Volvo, Sweden; ICT Automatisering Netherlands; CSIC, Spain; Halmstad University. In addition to strengthening existing ties, this project thus provides a great opportunity for new long-term partnerships at the international level.

Visit to MIT

One of the aims of Halmstad is to provide its students a variety of opportunities to visit other universities, through research collaborations, conferences, and research exchanges. During the period November 9, 2015 - December 20, 2015, Jennifer David, visited the Massachusetts Institute of Technology (Cambridge, USA) as a visiting researcher. The visit was hosted by Dr. Karl Iagnemma, a guest Professor at Halmstad. During her visit, Jennifer became immersed in MIT's research culture, by attending a variety of lectures and participating in aspects of campus life. She also spent time discussing her research with leading experts in multi-robot task allocation, the subject of her PhD studies.

ANTWaY

A necessity in transportation systems is to add efficiency and safety in work yards. For instance, truck maneuvering in a work yard to perform loading and unloading tasks usually presents several problems. Accidents can occur due to low visibility and unregulated traffic. There might be long queues due to maneuvering such big vehicles as well as traffic congestions due to unmanageable drive terrains. Likewise, human errors during low-speed maneuvering can occur especially in reverse parking.

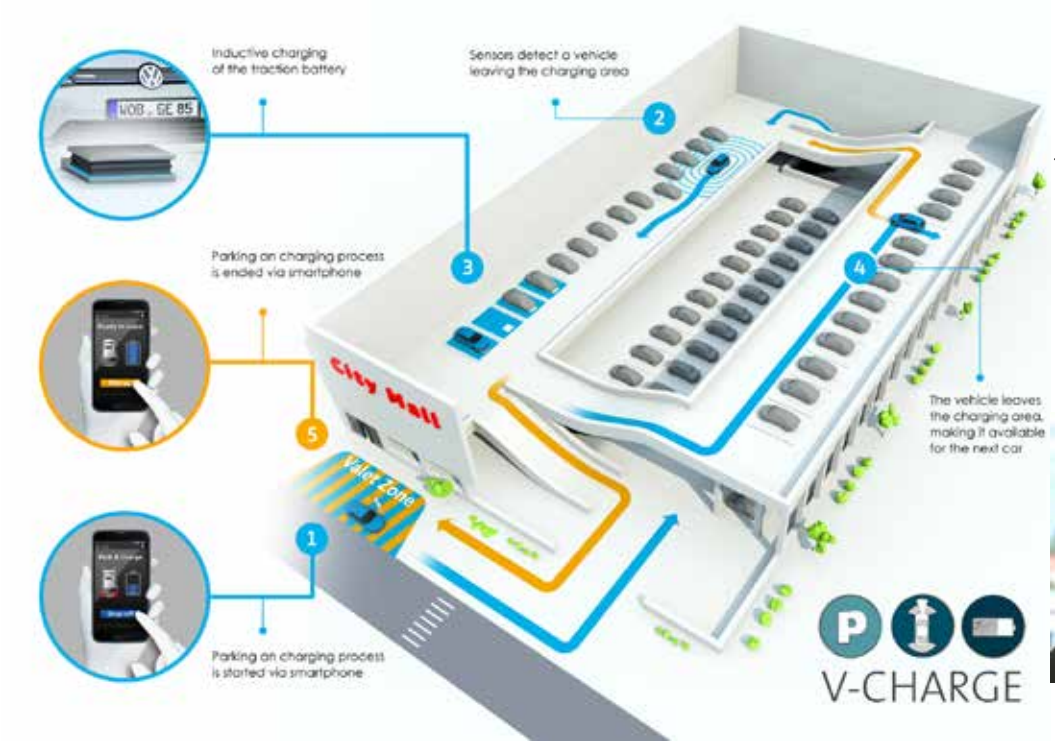
CAISR collaborates to solve the above issues in ANTWaY (Automated Next generation Transport Vehicle for Work Yard application). ANTWaY aims to create a driver driven truck that can transform into a fully-autonomous vehicle once it enters a work yard. This truck should be able to interact with the environment and the site control systems to localize and navigate by itself based on the information and commands it receives from the site control.

ANTWaY is funded by Vinnova. It started on May 2014 and runs for 3 years. The partners of this project include AB Volvo, Kollmorgen, Chalmers Tekniska Högskola and Halmstad University. In ANTWaY, CAISR is contributing towards path planning and interfacing between motion planning and site operation.

V-charge

The project V-Charge is based on the vision that, due to required drastic decrease of CO_2 production and energy consumption, mobility will undergo important changes in the years to come. This includes a new concept for an optimal combination of public and individual transportation as well as the introduction of electrical cars that need coordinated recharging. A typical scenario of such a concept might be automatic drop-off and recovery of a car in front of a train station without taking care of parking or re-charging. Such new mobility concepts require among other technologies autonomous driving in designated areas.

The objective of V-charge is to develop a smart car system that allows for autonomous driving in designated areas (e.g. valet parking, park and ride) and can offer advanced driver support in urban environments. The final goal in four years is the demonstration and implementation of a fully operational future car system including autonomous local transportation, valet parking and battery charging on the campus of ETH Zurich and TU Braunschweig. The envisioned key contribution is the development safe and fully autonomous driving in city-like environments using only low-cost GPS, camera images, and ultrasonic sensors.



Peter Mühlfellner was an industrial PhD student with Volkswagen (Wolfsburg) and did his thesis work within the frame of the V-Charge project (see description above and illustration to the left). He finished his PhD in three years, doing an outstanding job juggling the scientific and implementation aspects with several successful demonstrations.

Peter Mühlfellner

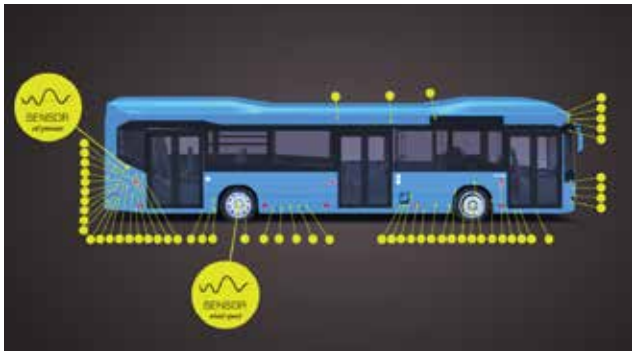
Awareness for **Improved Uptime**

In this area we aim at making vehicles aware of their inner workings, e.g. their health status or how the operator (human) is behaving. The research question is how to autonomously mine streaming control and sensor data on board vehicles, as well as data that are available off-line, and from this construct representations of vehicle behavior, detect deviations and relate these to recorded events in the maintenance (and other) logs of the vehicle.

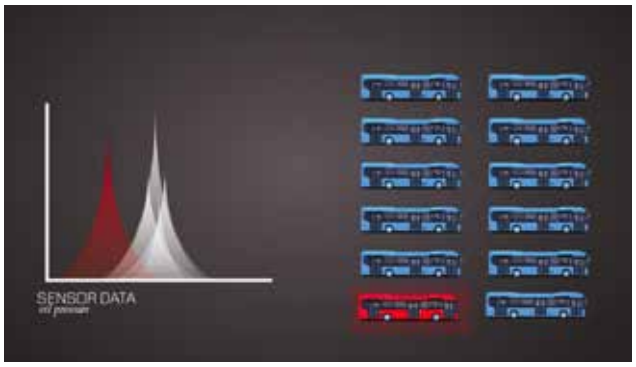
Examples of important issues to study, both from the research and applications perspectives, are: how to construct a "curious" explorer (software agent) that acts on board a vehicle and is able to discover relationships that can be used to describe the vehicle operation; how to detect deviations from normal operation without access to a predefined normal operation regime; how to perform data analysis in a continuous fashion, over data that streams endlessly, adapting to the changes in the environment and usage; and how to link operation characteristics and deviations to external databases with "expert" information on the vehicle. We also explore how more standard data mining in off-board data bases compares to this.

EISIGS uptime

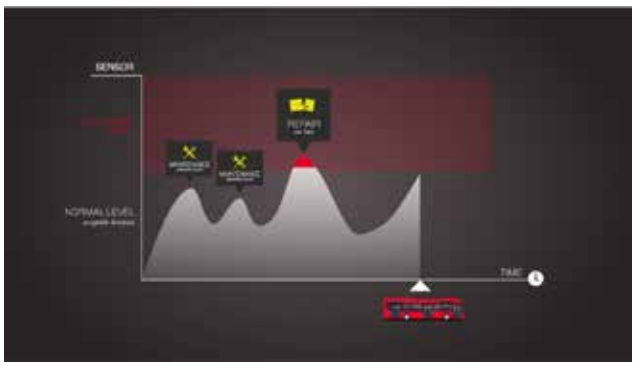
The objective of this project is to develop a remote diagnostic method for predicting component failures of heavy-duty vehicles. The study is based on a commercial fleet of 19 buses driving in inter-city traffic. The buses are equipped with electronic hardware that is capable of logging on board time series of sensor readings as well as transmitting compressed representations of these signals to a back-office server using telematics. The server runs an algorithm that detects anomalous behavior of individual buses based on the idea of 'wisdom of the crowd'. It assumes that the majority of the vehicles are 'healthy' and an individual that deviates from the group can be labeled as potentially 'faulty'. By comparing model parameters of each vehicle against the rest of the fleet, the system can estimate the probability of each vehicle being deviating from the group. A main usage of our system is to provide decision support on maintenance scheduling for eliminating unplanned stops by fixing risky components.



Our predictive maintenance algorithms can, based on data from multiple on-board sensors...



...detect vehicles that operate abnormally ...



...and require repair or maintenance.

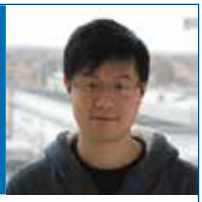
In4Uptime

The goal of the project is to develop data analytics methods that improve operation of commercial vehicles. Haulers and transporters require OEMs to provide vehicles having close to 100% uptime. That means no stops, unless planned, as well as guarantees on optimal performance of all components ensuring acceptable levels of CO_2 emission and fuel consumption.

We show that combining information coming from sources with different origin, such as on-board, off-board, structured, unstructured, private and public, allows for better driver, fleet operator and workshop support. For example, service contracts and maintenance plans can be adapted to the needs of individual customers and individual vehicles. Earlier projects, including ReDi2Service, have shown that predictive maintenance is effective. The next step is to develop long-term predictions, by collecting and exploiting many more sources of information about individual vehicles, including both on-board data about their operation and off-board data about their environment.

The project is coordinated by Volvo Advanced Technology and Research. Other partners of the project are: Volvo Information Technology, Halmstad University, Svenska Innovationsinstitutet and Recorded Future.

Yuantao Fan
Doctoral Student



My research is focused on data analysis for vehicle diagnosis. The objective is to build a self-monitoring system that make vehicles aware of their heath status and capable of autonomously predicting component failures by processing on-board sensor stream. By comparing compressed models (e.g. histogram, auto-encoder and recurrent neural network etc.) of signals between different individual vehicles, the system is able to define nominal behavior of the fleet online and estimate how likely a vehicle is deviating.

Rune Prytz Andersson
Doctoral Student

My research area is on machine learning methods for predicting vehicle maintenance. Currently I'm working on taking my own research into production at AB Volvo. This raises new research questions as its now possible to define the underlying data to a certain level.

fuelFEET

The project aims to understanding how does truck driver behaviour affect fuel consumption. The goal is to develop methods for machines to learn based on naturalistic data, i.e., data from real-world operations. Such data is becoming increasingly more available, and can be used to improve efficiency of many aspects of many different systems. We focus on automotive domain, since it presents many interesting research challenges.

We investigate how to quantify the influence of various factors under partially unknown external conditions. Our approach is based on expert and domain knowledge, extended by models learnt from data. We use the resulting understanding to increase the efficiency of the system, for example to lower fuel consumption of trucks, improve driver coaching, or detect deviations in normal operations due to component wear.

Iulian Carpatorea
Doctoral Student

My research area has as focus data analysis for driver performance with respect to fuel consumption. The main objective is to develop one or more methods that will allow us to compare drivers driving in different conditions. By using a normalization factor or data transformation we can have a better comparison by reducing or eliminating impact of unknown or unmeasured factors.

To the left: Planned stop for buses in inter-city trafic. A main usage of our system is to provide decision support on maintenance scheduling for eliminating unplanned stops by fixing risky components.

VASCO

This project aims to develop software tools and algorithmic methodologies for robot-aided building and annotation of rich maps in worksite environments. These maps will be used for planning and execution of tasks where the degree of automation can range from assisted manual control to autonomous operation in shared work-yards, such as harbors, quarries, or construction sites. We focus on integrating state-of-the art techniques for perception, mapping and planning while developing new approaches to allow human users to interactively annotate and modify maps, define work-site constraints and task goals. The project is a collaboration between CAISR and Volvo Group Trucks Technology.

Gaurav Gunjan
Doctoral Student

The project I am associated with is VASCO which deals with mapping and semantic labeling of outdoor work-yard type environments like harbor, shipyard, construction site etc. The objective is to create detailed maps for shared human-robot autonomy in a dynamic outdoor environment.

Smart grids

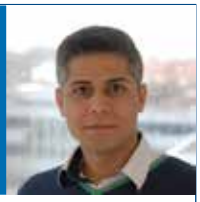
The performance of smart power grids depends upon a wide range of complex components and equipment. This project is a collaboration between CAISR and HEM Nät AB and concerns using multiple data sources to improve the reliability of the network, in particular to move from reactive to predictive maintenance. By discovering which components need maintenance we can proactively mitigate events that cause outages, or at the very least shorten their duration by pinpointing the location of the fault.

For example, power cables are one of the most important components. We calculate failure rates for various groups of cables as they reach a specific age as the first step towards estimating the probability of any given line experiencing a fault. Based on two types of historical data sources, cable inventory and historical failure reports, we consider the effects of factors such as number of joints, geographical location, load patterns, and so on.

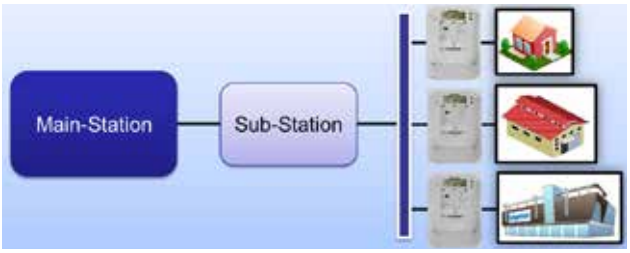
Another type of data comes from "Smart meters," distributed throughout the grid, which allow for continuous collection of information such as voltage, current, frequency, harmonic distortion, etc. It represents the current state of the grid, and can be used to detect early symptoms of upcoming failures.

Hassan Nemati in the monitoring and control room at HEM Nät. Most of the failures and malfunctions can be monitored using advanced metering infrastructure distributed throughout the smart grids.

Hassan Nemati
Doctoral Student



My research project is about using data to improve the reliability of smart power grids. Patterns such as common sequences of events that precede failures, or correlations between causes of failures and environmental factors, are a useful tool for planning maintenance and preventing outages. Similarly, by modeling the aging process in underground cables, we can evaluate the reliability of various power lines, identify their weaknesses and fix emerging issues before they become serious problems.



"Smart meters" provide continuous information about electricity consumption of different customers.

Aware systems for **Healthy and Active Living**

This area of research focuses on improving quality of life and health by using wearable equipment that can help users (and caregivers) be aware of their health status and well-being. Nowadays, wearable technologies embedded in clothing garments enable continuous monitoring of daily activities, providing valuable information that can be used to improve well-being, health, or sports performance. The development of such systems require continued research in a number of topics, ranging from methods for analyzing and evaluating gait to data mining.

MoveApp

Given the projections for demographic change and the increased demand for health care resources in the future, there is a need to transition our health care system from one where patients passively receive instructions from the doctor, to one where patients are active in managing their own treatment in a partnership with doctors. This new health care paradigm is often referred to as person-centered care. In order to speed up and facilitate this process we must empower patients with technologies to support self-assessment and self-management.

Self-management is what persons suffering from chronic diseases do to manage their own illness on a daily basis. It is the ability of the patient to deal with symptoms, treatment, and lifestyle changes. One important part of the process is to actively monitor symptoms and manage their impact on quality of life. Unfortunately, for many of these patients, there is a lack of continuous and objective assessment of their symptoms. In between sporadic visits to the doctor, patients must rely on their subjective feelings of how their symptoms interfere with their normal daily activities.

The MoveApp project aimed to develop new tools to support self-management of chronic conditions that are characterized by motor symptoms such as Parkinson's Disease. The main feature required for such a tool is the continuous assessment and monitoring of motor symptoms using a wrist-worn sensing device. In order to better understand the user requirements for the product, we conducted two workshops with members of the Parkinson's Association in Falkenberg, and interviews with neurologists at the Hospital in Halmstad. The outcome from these activities was the design specifications for the product.

HMC^2

Human movement is a complex process that requires a delicate balance between various interacting neuronal and musculoskeletal systems. As such, structural changes to any of these systems caused by aging, injury, movement disorders or degenerative diseases can in turn affect our movement. For example, walking, which is one of the most primal human movement, starts demanding more cognitive attention as we get older and is often used as a reference for healthy or active living. Thus, identifying fundamental walking events of Heel-Strike (when heel strikes the ground) and Toe-off (when the toe leaves the ground) is vital for developing many health-related applications such as assessing risk of falling in elderly, rehabilitation, identifying movement disorders very early, etc. These events also serve as the benchmark for commercial smart watches or physical activity monitors that are based on step counters. Such applications would immensely benefit if the analysis could be done in peoples' daily lives using non-invasive, non-obtrusive, cheap and durable wearable sensors, as they could lead to better and newer tools for gait assessment and enable interventions that were not previously possible. However, this demands very robust algorithms that can consistently perform in real-world environments and tackle dynamic challenges associated with human gait.

Siddhartha Khandelwal
Doctoral Student

My current research involves quantitative and qualitative analysis of human motion using wearable sensors (especially accelerometers) with focus on gait analysis. This includes developing robust algorithms for detecting gait events in real-world environments and assessing gait variability in order to develop tools for monitoring rehabilitation and predicting neuro-physiological diseases very early.

"An extensive data collection was done in different real-world environments, both indoors and outdoors. The subjects had accelerometers positioned on the wrist, waist, knee and ankles. The shoes were instrumented with force sensors to collect the ground truth information. The purpose of this data collection was two-fold:
1) to show that almost all gait event detection algorithms existing in literature have inconsistent and poor performance across different environments

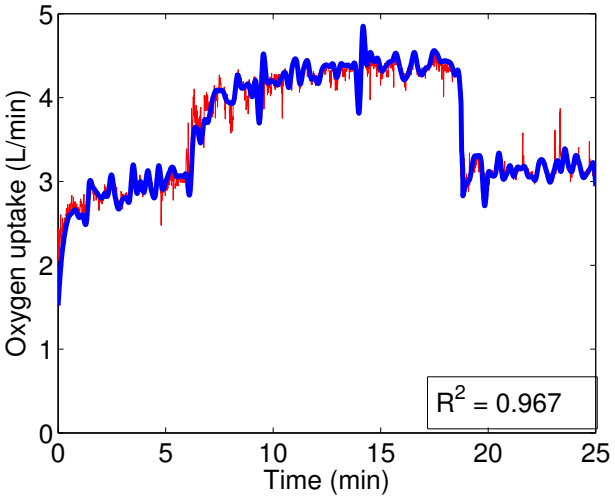
2) to develop a new algorithm that can detect gait events of Heel-Stike and Toe-Off across all environments; such that it can be used for daily life applications."

In order to develop a robust algorithm that can accurately detect walking events in the real-world, an extensive data collection was carried out. It consisted of 20 subjects performing activities of walking and running on treadmill, indoor flat space and an outdoor street; with changing speeds and varying surface inclinations. The subjects were equipped with accelerometers attached to various parts of the body and approximately 93,600 walking events were collected in total. The developed algorithm that utilized existing knowledge about human walking coupled with time-frequency analysis, displayed high performance across all environments.

Signals capable of reflecting muscle activity can be of great value in various health studies and sports related applications. Surface electromyography (sEMG) allows us monitoring muscle activity non-invasively. We have shown that multi-channel sEMG signals can be used for accurate prediction of blood lactate concentration and oxygen uptake, physiological parameters considered very important for setting and adjusting relevant training regimens and many other tasks. The developed algorithms are based on a set of novel time-domain features characterizing activity patterns of a group of muscles involved in an exercise. High prediction accuracy was observed using sEMG data collected during cycling.

Petras Ražanskas
Doctoral Student

My research area within CAISR is application of EMG signals to determine the levels of fatigue in cyclists and runners. I am investigating several approaches to this problem, using spectral data from the signals, as well as timing of different events within them, such as muscle activation and deactivation, and then applying data mining and statistical analysis techniques to build prediction models for some of the physiological parameters associated with fatigue.



Above: Predictions of oxygen uptake (red), compared to the interpolated ground truth (blue), made by the random forest regression models, built using data from the vastus lateralis muscle.

GoDIS

The GoDIS project (Go Digital innovations in Self-Determined Exercise Motivation) works with the future of health promotion in the form of e-health applications and interactive tools developed at break-neck speed, but despite this and a plethora of information about the health benefits of exercise, it has proved difficult to promote sustainable exercise behavior and motivation to exercise. The goal of this project is to develop and test an interactive tool based on ease of use and the needs of the e-health industry. In addition to potentially health-promoting effects at the individual and societal level through the promotion of sustainable exercise behaviors the project is expected to generate innovative digital solutions for e-health industry through cross-disciplinary application of behavioral theory, information technology and business model development.

The Basic idea behind GoDIS

To develop interactive ideas based on relevant motivation theory, in combination with IT and science innovation expertise, based on user-friendliness and needs within e-Health.

Cross cooperation steering group for the GoDIS project, from left: David Johansson, Tappa AB, Urban Johnson, Center of research on Welfare Health and Sport (CVHI), Nicholas Wickström CAISR, Karin Weman Josefsson, CVHI, Pontus Bremdahl, Tappa AB, Fawzi Halila, Center for Innovation, Entrepreneurship and Learning research, Anna Ruthberg and Peter Wallin, both HPI AB.

Health technology workshop March 10, 2015. From left: Jens Lundström, researcher, Pål Henrik Hagen, Head of the Norwegian department, Tappa Service AB, Chris Nugent, International guest professor, Siddhartha Khandelwal, PhD student, Peiman Khorramshahi, CEO, Daralabs AB, Anita Pinheiro Sant'Anna, researcher, Erik Hellmark, Head of Sales Northern Europe, UK.,Neat Electronics AB, Fernando Alonso-Fernandez, researcher, Antanas Verikas, professor, Martin Cooney, researcher and Nicholas Wickström (in front), researcher.

Aware systems for **Ambient Assisted Living**

The work in this area deals with improving quality of life and health of people by making their living environment aware. This is about empowering people's capabilities (to live independently and safely in their own home) by the means of equipped environments able to sense, adapt, and respond to human needs. The research questions we approach in CAISR are how to autonomously learn the habits of inhabitants, and thus be aware of their activities/health status, how to detect serious problems (e.g. falls), and how to interact with the inhabitants. We focus on low-cost, low-consumption sensors, as well as small moving robots that can interact symbiotically with humans (the robots will be available in our intelligent environment).

The intelligent home

A part of the CAISR funds have been used to build up infrastructure that makes CAISR an even more attractive cooperation partner. This is the Halmstad Intelligent Home. It is a fully functional research apartment that serves as a development and test platform for new technical solutions. It is instrumented with sensor, actuators and robots, and their associated power, communication, and computation infrastructure.

We target applications that go beyond health monitoring for elderly, ill or disabled individuals. Senior citizens nowadays are more tech-savvy and can heighten their quality of life by leveraging recent technology-based innovations such as social networks, video conferencing, or serious games. In addition, preventive healthcare has been identified as a priority by the European Commission in the Horizon 2020 program. Therefore, we target the development of innovative solutions for supporting healthy and active lifestyles, safe and independent aging, as well as effective healthcare services.

In the particular context of CAISR, we investigate awareness in embedded intelligent systems; questions of natural and user-friendly interfaces between humans and different elements in the system, such as robots, are of special interest. For example, we like to investigate how to make mechatronic devices that interact with humans in everyday environments inherently safe, how to integrate wearable sensors into the infrastructure of the intelligent home, how to distill the wealth of multi-modal data into information that is pertinent to quality of life, and how to effectively design systems that have a "human in the loop" such as tele-operation or co-manipulation as well as feedback and intervention for behavior change.

One goal of the intelligent home is to enable experimentation for novel ideas in real-world settings. This implies that we can rapidly extend the sensing and actuation capabilities for the specific needs of research projects and build prototypes for product ideas. This is interesting especially for SMEs to explore product ideas without major financial overhead, and to test their products and prototypes within a fully instrumented environment.

Playing chess with a robot? Maybe one way to heighten quality of life by the use of aware intelligent systems.

SA^{3}L

The SA3L (Situation Awareness for Ambient Assisted Living) project is concerned with developing methods and tools for detection and interpretation of potentially dangerous situations in the home of elderly people. The situations are inherently difficult to specify and generalize due to the diversity of homes, behaviors and the numerous ways of deviating. Thus, a system for detecting deviations based on manually specified rules is difficult (impossible) to build and maintain. We approach this problem by learning the activity patterns in the home.

Kitchen in the intelligent home located at Halmstad University - The kitchen is equipped with 12 sensors able to sense interaction with drawers and other appliances (e.g. stove, fridge and microwave oven). In the research project SA3L, indoor human behaviour is modelled using data acquired from sensors located in the home, such as sensors in the kitchen above.

In the data layer, a new method for representing time-dependent patterns of binary sensor deployed in-homes was proposed and used for modelling human activity patterns. To address the plasticity-stability problem were no prior assumptions made regarding the relevant sensors or the spatio-temporal relations between sensors.

The project has contributed to the modelling of human in-home activity patterns with an unsupervised approach to compare, cluster and relate (in space and time) similar behaviors. Deviations from such normal models are distinguished by indirect if-then rules and thereby contributing to both the information and knowledge layers of the knowledge pyramid. The method has been shown to work both for simulated and real data (in a demonstrator environment). A focus has also been on building up a realistic smart home simulator, in co-operation with Ulster University.

Ageing at home

This project is a continuation of the SA3L project and it aims at building models of human behavior patterns that can be generalized over different environments and individuals. Future capabilities of Ambient Assisted Living involve reaction to an otherwise normal sensor reading if it happens concurrently with something else, preventing or alerting of unwanted events or abnormal patterns without the need of constant attention of an operator. Additionally, the user should be able to interact or to "speak" to the system, telling that s/he is aware of the situation (perhaps thanks to the alert). Early detection of diseases is another example of a promising application by monitoring activity patterns of elder people. Research questions here include how to autonomously learn the habits of inhabitants, and thus be aware of their activities/status, and how to interact with the inhabitants. The planned research contributions will be on more robust models that handle data drifts over time, e.g. in situations with sudden behavior change, e.g. after a surgery, and thereafter also gradually changes during the recovery. This research will mainly target unsupervised learning in the data and information levels. However, we also want to explore knowledge representations in the knowledge layer that are non-opaque, i.e. can be used to communicate extracted knowledge to a human.

The project will also involve robots that interact with humans. We intend to build an autonomous robot with a simplified human-like "consciousness" based on prescriptions from the literature, as well as some simplified interactive and learning capabilities (e.g., the robot will be able to visually recognize faces of interacting individuals and learn new faces). Our approach involves using a grounded theory method to construct basic knowledge of how a robot can adapt its behavior from data of interactions with an initial model. The robot's recognition system employs a mixture of hard-coded rules (knowledge derived by us from testing in real interactions) and adaptive capability (e.g. parameters for how much weight a robot should attribute to cues in an interaction and how human-like a robot should behave). In more detail in regard to the knowledge pyramid, data representations will be required, e.g., to keep track of individuals who interact with the robot. For the information layer, event recognition will occur in a simplified manner after event detection: e.g., an interacting person will be identified or marked as new if a face is detected, a touch such as a hug will be recognized or marked as new if a touch is detected. For the knowledge level, we will manually find features and parameters that could be useful parameters will be adapted by the robot during inter-

actions based on evaluating success. (The understanding and prevision level will be an interesting potential future step as it would be useful if a robot could predict a person's past and future.)

Emotion-based automation of intelligent environments using brain-computer interface

Ambient Assisted Living aims to prolong a person's ability to live safely and independently in their own home, by increasing their autonomy and self-confidence, facilitating the performance of activities of daily living (ADLs), enhancing security, and saving resources. Smart home environments can support this aspiration by introducing technological solutions and seamless interfaces that are capable of recognizing and responding to the presence and needs of different individuals in an unobtrusive and intuitive way. For example, through a combination of bio-signals and environmental sensors, we aim to help the user relax and sleep, depending on the time of the day and if he/she is lying in bed. If the user is in this "wanting to sleep" context and his/ hers bio-signals detect anxiety and alertness, the environment will adapt maybe turning off the lights and using relaxing sounds, according to brain drive theories, in order to help him/her achieve a relaxed and sleepy mental state. In this project, we will study:

- Ways to detect different mental states through bio-signals,
- Ways to use a combinations of environmental and bio-sensors to speculate what the user wishes to do at the environment,
- How the environment can influence the individual's mental state,
- New ways of passive interaction between the user and the environment,
- How to put the "human in the loop" at controlling smart environments.

Maria Luiza Recena Menezes,
Doctoral Student

My thesis is focused on incorporating basic psychological processes into the automation of ambient intelligence. The goal of my research is to study ways to achieve Passive Control and Implicit Interaction through a combination of bio-signals and environmental sensors.

Science without Borders

Science without Borders is a large scale nationwide scholarship program primarily funded by the Brazilian federal government. The program seeks to strengthen and expand the initiatives of science and technology, innovation and competitiveness through international mobility of undergraduate and graduate students and researchers.

The Emotiv EPOC EEG wireless helmet is a brain-computer interface developed by the Australian company Emotiv Systems. This user friendly and affordable device is well suitable for Smart Homes solutions, while allowing the user to freely move around the Environment and complete usual daily tasks.

PhD Graduation

Anna Mikaelyan

Compact orientation and frequency estimation with applications in biometrics:
Biometrics on the orientation express

Abstract

Automatic feature extraction still remains a relevant image and signal processing problem even though both the field and technologies are developing rapidly. Images of low quality, where it is extremely difficult to reliably process image information automatically, are of special interest. To such images we can refer forensic fingerprints, which are left unintentionally on different surfaces and are contaminated by several of the most difficult noise types. For this reason, identification of fingerprints is mainly based on the visual skills of forensic examiners. We address the problem caused by low quality in fingerprints by connecting different sources of information together, yielding dense frequency and orientation maps in an iterative scheme. This scheme comprises smoothing of the original, but only along, ideally never across, the ridges. Reliable estimation of dense maps allows introducing a continuous fingerprint ridge counting technique. In the fingerprint scenario the collection of irrefutable tiny details, e.g. bifurcation of ridges, called minutiae, is used to tie the pattern of such points and their tangential directions to the finger producing the pattern. This limited feature set, location and direction of minutiae, is used in current AFIS systems, while fingerprint examiners use the extended set of features, including the image information between the points. With reasonably accurate estimations of dense frequency and orientation maps at hand, we have been able to propose a novel compact feature descriptor of arbitrary points. We have used these descriptors to show that the image information between minutiae can be extracted automatically and be valuable for identity establishment of forensic images even if the underlying images are noisy. We collect and compress the image information in the neighborhoods of the fine details, such as minutiae, to vectors, one per minutia, and use the vectors to "color" the minutiae. When matching two patterns (of minutiae) even the color of the minutia must match to conclude that they come from the same identity.

This feature development has been concentrated and tested on forensic fingerprint images. However, we have also studied an extension of its application area to other biometrics, periocular regions of faces. This allowed us to test the persistence of automatically extracted features across different types of images and image qualities, supporting its generalizability.

The Grading committee: Stefan Carlsson, Julian Fierrez and Gunilla Borgefors

Main supervisor:	Prof. Josef Bigun
Co-supervisor:	Dr. Kenneth Nilsson
Opponent:	Associate Professor Raffaele Cappelli
Grading committee:	Prof. Stefan Carlsson, Prof. Gunilla Borgefors, Associate Prof. Julian Fierrez

Next generation fingerprint analysis

Fingerprints found at crime scenes, left in a speck of blood or dust, are often incomplete. Criminals might go unpunished and there is a risk of wrongful convictions. Anna Mikaelyan's research aims to develop a more reliant method for fingerprint identification. Prints that cannot be used today might be used tomorrow – advanced image processing is the next generation tool for forensic fingerprint analysis.

– Today, identification of fingerprints is mainly based on the visual skills of forensic examiners. They can work for hours or days, trying to extract fine details from images manually, which they later insert in a matching algorithm. The human factor is crucial – if the examiner misses something, the result might be devastating. Our goal is to provide an efficient tool for image analysis to help the forensic examiners in their work.

Recycling garbage

The average human finger has 75 to 150 ridge characteristics creating a unique pattern that differs even in identical twins, unlike DNA. Fingerprints, which are impressions of the pattern, have been used for identification and evidence in criminal investigations since the 19th century. Nevertheless, fingerprints found at crime scenes are often only partial and of poor quality. In order to find a matching pair of fingerprints in a forensic database, the images need to have around 15 fine details in common.

– Only fine details from the fingerprints, extracted by examiners, are used, the rest is thrown away. There is information valuable for identity establishment in the discarded material, and our research has made it possible to use this material. Fewer details, for example five, can be as powerful as 15 if all available information is utilised properly.

We have therefore developed a tool for forensic examiners, an image descriptor called SAFE (Symmetry Assessment by Finite Expansion). SAFE can use pieces of a fingerprint that is thrown away today –recycling useful image material. Anna Mikaelyan explains:

– The image descriptor SAFE gives an additional identity to a fine feature by using the surrounding images that, until now, have been regarded as unusable. We hope that this image analysis tool, combined with the examiners' manual work, will increase the chance of correct identification.

Iris identification

The research has so far been focused and tested on forensic fingerprint images. However, there are other application areas within biometrics for SAFE, for example regions of the face and of the iris.

– The image descriptor is easily generalisable and can therefore be used for any image processing application, but this requires additional experiments.

- Our goal is to provide an efficient tool for image analysis to help the forensic examiners in their work.

PhD Graduation

Peter Mühlfellner

Lifelong Visual Localization for Automated Vehicles

Abstract

Automated driving can help solve the current and future problems of individual transportation.

Automated valet parking is a possible approach to help with overcrowded parking areas in cities and make electric vehicles more appealing. In an automated valet system, drivers are able to drop off their vehicle close to a parking area. The vehicle drives to a free parking spot on its own, while the driver is free to perform other tasks --- such as switching the mode of transportation. Such a system requires the automated car to navigate unstructured, possibly three dimensional areas. This goes beyond the scope of the tasks performed in the state of the art for automated driving.

This thesis describes a visual localization system that provides accurate metric pose estimates. As sensors, the described system uses multiple monocular cameras and wheel-tick odometry. This is a sensor set-up that is close to what can be found in current production cars. Metric pose estimates with errors in the order of tens of centimeters enable maneuvers such as parking into tight parking spots. This system forms the basis for automated navigation in the EU-funded V-Charge project.

Furthermore, we present an approach to the challenging problem of lifelong mapping and localization. Over long time spans, the visual appearance of the world is subject to change due to natural and man-made phenomena. The effective long-term usage of visual maps requires the ability to adapt to these changes. We describe a multi-session mapping system, that fuses datasets into a single, unambiguous, metric representation. This enables automated navigation in the presence of environmental change. To handle the growing complexity of such a system we propose the concept of Summary Maps, which contain a reduced set of landmarks that has been selected through a combination of scoring and sampling criteria. We show that a Summary Map with bounded complexity can achieve accurate localization under a wide variety of conditions.

Finally, as a foundation for lifelong mapping, we propose a relational database system. This system is based on use-cases that are not only concerned with solving the basic mapping problem, but also with providing users with a better understanding of the long-term processes that comprise a map. We demonstrate that we can pose interesting queries to the database that help us gain a better intuition about the correctness and robustness of the created maps. This is accomplished by answering questions about the appearance and distribution of visual landmarks that were used during mapping. This thesis takes on one of the major unsolved challenges in vision-based localization and mapping: long-term operation in a changing environment. We approach this problem through extensive real world experimentation, as well as in-depth evaluation and analysis of recorded data. We demonstrate that accurate metric localization is feasible both during short term changes, as exemplified by the transition between day and night, as well as longer term changes, such as due to seasonal variation.

Main supervisor:	Prof. Thorsteinn Rögnvaldsson
Co-supervisor:	Docent Roland Philippsen
Opponent:	Prof. Tom Duckett
Grading committee:	Docent Thomas Hellström, Docent Hedvig Kjellström, Assistant Professor Davide Scaramuzza

Can an automated car see?

Automated vehicles have to navigate according to their surroundings – just like a driver navigates by using her eyes. Our research makes it possible to create visual maps that are continuously updated. Together with these maps, cameras on an automated car determine the vehicle's position.

– A camera based navigation system allows the car to recognise landmarks in the area it is driving in. The problem is that surroundings change over time; weather will vary from day to day and cars in a parking lot will move. The shift between day and night, as well as seasonal variations over time, will cause drastic changes in what the area looks like.

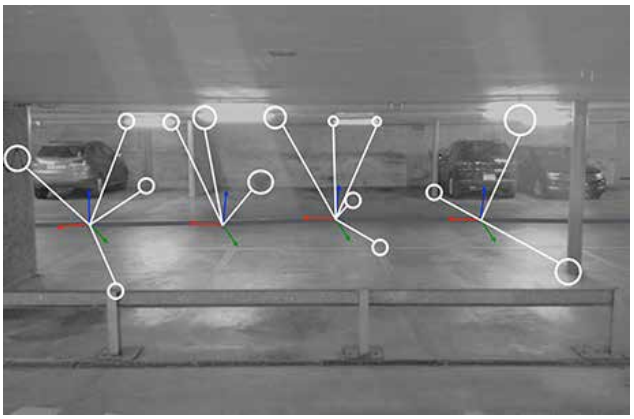
Peter Mühlfellner conducted his research in collaboration with Volkswagen. The research focus was on how to build visual maps over long time frames – over one year – and under extreme appearance changes.

– The suggested method allows a constant update of an existing map, while less important information is thrown away. The storage size and processing costs for a map can therefore remain the same, but it is still possible to react to change.

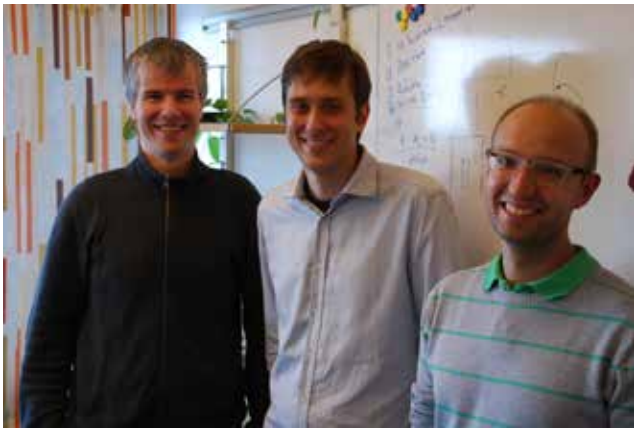
Automated cars – the future of personal transportation

The system that Peter Mühlfellner and his colleagues have developed works well. The research group has built consistent maps using data collected for more than one year, in sun and rain, day and night, winter and summer. The system was recently used as a basis for automated driving in the collaborative EU research project V-Charge external link.

– I believe that automated cars are a key concept for the future of individual transportation. They can help make traffic safer and more convenient. Automated valet systems, such as the one we worked on in V-Charge, can result in decreased fuel consumption and a relief of traffic congestion in cities.



The image shows how features of a parking garage can be used for localisation of automated cars.



Roland Philippsen, co-supervisor, Peter Mühlfellner and Wojciech Derendarz co-supervisor at the company.

3
PhD dissertations during 2015

PhD Graduation

Wagner Ourique de Morais

Architecting Smart Home Environments for Healthcare: A Database-Centric Approach

Abstract

Considering existing system architectures for smart environments, the database management system (DBMS) is the most common but the least exploited architectural component, devoted exclusively for data storage and retrieval. However, database technology has advanced and matured considerably over the years, and, as a result, current DBMSs can be and do more.

The scope of this thesis is therefore to investigate the possibility of using different features supported by modern DBMSs to create a database-centric system architecture to serve as a platform for smart environments. The thesis also investigates the development of applications for health monitoring and assistance: 1) a serious game for fall prevention that assists people in practicing Tai Chi at home, and 2) a non-intrusive home-based method for sleep assessment.

The event-driven architecture of active databases, extensions for in-database processing, and built-in mechanisms for inter-process communication are technical features of some novel DBMSs and are explored in this thesis to address general functional aspects of smart environments, such as monitoring, processing and control of various types of events in a given environment. Extensibility and security features and cross-platform capabilities of DBMSs are employed to accommodate non-functional properties of smart environments, including interoperability, extensibility, portability, scalability, security and privacy. Heterogeneous technologies are integrated into the system using programming language and platform independent software resource adapters.

The feasibility of the proposed system architecture was pragmatically investigated with the development of a "smart bedroom" demonstrator and with the implementation of a number of services to support ambient assisted living. In the proposed architecture, active in-database processing maintains sensitive data within the database.

This increases data security and independence from external software tools for data analysis. Changes in the system are managed during runtime, which improves flexibility and avoids system downtime. The developed architecture was evaluated taking into account different application scenarios and heterogeneous computing platforms.

As a conclusion, modern DBMSs support features that can be successfully employed in a database-centric system architecture to effectively and efficiently address functional and non-functional requirements of smart environments.

Main supervisor:	Prof. Bertil Svensson
Co-supervisor:	Docent Nicholas Wickström
Opponent:	Associate Professor Diego López-de-Ipiña González-de-Artaza
Grading committee:	Prof. Nahid Shahmehri, Prof. Boris Magnusson, Associate Professor Amy Loufti

Smart homes become smarter and more secure

"Smart homes" employ technologies that can increase the comfort, safety and energy management. In the future, smart homes will also serve for the care of older and disabled individuals. Wagner Ourique de Morais' research concerns an approach that makes it possible to handle sensitive information collected in smart homes in a more secure way. He has also developed a bed that monitors sleep behavior and a Tai Chi game that aims to show how serious games can contribute to fall prevention.

Wagner Ourique de Morais PhD thesis describes a particular method for architecting smart homes, that allows sensitive information to stay in and not be transferred out.

– With my method, the information is not exported to software applications for data analysis, but the methods for data analysis are moved to where the information is located, that is in the database. This is something new in the area of smart homes.

Database management systems (DBMS) are usually employed for information storage and retrieval. But the new approach shows that it is possible to use a modern database management system as a platform for designing smart homes.

The information that is collected by sensors in these homes is personal and therefore also very sensitive. Such information can for example reveal how a person acts and behaves in everyday life. It is therefore important that collected information is secured from being accessed by unauthorized people.

Needs in the future

A further aspect is that the smart home technologies can assist old and disabled individuals living alone in different ways. Eventually, thanks to the home-based technologies, those individuals can live independently for longer in their own homes, assisted by technology in their daily routines.

– People are living longer and in the future, as many older people will need home care, available healthcare resources, for example staff and settings, will not be enough.

Healthcare Technology for the elderly

The thesis also describes a bed demonstrator, that can monitor and assess older people's sleep behavior. The system measures movements, heartbeat, breathing and if the person is awake or asleep. This could be a valuable help for home care and detect abnormalities when older people are lonely at home.

Wagner Ourique de Morais also developed a computer game to assist and enable older people to practice Tai Chi at home on their own. The player attempts to mimic a virtual Tai Chi instructor displayed on the screen.

– These serious games have a different purpose than just being entertaining and can contribute to improving or maintaining health.

The bed demonstrator - a smart bed for a smart home

Chris Nugent

International guest professor

As demographics are rapidly changing globally there is an urgent need for new healthcare systems. This will very much rely upon stronger links between health, technology, behavioural science and smart environments. Chris Nugent, international guest professor at CAISR, has a key role within this area of research.

–I believe new technology can give people greater possibilities to take control of their own health and lifestyle management. This in turn can address the challenges we are facing today with a growing elderly population.

Chris Nugent is professor of biomedical engineering and works as director of the Computer Science Research Institute, Ulster University in Northern Ireland. He specialises in connected health and has been involved in several successful research projects focussing on the links between health and modern technology.

–Being a guest professor in Halmstad has opened the opportunity for new partnerships and collaborations in several ways. We've hade some exchanges with of both staff and Phd students. For myself, being here has been a refreshing experience! CAISR is a creative and energetic team to work with. A very positive element of their structure is the close link that they have between research and industry.

Chris Nugent's research especially addresses the development of mobile and pervasive computing solutions to support ambient assisted living. Amongst other things he has been involved in the development of a video based reminder app to support people with dementia to remind them throughout the day to engage with various activities.

He thinks that this kind of support and self-management of health and lifestyle through technology will be absolutely necessary in the future.

–There is a real crisis ahead due to the changing demographics on a global level. Having this change to our population will cause challenges to the current manner in which healthcare provision is provided. Additionally, many want to stay at home as long as possible. With modern technology I think we can address these challenges.

Chris Nugent's aim is to accommodate people with health problems, prevent the problems from happening and offer programs of rehabilitation all through connected health solutions.

Together with colleagues at Ulster and Utah he has designed an app that deliveres health education material to promote a healthy lifestyle change and provides a way for the user to monitor and receive feedback on their changes.

Chris Nugent

–We wanted to show that everyone can reduce the risk of gaining dementia later in life by changing their lifestyle. Two thirds of all people with dementia are affected due to lifestyle factors like bad sleep, little or no exercise, lack of social interaction, bad eating habits and smoking.

In the future he would like to see a global store where everybody could share their data about lifestyle and behaviour when it comes to such things as sleep and health.

–If we want to develop and avoid disease we need medical data on a global level. I don't know if I will ever achieve it, but my aspiration in life is to facilitate and find a tool for this.

> I believe new technology can give people greater possibilities to take control of their own health and lifestyle management.

Karl Iagnemma

International guest professor

Robotics has been in focus of Karl Iagnemma's research for almost twenty years. Within a not too distant future he hopes to see some of his software systems in autonomous cars and robots doing useful tasks in for example warehouses or shipyards.

–Like many other people I have been fascinated by robotics for a long time. It started already when I did my undergraduate degree in Michigan. I think it is the interdisciplinary aspects that make it so interesting. Mechanical, electrical and computer science – all these components must come together to create a system with some form of intelligence, to make a robot work.

Karl Iagnemma

Karl Iagnemma is director of the Robotic Mobility Group at Massachusetts Institute of Technology (MIT). Until February 2017 he is also a visiting professor of Mechatronics at the school of information technology at Halmstad University.

–My wife comes from Gothenburg and my family has spent a lot of time in Sweden. Becoming a visiting guest professor in Halmstad has been a great opportunity as I wanted to establish a connection with Swedish academia.

Karl Iagnemma is specialised in mobile robotics and software systems and has written more than 200 scientific articles. He is also the co-founder of Gimlet Systems, which specializes in software for autonomous vehicles and he has been designing robots for NASA and companies like Nissan and Ford.

–I think a lot of things will happen when it comes to autonomous vehicles within the next few years. We will perhaps not see self-driving cars on every road in the world, but definitely on a city-scale basis. We will also have robots that can do useful tasks in many other areas, we will see them zip around in warehouses, gather information and transport people or goods.

A lot of the chore technology that Karl Iagnemma has been working with is directly relevant to this development.

–I'm constantly trying to find ways to get my software into the real world by partnering companies, small businesses or upstart companies. It would be a very nice outcome if I could make a contribution to making mobile robots a little more intelligent and vehicles safer and more efficient in the future. Distilling theory into practical work is what Karl Iagnemma calls "the MIT perspective". This perspective is also something that he has brought to Halmstad University.

–The MIT perspective emphasises learning by doing, there should be a balance between theory and practical implementation and I hope this is something that I have brought to Halmstad University. However, Halmstad already does a good job. There are many good partnerships with local industries and there is a real need for what is being done. The research carried out here is relevant and useful.

Karl Iagnemma dreams about a future where automative vehicles are safer than they are today and he thinks that we will see this period in history as incredibly dangerous when we look back in time.

–I think with robotics we are already close to having the technology that is needed to make today's vehicles a thing of the past. At the same time we have great challenges ahead, not the least when it comes to autonomous passenger cars. Their impact will be so big globally.

In addition to his research, Karl Iagnemma is also an author of novels and has written several short stories about the drama behind science, mathematics and human-robotic relationships.

–I have been writing in my entire life. Some of the stories were inspired by people that I met in my career, but mostly they have been literary fiction. Lately I haven't been writing so much, as life is too busy. But I'm gathering a lot of material!

Misha Pavel and Holly Jimison

International guest professors

Misha Pavel is Halmstad University's first Bennet Professor. Together with Holly Jimison, also a Halmstad University Guest Professor, Misha Pavel's research focuses on monitoring human behaviour for a proactive and patient-centred healthcare.

– The cost of global healthcare is rising continuously, and since we live longer, there is also an increase in disorders associated with aging. Although 30 percent of premature mortality is due to genetic factors, more than 40 percent is due to poor health behaviours, accounting for a significant portion of the cost. At the same time advances in sensor and networking technology combined with computational modelling, have enabled unprecedented opportunity to monitor and interpret behaviours. Taking advantage of this confluence, we have been investigating ways to use technology to help us improve our health behaviours. The advance monitoring technology combined with computational modelling targeted to support better behaviours, enables in addition significant enhancements of our understanding of the underlying brain processes and the neurodegenerative disorders. We call this nascent interdisciplinary area behavioural informatics, says Misha Pavel.

Misha Pavel and Holly Jimison have been working together in the healthy aging domain for over 20 years. Their individual achievements are impressive, but their combined expertise is extraordinary and inspiring. Pavel and Jimison have, for many years, been monitoring older people in their homes with the ambition of improving their quality of life.

Continuous monitoring for health and wellbeing

The assessment of health-related behaviours such as exercise – both physical and cognitive – eating habits, sleep and socialisation combined with predictive models is an important prerequisite for generating optimal interventions. Specifically, the outputs from the sensors processed by the models are used in a coaching platform, created by Jimison. The platform provides coaching support that allows a single coach to manage a large number of people to help them to improve their health behaviours.

– Continuous monitoring and statistical computing enables tracking individual participants and detect subtle deviations from their baseline or "normal" behaviour. This information can be used by the coaching platform to potentially remediate or slow down decline. Rather than focusing separately on different aspects of health behaviours, for example sleep, exercise or diet, we try to get a holistic perspective. We are on a threshold to a revolution in the way we deal with health behaviour change, says Holly Jimison.

Healthcare coaching through Skype

In their prior work in Oregon Health and Science University, Jimison and Pavel have monitored and coached more than 40 patients testing the platform in improving a healthy lifestyle in older adults. The participants have been monitored unobtrusively in their homes, and this information has been used by the coaching platform to generate participant-specific coaching emails edited and further personalised by the coach.

– Although the asynchronous contact is effective, it is also important to complement it with face-to-face contacts with the coach. In addition to the emails we, therefore, also use synchronous communication technology like Skype in our coaching. As it turned out, the outcome of this communication strategy is not only physical improvements, but also social and emotional. In addition to communicating with the coach, the participants started to communicate with each other forming a social support network, says Holly Jimison.

Real-time exercise coaching

In collaboration with the University of California at Berkeley, their current research programme is focused on the development of a coaching system for helping older adults to exercise. Using Kinect cameras, the team developed real-time computer vision algorithms that assess and evaluate the participants' movements during chair exercises. The coaching process is interactive – the patient can follow a coach's movements on a screen and receive immediate feedback since the patient's movements are analysed by the coaching platform in real time.

During the last year, they have been evaluating this system with ten individuals with an average age of 85. The health coaching platform is still in a research stage, but Pavel and Jimison have been collaborating with a range of different companies – from larger corporations like Google and Intel, to smaller sensor companies – in order to enable creation of commercial products.

Misha Pavel is Halmstad University's first Bennet Professor. Together with Holly Jimison, also a Halmstad University Guest Professor, Misha Pavel's research focuses on monitoring human behaviour for a proactive and patient-centred healthcare. Pavel is a Guest Professor at School of Information Technology and Jimison is a Guest Professor at School of Health and Welfare at Halmstad University.

Privacy and security

An obvious question that comes to mind involves the privacy of the participants.

– The patients are willing to give up a part of their privacy in order to "age in place" and feel safe at home. It is, however, important that the participants have full control over who has access to their data. This includes the coach, formal caregivers and family members. In general, people are willing to give up aspects of privacy for valuable benefits – it is a privacy–benefit trade-off, says Holly Jimison.

The CORE project

When our health improves more people will live ever longer lives. But it also implies that we risk developing more chronic illnesses. This creates an increased need for methods that can help older persons retain their autonomy and to manage outside the healthcare sector as far as possible.

To support older people's living in their home environment is an all-important challenge. This is owing to the fact that both the economic resources and the scope for competence supply for the healthcare sector are limited.

This interdepartmental, cross-disciplinary university research project, called Aging and Self-management , investigates whether self-care capabilities can be strengthened through new ways of using welfare technology and e-health amongst older people treated with medicines.

Welfare technology as support in the case of medication in the home environment can be assumed to provide the older person with increased self-care capability, enhanced safety and wellbeing.

What are the different needs and experiences, where medication is concerned, for older people from a socioeconomic, gender and ethnicity perspective? What effects can future research results lead to at both the individual and organisational level? Who is willing to pay for welfare technology present in the home environment.

The University's first health innovation professor is tied to the project: Professor Misha Pavel and Professor Holli Jimison from North Eastern University in Boston, USA.

The duo's goal at Halmstad University

Pavel and Jimison want to support Halmstad University in developing collaborative and multidisciplinary projects.

– One important goal, recognised by Halmstad University, is to get engineers and clinicians to work together and to understand each other's culture, so that they can cooperate effectively. Halmstad University has a very good combination of theoretical and applied interests. Applications are absolutely necessary to see if a theory is correct, says Misha Pavel.

– Our second goal is to strengthen the relationship between the USA and Sweden. The global health problems need to be looked at from many angles, with multiple solutions from different cultures and countries. Combining our work is essential, says Holly Jimison.

Some Highlights

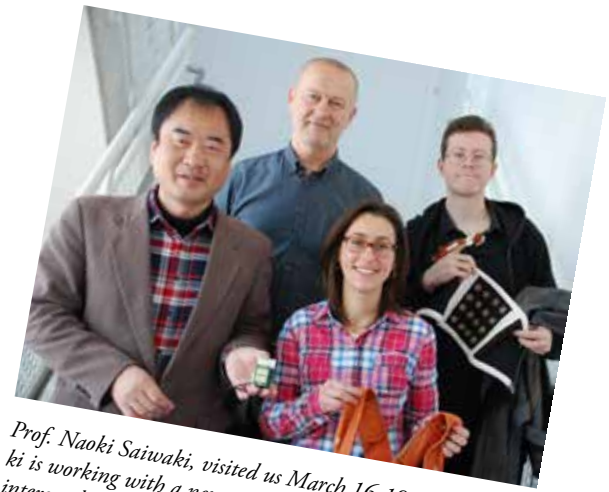
Dr. João Paulo Carvalho Lustosa da Costa, Ministry of Planning in Brazil, visited Halmstad University in February. Here he's talking to Wagner de Morais and Anita Sant'Anna about opportunities for Research Collaboration between University of Brasília and Halmstad University in Signal Processing Applications.

Misha Pavel (above) and Chris Nugent (right) are international guest professors from January 2015.

January

Albinas Brancevičius from Lithuanian University of Health Sciences visited Halmstad University February 26-27 to see more of the way we work with research and new products within Health science. During the visit Albinas met staff from CAISR, Hälsotek-nikcentrum Halland, Science Park and the unit for strategic support.

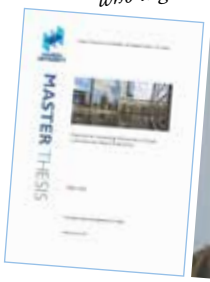
February



Prof. Naoki Saiwaki, visited us March 16-19. Prof. Saiwaki is working with a new graduate school in 2016 and interested in collaborating with us in research and on the student exchange level.

Welcome to the dissertation, Magnus Jonsson chairman for the event and Anna Mikaelyan who is going to defend her thesis.

Anna Mikaelyan defended her doctoral thesis Compact orientation and frequency description with applications to biometrics on April 17



Matej Uličný completed his master thesis during Spring 2015 at the Master programme in Embedded and Intelligent systems. He wrote a paper based on the thesis entitled "Robustness of Deep Convolutional Neural Networks for Image Recognition" together with his supervisors (Jens Lundström and Stefan Byttner) and it was accepted to the International Symposium on Intelligent Computing Systems, March 16-18 2016, Merida, Mexico.

March

April

The Industrial Advisory Board and CAISR staff gathered on March 10 for a workshop with focus on the coming four years in the research cooperation. One part of the day the work was split into two groups dealing with CAISR application areas. The upper photo is from the Health technology session, and the photo below shows some of the IAB members working with Intelligent Vehicles.

The Industrial advisory board, The Reference group and CAISR staff gathered for a joint meeting in May

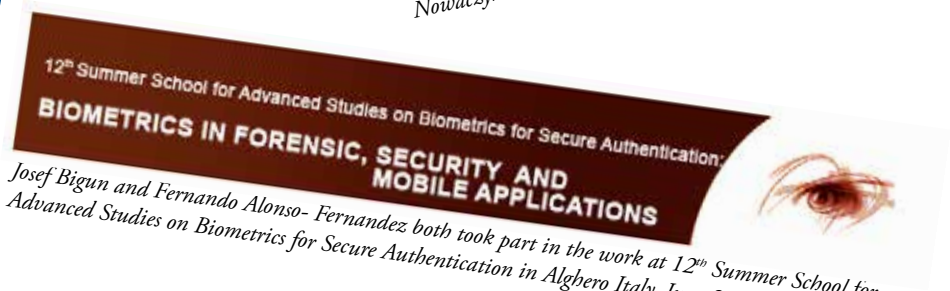
Professor Enrique Alba from University of Málaga, Spain, gave a talk "Intelligent Systems for Smart Cities" at Halmstad Colloquium on June 4.

May

Peter Mühlfellner defended his doctoral thesis Lifelong Visual Localization for Automated Vehicles on May 13.

June

Jonas Kalderstam visited us on June 10 and had a meeting with our "uptime" group. Jonas gave a presentation about survival analysis. In the photo Thorsteinn Rögnvaldsson, Jonas Kalderstam, Sławomir Nowaczyk and Sepideh Pashami.



Josef Bigun and Fernando Alonso- Fernandez both took part in the work at 12th Summer School for Advanced Studies on Biometrics for Secure Authentication in Alghero Italy, June 22-26

Josef Bigun was awarded a Honorable mention for Most Cited CAISR paper 2005 - 2015. The paper is titled: Discriminative multimodal biometric authentication based on quality measures, and cited 61 times.

Dr Ivandro Sanches, a speech analysis researcher at FEI university in Sao Paulo visited us at the end of August. Here together with Anita Sant'Anna, Mareike Lutz and Maria Luiza Recenta Menezes.

July

Sławomir Nowaczyk and Björn Åstrand held docent lectures on June 18. Sławomir gave a talk with the title Data Mining for Predictive Maintenance of Heavy Duty Vehicles. Björn talked about Perception systems for mobile robots with applications in Agricultural and Automatic Guided Vehicles domain.

August

Jérémy Heyne, Student at Polytech' Clermont-Ferrand, France, spent three months at CAISR on an internship. Here with a quadcopter.

The external evaluation experts for the CAISR halftime hearing on September 10. From left Per Stenström, Malin Henningsson, Susanne Andersson, Jörgen Appelgren, Maria Lindén, Xin Yao, Marianne Treschow and Stefan Östholm.

Nicholas Wickström, Siddhartha Khandelwal, Rögnvaldur Saemundsson and Anita Sant'Anna gathered for a discussion about cooperatioon between CAISR and CIEL.

Wagner Ourique de Morais defended his doctoral thesis Achitecting Smart Home Environments for Healthcare: A Database-centric Approach on Sept. 16

September

Inauguration of the Halmstad Electronic Center and Halmstad Intelligent Environment at September 11. The opening was framed by a conference where Research for Innovation was presented to representatives of the region in industry as well as the public sector. The opening was held by Helene Hellmark Knutsson, Minister of Education and Research.

October

Left: Best Paper Award to Master Student Andreas Ranftl, at the 14th International Conference of the Biometrics Special Interest Group (BIOSIG) in Darmstadt (Germany) for the paper "Face Tracking Using Optical Flow: Development of a Real-Time AdaBoost Cascade Face Tracker".

Stefan Byttner was appointed as docent on September 1

The 13th Scandinavian Conference on Artificial Intelligence (SCAI 2015) was held at Halmstad University November 5–6. Maj Stenmark from Lund University spoke about challenges and opportunities with Swedish robot programming.

The Intelligent Home workshop at November 4. Live demo of a self-fixing robot, created by master student Yinrong Ma. The robot finds itself in the mirror, checks if its appearance is OK, and fixes whatever is wrong. In this case, the robot is fixing the letter "T" on its label "ROBOT".

Johan Engdahl from Halmstad hospital, Antanas Verikas, Per-Arne Wiberg and Fernando Alonso-Fernandez in discussion about possible research cooperation regarding cardiological measurements

Jennifer David spent six weeks at the Robotics Mobility Group, MIT, where they have developed an autonomous highway navigation planner for vehicles and it was run in this car. On the photo, Jenni acted as a test subject for an experiment.

November

December

The AIMS project made a video showing the results in the project. The video was launched in the end of December. See it on Youtube.

Researchers at CAISR informed bachelor students about current research at the lab. Martin Cooney showed some of the robots he's working with.

Stefan Byttner, Björn Åstrand, Jens Lundström, Fernando Alonso-Fernandez and Martin Cooney discussed the second half of CAISR during a workshop in the end of November.

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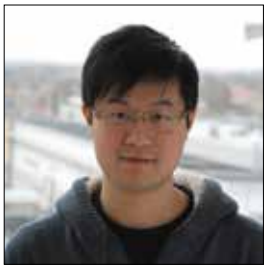

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CAISR Publications 2012–2015

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