ANNUAL REPORT 2018

CAISR

Center for Applied
Intelligent System Research

HALMSTAD
UNIVERSITY

Cover: After a 72-hour hackathon arranged by Volvo, a group from Halmstad University won the Best Build Team award with its smartphone prototype app Intelligent Probe. From left: Yuantao Fan, Maytheewat Aramrattana, Sepideh Pashami, Hassan Nemati and Eren Erdal Aksoy.

CAISR

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Intelligent Systems Research

Annual Report 2018

Knowledge Foundation

Table of contents

CAISR

Annual report 2018

Director's statement

The Center for Applied Intelligent Systems (CAISR) started in 2012. The overall goal we set was to establish a long-term joint program towards aware intelligent systems and build up CAISR to an international level environment for research, undergraduate, graduate and post-graduate education, characterized by being very attractive to industrial partners and with high quality research and innovation. What this meant was qualified and quantified in several goals for different subfield, goals that should be met by 2018. The goals related to research volume, education volume, quality of research output, quality of education, volume of scientific papers, volume of student theses, volume of PhD education, international aspects in the PhD education, amount of research together with external partners from industry and public sector, and the international and open culture among the staff. A review of the goals shows that we have met almost all of them, and as director for the center I am very proud of our joint development.

CAISR has continuously grown over the last 7 years, and during 2018 we continued to recruit staff. CAISR has now successfully gone through a generation shift, with one prominent professor retiring and now replaced by two new very interesting professors. Despite this generation shift, in 2018 we managed to publish our hitherto highest number of scientific journal papers.

We have managed to nurture our culture of being good cooperation partners for external partners. An evaluation of how our partners appreciate the collaboration shows that we continue, in their opinion, to be excellent at research in co-production. During 2018 we also ran a series of challenge workshops together with the industrial partners to form the future of CAISR, from 2020 and onwards.

We see that both our staff and our graduated PhD students are attractive to industry, but we also see that there is an entrepreneurial culture in CAISR. Not only is our joint research resulting in patents and implementable solutions, it also produces new companies and develops new important competence. A further sign of this competence was when a team with assistant professors and PhD students from CAISR took part in a 72 hour hackathon organized by Volvo and were awarded the best build prize (see cover).

Finally, we continue to see strong results from the students in our undergraduate programs. In 2018 a team of bachelor students, from three different engineering programs in Halmstad, participated in the National Science Foundation Cyber-Physical Systems Challenge and came in second place in the finals in Arizona. It was a great experience for the students and a lot of fun for us.

Thorsteinn Rögnvaldsson

Scientific Core

CAISR's scientific agenda is aware systems research, defined 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.

In the field of knowledge management, the ability to create and transfer knowledge efficiently is considered to be a key competitive advantage for a company or an organization. It follows that, in the age of digitalization, the ability to use computers to create transferable knowledge from product and customer data is a key competitive advantage. This is the common research topic for CAISR, and we call a system that can autonomously create knowledge an *aware* system.

But what is knowledge? An often used definition in knowledge management is that "knowledge is the whole body of cognition and skill which individuals use to solve problems. It includes both theoretical and practical everyday rules and instructions for action. Knowledge is based on data and information, but unlike those two, it is always bound to persons. It is constructed by individuals, and represents their beliefs about causal relationships"[1]. This definition is unfortunately neither very precise nor useful for approaching the question on how to create knowledge in the context of machine learning (ML) and artificial intelligence (AI).

A better formalism, for our purpose, is the *Data, Information, Knowledge, and Wisdom* (DIKW) hierarchy[2], which builds on ideas presented by Russell Ackoff[3] in his 1988 address to the Presidents of the International Society for General Systems Research. In it, Ackoff discusses what is required to generate knowledge and wisdom, and seems quite critical towards computer-based methods that claim to generate knowledge. Ackoff ends his address by saying that "wisdom-generating systems are ones that man will never be able to assign to automata".

Ackoff describes a hierarchical structure for the process, stating that "Wisdom is located at the top of a hierarchy of types, types of content of the human mind. Descending from wisdom there are understanding, knowledge, information, and, at the bottom, data. Each of these includes the categories that fall below it – for example, there can be no wisdom without understanding and no understanding without knowledge. Nevertheless, it is my impression that on the average about forty percent of the content of human minds consists of data, thirty percent information, twenty percent knowledge, ten percent understanding, and virtually no wisdom." (The last statement followed by a joke-like comment about politicians.)

The DIKW hierarchy and the construction of wisdom is often illustrated with a pyramid (see figure below); the higher a system reaches on the pyramid, the more aware it can be. There can be interactions both upwards and downwards in the pyramid.

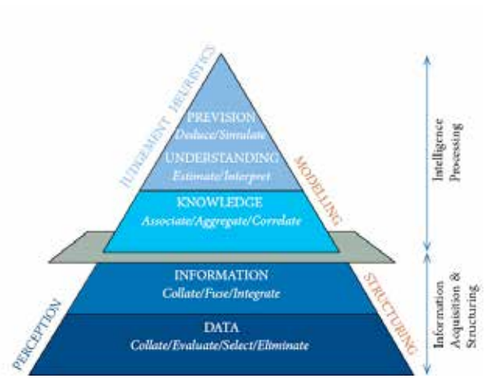


Figure 1. The knowledge pyramid, adapted from Ackoff (1989). "From Data to Wisdom". Journal of Applied Systems Analysis 16: 3–9.

The bottom level in the pyramid, *data*, deals with collecting and representing data. A key research question here is how to autonomously select what data to collect. How can a system decide what data are (or will be) relevant? A related question is how to construct (learn) general features that apply to many problems, or to transfer features from one setting to another. Furthermore, with endless streams of data (the "internet of things") it is impossible and uninteresting to save all data; it is necessary to save snapshots, compressed, or aggregated representations of the data. These representations should apply to many different tasks. Also, features that look unimportant today may end up being important tomorrow. An aware system needs to be curious, able to explore and learn.

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. Important open research questions here regard autonomous clustering and categorization of events. How can events be autonomously grouped 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 data source associated with another "event" in another data source? Can such associations be formulated into rules? An obvious example is the supervised learning setting, where "events" (input) are matched to correct responses (target) provided by an expert and encoded into a rule (model). An interesting 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, 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 must be capable of extrapolating information into the future, and be able to estimate and evaluate the consequences of actions based on previous observations.

It is obvious that being able to do tasks on each level autonomously would be a sought after ability, and even more attractive to merge them into an autonomous information creating, knowledge creating, or even wisdom creating system.

The example paper referred to on this page shows how these skills fit very well for building predictive maintenance systems. In predictive maintenance (be it for people or for machines) we do not always know beforehand what are the important data, we do not know (or cannot list) all possible events that can occur, and we cannot have experts state all possible faults beforehand. Furthermore, we do not always know ourselves the causal connections, why certain things happen and others do not. However, we are now collecting more and more data, from vehicles (or people), from workshops (or hospitals and general practitioners), from all sorts of sources, that enable information driven approaches to find the connections, and to create the knowledge.

Paper in Focus

Self-monitoring for maintenance of vehicle fleets

Data Mining and Knowledge Discovery, 32(2), pp 344–384.

Authors: T. Rögnvaldsson, S. Nowaczyk, S. Byttner, R. Prytz, M. Svensson

An approach for intelligent monitoring of mobile cyberphysical systems is described, based on consensus among distributed self-organised agents. Its usefulness is experimentally demonstrated over a long-time case study in an example domain: a fleet of city buses. The proposed solution combines several techniques, allowing for life-long learning under computational and communication constraints. The presented work is a step towards autonomous knowledge discovery in a domain where data volumes are increasing, the complexity of systems is growing, and dedicating human experts to build fault detection and diagnostic models for all possible faults is not economically viable. The embedded, self-organised agents operate on-board the cyberphysical systems, modelling their states and communicating them wirelessly to a back-office application. Those models are subsequently compared against each other to find systems which deviate from the consensus. In this way the group (e.g., a fleet of vehicles) is used to provide a standard, or to describe normal behaviour, together with its expected variability under particular operating conditions. The intention is to detect faults without the need for human experts to anticipate them beforehand. This can be used to build up a knowledge base that accumulates over the life-time of the systems. The approach is demonstrated using data collected during regular operation of a city bus fleet over the period of almost 4 years.

1 Probst, G., Raub, S., & Romhardt, K. (2000). *Managing knowledge: Building blocks for success.* West Sussex, England: John Wiley & Sons Ltd.
2 Rowley, J. (2007), "The wisdom hierarchy: representations of the DIKW hierarchy", *Journal of Information Science,* **33**, pp. 163-180.
3 Ackoff, R.L. (1989), "From data to wisdom", *Journal of Applied Systems Analysis*, **16**, pp. 3-9.

CAISR **development** 2012-2018

The Center for Applied Intelligent Systems Research (CAISR) started officially in January 2012. The overall goal for Halmstad University with CAISR was to establish an international level environment in intelligent systems for research, undergraduate, postgraduate, and PhD education, characterized by high quality research and innovation with a strong emphasis on applications. In 2011 we set up several goals for CAISR that we wanted to achieve by 2018, goals for the desired development in research, education, and cooperation.

The *international level in research* was qualified and quantified in terms of publication outputs, the volume of external research grants, and looking at where the grants came from. The desired research volume by 2018 was set at 25 million SEK (Swedish kronor), about 2/3 larger than in 2011, and this should lead to a production of at least 20 scientific Journal papers per year (and equally many conference papers). The expected ratio of number of papers to research turnover was estimated from international and national comparisons [1, 2, 3]. A high fraction of the papers should be published in high level journals and conferences.

The research turnover for CAISR exeeded 25 million SEK in 2018. The research lead to 25 journal papers and 17 conference papers, which is two times the scientific production in 2011 and 2012. About 25% of our journal papers the last four years have been published in journals that are either among the top 10% in computer science or engineering in the Scopus database, or top 20% in the Norwegian DBH system (so-called "level 2" publication channels).

Strong research should mean top quality *education* to a large group of students. CAISR's expected contribution to education by 2018 was qualified and quantified in terms of a desired amount of time devoted to education, a desired quality of courses as evaluated by the students, and a desired number and quality of master and bachelor theses supervised by CAISR staff. The target amount of teaching by 2018 was set to the equivalent of 15 half time positions, which was almost double that in 2011. The number of master theses should be at least 10 per year, with equally many bachelor theses, and a significant ratio of the master theses should lead to scientific publications.

The amount of teaching done by CAISR staff in 2018 equaled almost 16 half time positions. Not only are CAISR staff now engaged in more courses, but student interest in intelligent systems has also increased, showing the good foresight when making the CAISR investment. CAISR staff have consistently worked with improving course quality, and as many as 96% of the students who filled in course evaluations 2018 graded the courses given by CAISR staff as "good" or "very good" (as a comparison, this number was 85% in 2015). Over the last four years, CAISR staff members have supervised more than 10 master and more than 13 bachelor theses per year. About 1/6 of the master theses have resulted in scientific publications, and our students have received prices and won international competitions in relation to their thesis work.

High quality research should mean *high quality PhD education*. This was qualified and quantified such that CAISR should reach 2-3 PhD dissertations per year in 2018, that PhD students published their work in good scientific channels, that PhD students got good placements after finishing their degree, that CAISR should have a PhD student exchange program with other universities, and that PhD students thus got a longer experience from within another research environment during their studies. The target was to have 10 PhD dissertations between 2012 and 2018.

In 2018 there were two PhD dissertations in CAISR, and 2-3 are likely during 2019. There have been in total seven PhD dissertations in CAISR between 2012 and 2018. This is below the target and there has been a higher than expected number of students who left after their half-time Licentiate degree. All but one of the seven PhD students who defended their PhD thesis have papers in their thesis that are in journals that are at least level 1 in the Norwegian DBH system, some in journals that are level 2. Only one of the seven did not spend a longer time (at least some weeks) in another research environment, and that was because of visa issues. One of the industrial PhD students finished his PhD in much shorter time than the stipulated four years.

1 Gaughan, M. and Bozeman, B. (2002), "Using curriculum vitae to compare some impacts of NSF research grants with research center funding", *Research Evaluation*, **11**, pp. 17–26

2 Larivière, V., Macaluso, B., Archambault, É., and Gingras, Y. (2010), "Which scientific elites? On the concentration of research funds, publications and citations", *Research Evaluation*, **19**, pp. 45–53

3 Swedish universities are required to report the ratio between scientific publications and research turnover in their annual reports.

Industrial cooperation is a key ingredient in CAISR. Being excellent at cooperating with industry (and other external partners) is a characteristic that should be very clear in CAISR. The level of the industrial cooperation was qualified and quantified as having many research projects in cooperation with industry.

It was clear from the start that intelligent systems, e.g. artificial intelligence and machine learning, would be an increasingly relevant topic for Swedish industry and society. There was thus never any question about the potential relevance of the research; it was a matter of making the cooperation work well and create value from it. Some of the initial CAISR researchers and industrial partners had several years of experience with academy-industry cooperation and ideas on how to develop this further. Mobility, i.e. that researchers spend time embedded in the partner companies, was identified early as an important ingredient in successful cooperation. Several of the CAISR researchers today are mobile and spend about two days every week with the industrial partner.

Peter Berck (CAISR), Petter Wirfält (Volvo Group), Robert Valton (Volvo Group) and Björn Åstrand (CAISR) at the workshop "CAISR Future Directions".

In the CAISR evaluation done in 2015, the expert panel evaluated the coproduction with industry as excellent, and further commented that this was a real strength and should be carefully fostered and grown into a unique selling point of CAISR. The expert panel also conducted a small survey with the CAISR industrial partners and concluded that CAISR's quantitative and qualitative goals for coproduction had been achieved. In late 2018, the CAISR management commissioned an updated, and both wider and deeper, study of the industry partners' opinion on the value of the collaboration with CAISR. This study (summarized later in this report) confirms the conclusions from 2015.

In the fourth quarter of 2018 CAISR researchers conducted several workshops with the external partners, discussing the challenges that they see and what would be important directions to take from January 2020.

Finally, an open and international culture is important for a creative research and education environment. There should also be a good balance between permanent staff on different academic levels, and temporary staff like visiting professors and postdocs. We qualified and quantified this such that CAISR should have 25-30 members, of which 5 should be professors, and that the majority of the staff should have postdoc experience from another international research environment, and the majority of the staff should have their PhD degrees from another university. The decision to have this mix was made against the background that Swedish universities tend to be dominated by faculty that have their under- and postgraduate degrees from the same university as they work in[4, 5].

Today, about 80% of our staff have their PhD and undergraduate degree from other universities. We have four full professors, and there are many more than 25 staff members. We have several postdocs and our faculty recruitment is most often through "tenure track" type of positions: assistant professors who prove themselves and get offered permanent associate professor positions.

All in all, we can be proud of CAISR's development from 2012 to today. It has been good and according to an ambitious plan.

4 Gerdes Barriere, S., Baard, P., and Nordstrand, J. (2016). "Rekrytering av forskare och lärare med doktorsexamen vid svenska lärosäten", the Swedish Research Council. VR 1601, ISBN 978-91-7307-309-7

5 Bienenstock, A., Schwaag Serger, S., Benner, M., and Lidgard, A. (2014) "Combining excellence in education, research and impact: inspiration from Stanford and Berkeley and implications for Swedish universities", SNS Förlag

Creating Value with CAISR

In late 2018, CAISR commissioned an evaluation of the center's industrial impact and value. This was done both to gauge CAISR's industrial relevance over the first seven years, and to create a basis for how to develop CAISR beyond 2019. In 2018, 21 external organizations were active partners in CAISR research and a selection was made of 12 of them, focusing on the ones with a longer and more extensive involvement. The seven core partners in the CAISR consortium were included, plus five more from other projects in CAISR. The companies ranged from rather small start-ups, to mid-size ones (from Sweden or part of an international business group) and large international organisations. An external evaluator, Dr Lena Holmberg (IMCG[1]), conducted interviews with the partners and wrote a summary report.

Dr Lena Holmberg, conducted the interviews and wrote the report "Creating Value with CAISR"

The result is that the organizations and individuals interviewed are satisfied with the collaboration within CAISR. They are impressed with the competence among the researchers and very positive regarding the researchers' attitude towards working with companies. The companies really appreciate the opportunity of having the researchers on site, working together with the personnel on genuine problems using real data. No radical changes are suggested to either direction of the research or the kinds of collaboration activities.

Several organizations mentioned concrete results as an important value delivered through CAISR. Through collaborating with researchers who work on real data and with real systems, new services and patents have been developed. Some of the results have been put to use in the organizations delivering value. However, not all projects have (yet) resulted in tangible results. Sometimes this has been the result of changes in the project due to lack of resources or focus, and sometimes the external partner organisation has not managed to make use of the results.

Most organizations mentioned competence development as the main value from CAISR. They always learn through the project, mostly new methods but sometimes also how difficult it is to create value from AI and Machine Learning. Sometimes the learning has been to not go in a specific direction. The competence and capacity building have been done in various ways. Some organizations have appointed an industrial PhD, whereas others have received training or just worked together in projects. Through CAISR they get access to competence they do not have in-house.

Large partners seem to value competence development most, whereas smaller ones really depend on getting results that can quickly be transferred into real results. One challenge for CAISR is to continue to address both these needs. Other kinds of values created for the companies include recruiting and branding, which is very much in line with the center's objectives.

Several organizations point out that when CAISR started, they were rather alone in Sweden focusing on this kind of AI and Machine Learning. In recent years many of the larger universities have received large amounts of funding within this area, why the competition is getting fiercer. However, the evaluation indicates several opportunities for CAISR to continue to create a competitive environment, by making strategic decisions regarding the future research focus and application areas, but also by fine-tuning collaboration processes. The largest opportunity might be to develop better processes for how to implement the knowledge created in the research projects and make it work on an industrial scale. Achieving real impact requires a devoted effort from the industrial/external partners, since the benefits are primarily reaped outside the academic setting. However, multidisciplinary research is needed to enhance this process further.

1 https://imcg.se/

Volvo Buses
Core business transformation

An interview with Ervin Omerspahic Feature Owner Quality & Uptime, Volvo Buses

Imagine a bus heading towards the ski slopes in the Alps stops right in the middle of Autobahn, creating a really problematic situation. Or that a bus on Oxford Street gets engine failure and thus clogs up the whole of London. With the help of AI, this can be avoided by collecting and analysing data so that potential risks with vehicles can be identified and addressed with service before breaking down.

According to Ervin Omerspahic, using bus parameter data for predictive maintenance provides several benefits for the customers. Fewer will experience discomfort due to delays and the risk for accidents will drop. The buses can last longer and thus become a better investment. Better precision in service can be obtained, thereby decreasing the costs. Not to forget positive impact on environment!

"I've learned a lot from the collaboration with CAISR, among other things, I've realized that everything is not perfect. In addition, I now understand how important it is with cross functional collaboration and that we cannot do everything ourselves, so collaboration with CAISR is necessary."

Ervin Omerspahic

Volvo Buses has a vision that by 2030 none of their products will have any unplanned stops. With the help of machine learning, they can go from selling buses to selling uptime, i.e. providing mobility instead of vehicles. It affects technology development but, to a very high degree, the business processes from purchasing to sales, and requires a cultural change and a new mindset for product development.

The demand for people with machine learning competence is great right now, why the support from the researchers from CAISR has been crucial.

Region Halland
Learning to manage risks

An interview with Markus Lingman, Strategic Developer, Consultant Physician and researcher at Region Halland

Can the healthcare area learn anything from the automotive industry? Are human beings and care systems really similar to cars? Yes, in some ways, says Markus Lingman, since at a higher level of abstraction it is all about pattern recognition and risk evaluation.

Markus Lingman

Region Halland contacted CAISR to investigate whether their experiences of working together with the automotive industry could be of benefit to the healthcare system based on the question of how to identify which patients are at high risk of being re-admitted. Today, extensive planning is done for very many patients, which is time-consuming and in addition many are still coming back within 30 days. When all available data were gathered and the algorithms applied, it turned out that it is possible to predict with high precision at the individual level which ones have a high risk of re-admittance. This makes it possible to focus more efforts on those who are most at risk. Furthermore, the situation is of a relatively general nature, so it can be applied within other activities, such as predicting what happens to patients after visiting the emergency department.

"Since I am a doctor and have spent a long time understanding how to deliver better care, I find it very exciting to see the possibilities with AI. I would like to call it a disruptive innovation, where we can take a great step in a new direction unlike other developments that are more of stepwise modifications and refinement."

Within Region Halland, they are increasing the number of people with AI competence by bringing in educational elements for doctoral students. They work according to the motto "think big, start small, scale fast".

Predictive maintenance - **health**

Healthcare is facing major challenges, in Sweden and worldwide. Changes in demographics, like ageing populations, and more people living with chronic conditions create a greater demand for care. The discrepancy between the number of people in care-needing ages and the number of people in the labor force increases rapidly. Some nations even see problems with educating enough skilled staff to replace those that leave the healthcare professions. In parallel to this, the disease panorama is changing, as well as the ability of the medical care to diagnose and treat diseases and treat patients in more specific and individualized ways. New methods and drugs that reach the market tend to be advanced and costly.

Healthcare costs grow faster than the economic growth, and have done so for a long time, which is clearly not a sustainable situation. The healthcare system will simply put not fulfill its mission if it does not work differently from today and becomes more aligned with expectations and more flexible.

In that perspective, technology becomes central. There is considerable expectation that new technologies, and digitization, will fill the increasing gap between needs and resources. Large international investments are made in this area. Not least aimed at artificial intelligence (AI) since its methods are well suited for tasks that constitute the working days of healthcare workers: prediction and pattern recognition (read risk assessment and diagnostics). Machine learning and other AI methods are particularly suitable for contributing to increased understanding of both complex organizational and biological systems. Healthcare needs to be part of the rest of society, where intelligent systems are developing and applying rapidly. Healthcare is no different from business in this context in that vast qualities of digital data are being generated and stored, and automated means of analysis are essential if we are to improve the system and patient outcomes. However, healthcare is different from many other aspects of society in that we insist that solutions and methods are evidence based and verified to a high standard. This is often difficult to achieve with AI based solutions and is one of the main academic challenges.

Region Halland has developed a strategic healthcare analysis and research platform, which offers a unique integration of data sources for people in Halland, from all levels of the care chain including measurements from primary care, ambulance, emergency care, inpatient care and electronic health records together with resource data. Halmstad University, through CAISR, and Region Halland established a research collaboration that enables real life studies using the platform, where the conditions are optimized by having research staff employed with both parties. This allows researchers to work in the IT environment where the solutions will be applied. Ongoing studies include predictive studies of emergency care patients, understanding how we can help patients achieve prescribed treatment, intelligent home development work and collaboration within the Halmstad Health Technology Center (HCH). We have also begun exploring the opportunities for dynamic, need-driven duty roster planning in healthcare units based on predicted needs. Another ongoing project looks at early detection of risk for adverse outcomes in patients with other using electrocardiograms (ECGs) and deep neural networks. Here the data consists of over five hundred thousand ECG samples, collected over time throughout Halland.

Knowledge transfer between different applications has been key. Such disparate fields as intelligent vehicles and clinical decision support have much in common in their methodology and technology base (sensors, algorithms, etc.), and CAISR strives to exploit these synergies. The collaboration, through Region Halland, with researchers affiliated with Brigham and Womens' Hospital, Harvard Medical School, and Berkeley has contributed a lot to our knowledge base.

A development area that needs to be addressed is the integration of data from different sources. The development on the sensor side is swift, but it is necessary to integrate the information from many sources to get the overall picture of a person's or organization's current state and change. In order to meet the need for a more comprehensive picture, we will continue the work on infrastructure initiatives. The continued development of HCH's Test Environment Halland and the Halmstad Intelligent Home (an initiative within CAISR) is central in this regard. Investing in test beds where companies, developers and public actors can meet is important to support the development and introduction of new digital products and services. There is also an ongoing need to meet ethical concerns about handling sensitive personal data; architectures such as edge computing can solve some of these issues and need further research.

Digitization leads to increased expectations for personalized solutions (services) with high quality and good accessibility. The rapid development we see in AI and the pressed resources means that a paradigm shift will take place in healthcare. When intelligent systems become more and more common in areas such as prevention, detection, diagnosis and treatment, the pathways in healthcare will change, as well as the professional roles. The way we prioritize within care will evolve and home healthcare will develop and work methods will be streamlined. All signs indicate that more and more people will be cared for in their homes. Prevention services increase and people will gain (or will be expected to gain) greater influence over their health and care. The overall objective of our proposed project is to enable industry and the public sector to deliver the most competitive products and services for public and private care at home, with the individual at the center. A key part is to create a technical infrastructure that enables interoperability between different products and services, as well as enabling a transfer of information in the healthcare system. Among other things, the technical infrastructure will be evaluated and implemented in a private residential area – a test bed.

Data driven healthcare

Data driven healthcare, i.e. using data to guide the decisions and strategic planning, has a large potential to improve the healthcare system in Halland, in Sweden, and in the world. Region Halland have demonstrated in very concrete terms how comprehensive data can be mined to support a basis for decisions that both decrease cost and increase quality.

During a period when the population in Halland increased by more than 4% and there was a 7% increase in patient arrivals to the emergency department, Region Halland implemented changes that had the following effects:

- The hospital bed days were reduced with the equivalent of 2-3 hospital wards across the system, at the same time the occupancy levels remained stable on inpatient wards.
- The 30-day all cause readmission rate went down by 11%.
- There was a 25% increase in patients discharged before noon.
- The overall hospital length-of-stay (LOS) decreased by 18%.
- The total hospital admissions decreased by 8%.
- The admission rates from the emergency department (ED) to the hospital decreased by 18%.

Taken together, these correspond to annual productivity improvements of up to 80 million SEK in Halland.

Some changes were motivated from data analysis, using statistics, AI, and machine learning – tools adding to conventional healthcare management. In part the work was done in cooperation with researchers from CAISR, Brigham and Women's Hospital (Boston), Harvard Medical School (Boston), and Berkeley (Berkeley).

Predictive maintenance - **machines**

Predictive maintenance builds on monitoring the condition of specific equipment, observing its history and forecasting its future usage and wear trends in order to identify the optimum time to perform maintenance on it. In most industries today, unexpected downtimes and failures are costly, which is why accurate predictions of maintenance needs and possible imminent problems become crucially important.

The predictive maintenance paradigm significantly improves upon preventive maintenance by building on predicting individual health status of the actual piece of equipment, not a general expected health. This allows taking into account, among others, that usage profiles can be very different, due to global aspects (e.g. climate, education levels, and maintenance culture) or the particulars of the assignment (e.g. digging rocks or gravel, driving on the highway or in the city, etc.). Many market analysis reports indicate that the predictive maintenance market will grow very rapidly the coming years. Digitization and "big data," faster computers with cheap memory, and especially machine learning algorithms that learn from very large data sets have demonstrated the possibility of making such specific predictions with very high accuracy.

Predictive maintenance fits perfectly aware systems research, i.e. the research on systems that construct knowledge (semi-) automatically from observing data. In many domains "normal" operation of a system is difficult to characterize precisely before deployment, and what is "normal" will vary throughout the lifetime of the equipment. Similarly, possible faults are often unknown or hard to describe precisely. Finally, due to cost and design reasons, it is never possible to measure everything of interest; the condition of the equipment needs to be evaluated based on data that is available because it is convenient to capture – not necessarily the ideal data.

Over the last 10-15 years, we have been involved in many predictive maintenance projects. The majority of them in collaboration with Volvo Group, including both trucks and buses. In some cases the focus was on unsupervised machine learning and detecting anomalies directly from the data, while in others we focused on supervised learning with the goal of replicating the current repair behavior of the workshops. We have worked with warranty data as well as with combining internal and public information. The most recent project focuses on the emerging field of electromobility and extending the lifetime of batteries.

The majority of projects within predictive maintenance projects have been done in collaboration with Volvo Group.

CAISR researchers have also done predictive research in the Smart Energy sector. Reliability analysis of underground power cables in electrical power grids helps the local distribution company Halmstads Energi och Miljö (HEM) in providing better services. We have developed a meta-framework for self-monitoring systems to be applied in district heating (together with HEM & Öresundskraft) and for analysis of heat pumps (with EasyServ and Sydpumpen). Our other partners come from manufacturing (Alfa Laval), connectivity (HMS) and even healthcare (Getinge Group). We also collaborate with other academic partners, for example on developing scalable machine learning methods for massive streaming and distributed data.

From the scientific perspective the most important outcome of the predictive maintenance research within CAISR are the methods, algorithms and approaches we have developed in order to solve problems together with our industrial partners. This work has resulted in almost 50 scientific peer-reviewed publications, several Licentiate & PhD degrees, as well as patents. CAISR researchers have developed both theory and practice. Examples of the former include: theoretical foundations of hierarchical machine learning, transfer learning; multi-task representation learning; clustering techniques; and our anomaly detection framework (COSMO). Examples of the latter include: an efficient approach to compress bivariate histograms of truck engine data; and an algorithm for predicting maintenance needs of heavy-duty vehicles based on telematics data and repair logs.

From the scientific perspective the most important outcome of the predictive maintenance research within CAISR are the methods, algorithms and approaches we have developed in order to solve problems together with our industrial partners.

CAISR research is not only about developing new methods. It is very much about applying those methods to real problems together with our partners. With HEM we have developed a ranking of electrical cables based on probability of failure, and with Öresundskraft a ranking of the most deviating district heating substations. By analyzing regularities in heat load patterns, we have discovered that many buildings use outdated, inefficient heating control strategies. In many domains, we have developed informative features that describe the data in an understandable way and lead to better analytics performance. Examples include using long short-term memory (LSTM) neural networks to model the activities of forklifts, or interpreting the timing of different phases of the sterilization process as early symptoms of failures.

In addition, we implement those methods and make them available as tools[1] , as well as support our partners in developing and deploying within their infrastructure – such tools are used today within Volvo Group, HEM, Getinge Group, and others. Being a university, we are very much active in education, and predictive maintenance is heavily featured both in our on-campus courses at MSc level, as well as in our professional education (described later in this report).

Together with our partners, we have identified several important directions for further research on predictive maintenance. The most broadly applicable one relates to representation learning. Often the data collected are quite noisy, with many redundancies and complex inter-dependencies. This makes it difficult to build models directly from raw data, and instead requires creation of informative features. Current state of practice is to spend a lot of engineering effort to do this manually. The desired situation is to use machine learning to learn good representations from the data. State of the art of representation learning focuses on supervised approaches, which are, however, of limited use for many practical cases where labelled data is sparse.

Another direction is related to edge computing, where we develop methods for distributed and decentralized machine learning – to facilitate both lower communication costs and higher privacy. A third direction is about combining models built from data with expert and domain knowledge. In most predictive maintenance settings there is a lot of knowledge available, from engineering, design and workshop experience. This knowledge is valuable and can significantly strengthen the performance of data mining methods. We have coined the term "Joint-Human Machine Learning" to describe the ideal interactions between a user and the self-monitoring system. A fourth important direction is causal inference. Immediate action after predicting imminent failure is usually scheduling a workshop visit. However, identifying plausible explanations of the causes of the failure can lead to prescriptive actions for the driver, corrective actions for design engineers, and supportive action for workshop personnel.

1. https://github.com/caisr-hh/cosmo and https://semi.hh.se/

To the left: Data mining workshop with the industrial partners at the Smart Energy Conference

To the right: Reliability analysis of underground power cables in electrical power grids helps in providing better services.

Halmstad University team wins Volvo hackathon

The winning team, from left: Yuantao Fan, Hassan Nemati, Maytheewat Aramrattana, Sepideh Pashami and Eren Erdal Aksoy.

The developed computer vision solution detects various features on the excavator. Once the camera is close enough, the app starts detecting the borders of the shoe plate and returns the height.

After a 72-hour hackathon arranged by Volvo, a group from Halmstad University won the Best Build Team award with its smartphone prototype app Intelligent Probe.

– We created a smartphone app for automatic inspection of the undercarriage system of excavators. By using the smartphone camera, pictures of various excavator parts are analyzed through computer vision methods to measure sizes of, for instance, steel shoe and rolling bodies in the undercarriage system. "The analysis will for example determine the need for repair and can reduce the workload of Volvo Technicians", says one of the winning team members Eren Erdal Aksoy.

The competition was organized by Volvo Construction Equipment and Volvo Group Connected Solutions, and took place in Gothenburg, November 23–26, 2018. Sixteen international teams competed in using image intelligence to solve existing problems for heavy equipment and machines. The Halmstad University team from the School of Information Technology (mostly CAISR staff) consisted of PhD students Maytheewat Aramrattana, Yuantao Fan and Hassan Nemati, and assistant professors Sepideh Pashami and Eren Erdal Aksoy.

The app can become reality

Volvo Construction Equipment went on with analyzing the potential of the provided app prototype. There were also some negotiations between the winning teams. – We received an invitation to collaborate with two other winning teams in order to extend the prototype and make a more comprehensive demo in the coming Bauma fair in April 2019, which is the world's largest machinery and construction equipment trade fair, says Eren Erdal Aksoy.

About the hackathon

There were 220 international applicants to the VOLVO x HACK SPRINT, and 80 were selected for the competition. There were in total 16 teams from different countries such as Japan, UK, France, Ukraine, and Sweden. The final judgment was based on five criteria: Technical Innovation, Execution, Creativity, User Experience, and Pitch. Awards were given for Best Hack (awarded to the team that solved the real-world problem the best), Best Build (awarded to the team that built the most deployable solution), and Honorable Mention. The team from Halmstad University received the Best Build Award for its app Intelligent Probe.

VOLVO x HACK SPRINT

The VOLVO x HACK SPRINT was the first Volvo Construction Equipment and Volvo Group Connected Solutions hackathon that brought together multidisciplinary teams of three-to-five members in Gothenburg, Sweden, 23-26 Nov. to hunt for the next big innovation in image intelligence.

IJCAI **industry days**

Sepideh Pashami, together with Anders Holst, organized the industry days event at IJCAI-ECAI 2018 where companies known in the area of AI gave talks about their advancement and strategies with regard to AI. Several large AI companies -- such as Baidu Inc, Tieto, IBM research, Tencent AI lab, Zenuity, Ericsson, Alibaba AI Labs, Scania, Volvo Group, etc -- attended this event. The event took place on July 18 and 19, 2018 in Stockholm.

IJCAI 2018 Industry Days hosted two-panel sessions.

On the first day, Anita Sant'Anna moderated the AI in healthcare panel on the theme "How do we reach the utopian healthcare of the future?". Panel participants were Stefan Harrer (IBM), Christian Guttmann (Tieto), Claus Bentsen (AstraZeneca), and Mohammed El-Beltagy (RaceFox).

The discussion of the autonomous driving panel was moderated by Thorsteinn Rögnvaldsson on the second day. The topic of this panel was "Will we be able to buy fully autonomous cars in 2030?". The panel participants were Saimir Baci (Volvo GTT), Marcello Cirillo (Scania), Shashank Pathak (Visteon), and Nicholas Wickström (Zenuity).

Collaboration with Volvo

Volvo Group and intelligent systems researchers at Halmstad University have collaborated around predictive maintenance and uptime related projects for more than 12 years. This research has to the major part been funded by Sweden's Innovation Agency's (Vinnova's) Strategic Vehicle Research and Innovation Program (FFI). This has led to patents, algorithms, scientific papers, academic degrees, and services; services that are about to be deployed within Volvo Group. The next step together with the Volvo Group is to approach predictive maintenance in electromobility.

Peter Berck (left) and Reza Khoshkangini (right) are our boundary spanners collaborating with Volvo Trucks Aftermarket. Vera (Volvo's autonomous, electric truck) is visible in the background.

Halmstad University, **Research for Innovation** and CAISR

Halmstad University's vision is to prepare people for the future by creating values, driving innovation and developing society. The vision builds upon a university-wide vision and strategy process between 2011 and 2013, which also produced a research and education strategy for the period 2013-2020. The strategy emphasizes four dimensions that are important for both research and education: position, profile, quality and relevance.

Positioning means to position the university in education and research with respect to impact and specialization, and with respect to applied and fundamental. There should be both high consideration of use and high contribution to understanding in the research. The education programs should have a strong aspect of applied science. The students should learn how they can gain new knowledge and from this create innovations and value.

Profiling means that the university's profile as "The innovation driving University" shall be well known and recognized regionally, nationally and internationally. This means that we should emphasize this in student recruitment and promote the students' participation in different international venues with innovation, value creation and societal development. It also means that we should often show how research at Halmstad University leads to innovation, value creation and societal development.

Quality means to have high quality in research and education, for students, for faculty and staff. Programs and courses should be excellent and well appreciated by the students. Students should get good positions after graduation and their education should be relevant in their work. Research quality should be high, e.g. when measured with peer reviews and bibliometrics.

Relevance means that Halmstad University shall be a strategically important partner for industry and public-sector organizations to maintain and develop their quality and regional, national and international competitiveness. This means that a large part of the research should be done with external partners. It means that students should have frequent interaction with actors outside of the university during their education.

Halmstad University has a ten-year contract with The Knowledge Foundation to develop as a *Foundation Research Center.* The name for this venture is *Research for Innovation* and it stretches between 2012 and 2021. The Knowledge Foundation's annual funding to Halmstad University is between 30-35 million SEK, which equals almost half the government direct research funding to the university. Thus, Research for Innovation is a major tool for the development and profiling of the entire university. The goals of Research for Innovation are also expressed with respect to the four dimensions position, profile, quality and relevance.

CAISR is a major contributor to meeting the goals set for Research for Innovation, and the targets for CAISR (reviewed earlier in this report) were well aligned with the desired development for Research for Innovation.

PROFESSOR PORTRAIT

Mattias Ohlsson

”Here, I hope to continue my research with a focus on health and medical care, to be able to help in medical decisions as well as practical, clinical issues.”

The connection between computer algorithms and AI has fascinated Mattias Ohlsson for a long time. As a newly appointed Professor of Information Technology, it is a subject that he intends to continue to explore within CAISR. “My research area borders to AI, i.e. getting computers to display intelligent behaviour. It is very exciting and there is today a lot of interest in this type of knowledge in industry. I personally took an interest in one particular type of AI, so-called artificial neural networks, early in my career in the late 1980ies, and I have been able to stick to that interest even though artificial neural networks have been going in and out of fashion.”

Mattias Ohlsson is a physicist by training and started his PhD studies in Lund about 30 years ago, within a then newly formed group that focused entirely on artificial neural networks and machine learning. His PhD work started out with optimization problems using methods inspired from the Hopfield network, and one of his contributions here was an algorithm for tracking particles in high energy physics experiments.

After the PhD he did a two year postdoc at the Technical University in Denmark, and his research turned towards clinical decision support with machine learning methods. This has since remained his passion and he has published many papers on this, mostly dealing with cardiology and cancer. One noted paper deals with embedded intelligence for personal eHealth services and how to use machine learning to interpret electrocardiograms (ECGs) measured with mobile handheld devices[1]. Another noted paper presents machine learning methods for automated bone scan index scoring in relation to prostate cancer patients[1].

As is perhaps obvious from these two examples, Mattias Ohlsson is keen on developing methods that can lead to real health innovations. “By developing different support aids for health care, my research fulfills an important function, for example, helping doctors interpret images or giving diagnostic suggestions.” In the late 1990ies he co-founded Exini Diagnostics AB (https://exini.com/) that develops automated medical decision systems. The automated bone scan index method mentioned above is one of their products. Mattias also holds a couple of patents, one of which is about analysis of ECGs.

When asked about his most interesting research papers the last five years, Mattias mentions one where deep convolutional neural networks are used for the analysis of microscopic images related to prostate cancer[2], one with biomarker analysis with support vector machines (SVMs) and random forest (RF)[2], and one where artificial neural networks are used to better predict short-term and long-term mortality after heart transplants[3]. The latter study also estimates the expected benefit to the individual patient.

Mattias Ohlsson has been employed at Lund University for over 20 years. In 2004 he was promoted to associate professor (docent) there in theoretical physics in the subject field computational biology. He has taken on leadership responsibilities, as program manager for the undergraduate theoretical physics program, and as deputy head of the department for Astronomy and Theoretical Physics at Lund University. He is an appreciated teacher, and has e.g. given courses in artificial neural networks and machine learning at Lund University for many years.

”Much of what we consider to be science fiction today is something that we will actually experience in the future.”

The interest for these courses have tenfolded in the last years, from about 15 students to about 150 students each time. In Halmstad he will be providing his pedagogic skills in the new professional education that focuses on teaching machine learning and artificial intelligence to professionals. However, his main focus is on developing machine learning research for medical decision support together with Region Halland based on their healthcare analysis and research platform..

“In Halmstad, the research group focusing on machine learning and AI is larger than the one in Lund. Here, I hope to continue my research with a focus on health and medical care, to be able to help in medical decisions as well as practical, clinical issues. The good cooperation with Region Halland offers unique possibilities to do this.”

On a more philosophical note, Mattias Ohlsson thinks that AI will be a central part of our future. “Much of what we consider to be science fiction today is something that we will actually experience in the future. For example, robots will become so intelligent that it will be difficult to distinguish their behavior from human behavior.” He believes that the human awareness and ability to reason are the result of having a really large number of neurons and synapses, connected together in a complex structure. “If our mental abilities are a result of this complexity, then we should be able to construct artificial neural networks with the same capabilities – but we are far from that today.”

1 Rubel, P. et al. (2005), ”Toward personal eHealth in cardiology. Results from the EPI-MEDICS telemedicine project”, Journal of Electrocardiology, **38**, pp. 100 – 106

2 Ulmert, D. et al. (2012), ”A Novel Automated Platform for Quantifying the Extent of Skeletal Tumour Involvement in Prostate Cancer Patients Using the Bone Scan Index”, European Urology, **62**, pp. 78-84

3 Gummesson, A. et al. (2017), ”Automatic Gleason grading of H and E stained microscopic prostate images using deep convolutional neural networks”, SPIE Medical Imaging, 2017, Orlando, Florida.

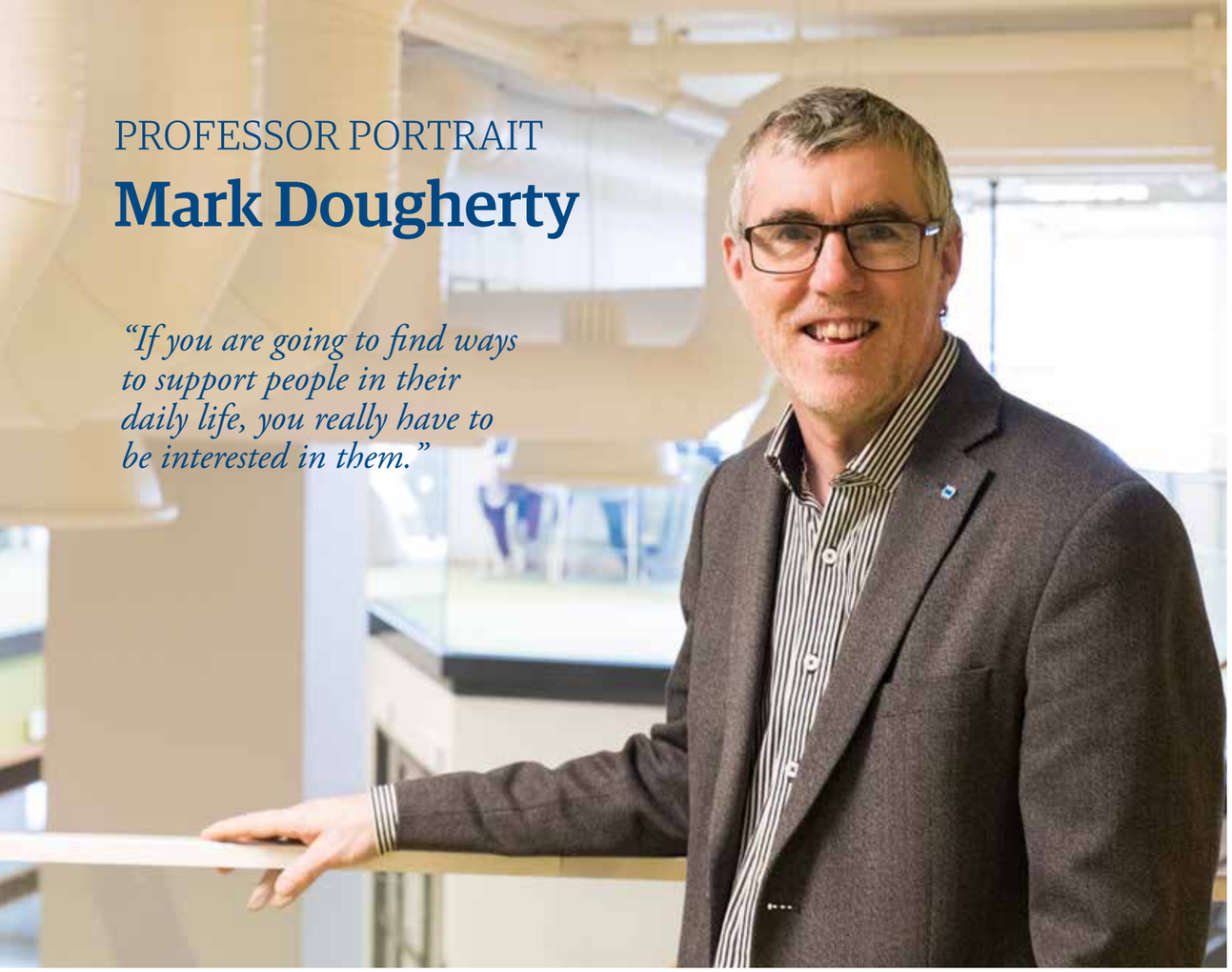
4 Delfani, P. (2016), ”Technical Advances of the Recombinant Antibody Microarray Technology Platform for Clinical Immunoproteomics”, PLoS ONE **11**(7): e0159138

5 Nilsson, J. et al (2015), ”The a Heart Transplant Survival Algorithm (IHTSA): A New Model to Improve Organ Sharing and Survival”, PLoS ONE 10(3): e0118644

PROFESSOR PORTRAIT

Mark Dougherty

"If you are going to find ways to support people in their daily life, you really have to be interested in them."



Vehicle activated signs, artificial intelligence's inability to forget, and tools to evaluate Parkinson's disease – these are just a few of the topics that Professor Mark Dougherty has spent his time on the past few years.

Now he has joined Halmstad University as a Professor in Information Technology. He will divide his time between teaching digital forensics, and doing research in CAISR on intelligent environments and elderly housing.

– I'm sure it will not be long before I work with people in healthcare and in economics too. That's what I like, to go into a lot of different fields. I'm a very eclectic person, which is also reflected in my background in education.

Mark Dougherty grew up close to Cambridge and started in academia in the equivalent of a Swedish "civilingenjör" education. He fluctuated between this and the much more theoretical subject of computer science, throwing in a number of economy seminars in the mix. It is hardly surprising that his research has spanned a large number of areas and faculties, and that he is also interested in the methodology of multidisciplinary work.

In CAISR, Mark Dougherty will work in the intelligent home lab, designed to explore new technology to support elderly and people that need home care. One of his areas of exploration will be "change detection". What this means is that data from different types of sensors will be analyzed by artificial intelligence, targeting signs of change in a person's daily routine such as getting out of bed at unusual times or simple changes in movement patterns.

– You want to spot things that are different, but because they haven't happened before, it is difficult to program a system to find them. This is a classical AI problem.

Mark Dougherty would like to try using audio sensors, and develop AI systems to analyze sounds. He has in a previous study analyzed speech in people with Parkinson's disease to note disease progression. In another study, sounds were collected from cars on gravel roads and were analyzed to determine if the roads needed maintenance.

– Humans are really good at sound, but AI is not – yet. Computer vision has actually gotten much further than AI has on sound. I would like to push this development along.

Mark Dougherty points out that microphones are already present in many old or disabled people's homes, for example in emergency telephones. If the microphones were constantly activated, this would provide an AI with plenty of information making data collection simple in practice – but ethically challenging. Mark Dougherty emphasizes that the project must be designed carefully and respectfully, and of course the trial participants must be well informed and interested in the project. It is also crucial that the researcher is a person genuinely curious about people.

– If you are going to find ways to support people in their daily life, like helping them to choose or manage a medical treatment, you really have to be interested in them. If you're not, you won't create anything useful. It's the same if you want to make transport safer. You can't do anything without asking "what do people do?"

He claims there are numerous support systems that people simply don't comply with. Just like they don't necessarily comply with doctors' prescriptions, or tell the doctor the whole truth.

– Old people say "everything is ok", because they don't want to be a burden. That's why it can sometimes be a real breakthrough to measure people, like we do. This makes it possible to say "we can see it is not ok, and we can help you".

Teaching interests Mark Dougherty a lot. This is actually what first brought him to Sweden. He came from the University of Leeds, with three times as many researchers as teaching staff, to take a lecturing position at Högskolan Dalarna.

– I wanted to do much more teaching than I did. In Swedish universities we also have great freedom to set our own agenda and methods compared to many other countries, where you are more micromanaged.

He tries to have an ongoing discussion with the students, and evaluate courses in the middle rather than the end. Should we do more of this? Skip that? Change direction?

– If they are not interested in the stuff I'm telling them, it won't work. And to get a true collaboration we have to get the students involved early in the process, not at some late formal meeting when the course plans are set already.

Recently Mark Dougherty has developed a rather exciting extracurricular interest: speedskiing, where the skier tries to reach maximum speed on a specially prepared hill. (World records are well over 200 km/h.) Although Mark Dougherty started practicing as an adult, he has become skilled enough to be in several competitions.

– Most people that start late never get to a very high level, but I put a lot of work into this. My two children competed in alpine skiing and my daughter is training for a position in the Swedish national speedski team. I thought it would be fun to do the same, and race together.

When Mark Dougherty lectures, he occasionally shows a film of himself speedskiing.

– I want to show my students that if you really want to do something, it doesn't matter what age you are or if you have some disadvantages. You can do it! Many students today have a problem with commitment; they want to play safe instead of pushing themselves into something different. But at some moment you just have to find the courage to go over the edge. It doesn't matter if you're skiing or giving a presentation: Once you are over, there's no room for fear. You just enjoy the ride.

Mark Dougherty

Mark Dougherty was born in 1967 in Cambridge, England. He studied engineering and computer science at Cambridge University before moving to the Institute for Transport Studies, University of Leeds. Here he defended his thesis: Neural Networks Applied to Transport. He moved to Sweden in 1996 and was appointed as docent at KTH (1999) and professor in Computer engineering at Dalarna University (2001). His main focus in research is machine learning applied to transport systems, infrastructure maintenance and medical diagnosis. He is an enthusiastic teacher and developed one of the first educational programmes in digital forensics in Sweden. During 2018 he was guest professor in CAISR, and in 2019 he was appointed full professor in information technology at Halmstad University.

Engineering **education** within CAISR

Campus based

CAISR staff members are involved in teaching on all academic levels. On the bachelor level there are three different programs (*computer, electrical and mechatronic engineering*). The education on this level provides the fundamental education base in mathematics, electronics and programming. Even though the emphasis is not on intelligent systems, our bachelor students often do excellent thesis projects with a basis in intelligent systems. One example is the drone competition described in this report. Other examples include automated aeroponic culturing (soil free growing of vegetables indoors with artificial light), which was nominated from Halmstad University for the Swedish Embedded Award student prize in 2018, and the Indirect Tire Monitoring System, which was awarded the HMS prize for best Halmstad IT-engineering thesis in 2017 and also resulted in a scientific publication.

On master level there are two international two year master programs (*information technology and embedded and intelligent systems*) which provide advanced level education. Additionally, CAISR staff teach in two five year long "civilingenjör" programs, similar to the German diploma engineer, which ultimately lead to a master of science in engineering: *Intelligent systems and Computer science and engineering*. The topics in these programs closely match the research areas of CAISR, with subjects such as machine learning, data mining, embedded systems programming, and robotics. In both international master programs there are courses with applications in the areas of autonomous vehicles and smart healthcare. Our ambition is that many (say 20%) of the master theses should lead to scientific publications, as a sign of their scientific level. This is of course highly dependent on the students' motivation for co-writing a scientific paper after their degree is finished. During the period 2012-2018 have 10 out of 64 master theses supervised by CAISR staff resulted in a scientific publication. One was awarded the prize for best Swedish AI thesis, in 2017, by the Swedish AI Society.

Sparbanksstiftelsen Kronan 2018 prize ceremony in Halmstad for student thesis projects. Three of the projects (four students) were supervised by CAISR staff. Back from left: Lars Ekman, Sparbanksstiftelsen Kronan, Fredrik Nilsson and Erik Karlsson. Back from right: Vice-Chancellor Stephen Hwang, Jacob Harsten and Dawid Ejdeholm.

Professional education

CAISR and Halmstad University have initiated several education activities towards offering education to professionals. The MAISTR Expert Competence program *Data Analytics and Service Innovation based on Artificial Intelligence* is directed at professionals who want to get continued education in AI technologies, specifically machine learning and business and service design with AI (see separate article about this). The program is under development and two pilot courses are given during the Spring of 2019 to evaluate the content and the flexible format together with participants from companies. A full portfolio of courses corresponding to a two year master program is planned to be launched in 2020. The development of the MAISTR Expert Competence program is funded by the Knowledge Foundation.

Late in 2018, the DAP project (Digital Design and AI Podcasting) was started. This is also directed towards continued education of professionals in AI and Service design, but focusing on a specific form for the course: the podcast. The project aims to evaluate podcasting as a flexible education format for a university level course. The development of this course is supported by Sweden's Innovation Agency (Vinnova), and it was a result of a special invitation from the government to increase the Swedish universities' offers to professionals.

To the left: Yuka Morimoto is from Japan. She studies the master program Embedded and Intelligent Systems, and wants to work with autonomous vehicles after graduation. https://www.youtube.com/watch?v=1Nkl7ZdaruQ

To the right: Lecture with the MAISTR Expert Competence program for professionals. The lecture can also be followed via link.

Online education

CAISR staff are also driving in the development of online education: education that is accessible over the internet and can reach international students. This of course also works for professionals, in Sweden and abroad. CAISR staff developed in 2017 a fully online course in data mining. Two iterations of the course have so far been given with very good course evaluations.

Another online based education relates to new course formats for the Swedish "civilingenjör" program. Halmstad University is host for the national project "Civilingenjör 4.0", which is funded by Sweden's Innovation Agency (Vinnova). The initiative for this project comes from the government and the Swedish production industry.

"Civilingenjör 4.0" is about offering online course modules for engineering education in the age of Industry 4.0. Here, CAISR staff is involved (together with Lund University) in a course module related to machine learning for manufacturing applications.

Education in **AI** for **professionals**

Professor Mattias Ohlsson, waiting for the students in the professional programme "Data Analytics and Service Innovation based on Artificial Intelligence"

The School of Information Technology started in the autumn a professional education within artificial intelligence that combines information technology with innovation sciences.

The program "Data Analytics and Service Innovation based on Artificial Intelligence" (MAISTR) is directed towards professionals who want to get continued education in Artificial Intelligence (AI) technologies, specifically Machine Learning (ML), and business and service development techniques with AI/ML. The program is on the advanced level and will (after step 2) comprise courses corresponding to a total of 120 credits (hp). The program has unique aspects by combining courses on both AI technology and courses on service design with AI.

A flexible program

The program is flexible and can be carried out at the same time as an ongoing professional career. The education builds on previous experiences with developing a web-based Data Mining course for industry professionals. Two courses are suggested for the first year: one within Service Design Based on Data Analytics – Perspectives and Possibilities (7.5 credits) and one about Deep learning with applications (7.5 credits). Each course will run over a full semester at a pace of 25% (200 hours), and follow a distance-based format with visits from and to the participating companies during the teaching periods. The detailed contents for these courses will be developed in cooperation with the participating organisations and company representatives through several co-production workshops.

About the program

The "Data Analytics and Service Innovation based on Artificial Intelligence" is an Expertkompetensprogram co-funded by the Knowledge Foundation. It is developed by Halmstad University, University of Skövde and RISE SICS. The program is supported by Volvo Cars, AB Volvo, Autoliv, Zenuity, Stena Line, Easyserv, Fysiotest, Hotswap, Jayway, Digital Reliance, InUse, RISE Viktoria and Nibe.

The project management group at Halmstad University consists of Stefan Byttner, Sepideh Pashami, Rafik Bouguelia and Pontus Wärnestål.

Engineering students in second place in international drone competition

Six engineering students from Halmstad University were runners-up in an international competition for autonomous drones[1]. The team qualified earlier this spring to the final, which took place in Tucson, Arizona, May 15-17.

The students designed an advanced autonomous drone that automatically can pick up another drone. The goal of the competition was to search an area and identify another drone, pick it up and fly it to a drop-off point.

During the final in Arizona, the team from Halmstad competed against three American universities: Embry-Riddle Aeronautical University – who won the competition – as well as Vanderbilt University and the University of Pennsylvania. The students from Halmstad were the only team outside of the United States to qualify for the final.

Top row from the left: Emil Andersson, Emil Johansson, Marcus Rodén and Jakob Carlsén. Bottom row from the left: Patrick Karlsson and Anders Bogga.

– We had some challenging but very fun days in Arizona. It was great to meet students from other universities and see how they had designed their drones, says Marcus Rodén, one of the team members.

During the competition, the Halmstad students received an award for the best drone design with the motivation: "Halmstad University came very close to finishing the mission autonomously, and given the complexity and sophistication of their UAV design, the near miss was a commendable achievement!"

PhD student Jennifer David and the team member Anders Bogga preparing the drone.

–The students' efforts are truly impressive. They have never before worked with drones, yet they succeeded in developing an autonomous drone that is advanced in all three areas – electrical, mechatronical and computer engineering, says Wojciech Mostowski, Senior Lecturer at the School of Information Technology and one of the group's supervisors.

The six students graduate this summer from three different engineering programs at Halmstad University. Patrick Karlsson and Emil Johansson are computer engineers, Marcus Rodén and Jakob Carlsén electrical engineers and Anders Bogga and Emil Andersson mechatronic engineers. The students' three different areas of expertise have all been required to create the drone. The computer engineers were responsible for the drone's ability to search, find and land through image analysis. The mechatronic students were in charge of the design and construction of the drone and its gripping claw, and the sensor and navigation system was developed by the two electrical engineers. The project was done as the students' bachelor thesis projects.

1 https://cps-vo.org/group/arcompetitions

Taking on **challenges outside** academia

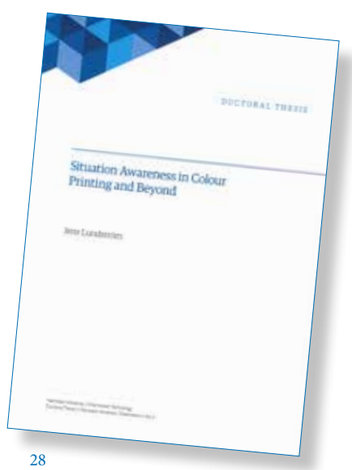
Siddhartha Khandelwal

Siddhartha Khandelwal started the company VectorizeMove during 2018 to commercialize the results from his thesis work "Gait Event Detection in the Real World. In December, he was selected to be among the 20 best business ideas in the country in competition with 300 contributions in Venture Cup 2018. Meet Siddharta on next spread.

Anita Sant'Anna has started Viniam Consulting. The company is building a generic infrastructure for data collection in research projects. Instead of looking for grants for this, she finances her business by providing a service to others who already have grants. Read more about Anita on the coming spread.

Anita Sant'Anna

Jens Lundström



After the doctoral education and four years as a researcher at Halmstad University I started working in the industry focusing on machine learning. In the own company Convergia Consulting we help customers with planning and implementation of machine learning to create value by integrating into existing and new products. The world has changed rapidly and today many companies realize that machine learning (or broader artificial intelligence) can provide a great value. We want to crack the myth that machine learning is equal to large costs and long development times. In parallel with our consulting services, we have packages for knowledge transfer to customers' staff so that competence is managed and maintained within their company. Convergia Consulting was started already in 2003 and has recently undergone a change of name and focus to completely work with machine learning.

Without the doctoral education, the research thereafter, the contact network and the experience of teaching (and the leadership thereby) the company's direction had not been possible. I'm also an employee of the company Raytelligence which develops radar-based services and products for the elderly care. At Raytelligence I lead the development of algorithms for signal processing and machine learning. The need for AI-based services for the industry is enormous and the cutting-edge expertize I acquired through my postgraduate education at the Halmstad University has given me a fantastic specialist competence to stand on.

During my PhD studies I investigated how the driver of a heavy-duty vehicle influences fuel consumption. For this, two methods were proposed. One focused on real-time analysis while the other captures the overview of a trip.

In my current role, I develop and apply existing methods to predict the demand of spare parts, automate decision making, and contribute to enabling the use of Machine Learning within Volvo Group Trucks Operations. This involves analysis of both streaming and batch data in large quantities and with varying quality.

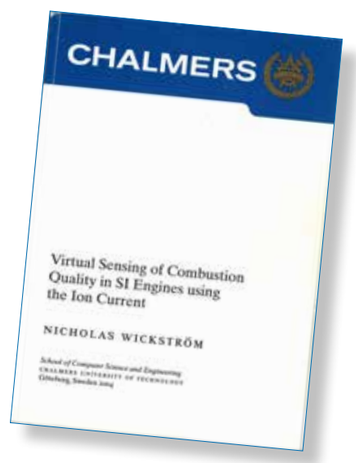
My time at the university taught me the rigors of validating the results and creating models that are robust and scalable. One of the key differences I see working in industry compared to academia is that in industry you compare your performance with your past results while in academia you compete against other people.

Iulian Carpatorea

Saeed Gholami Shahbandi

- Background (Mobile Robotics): signal processing, machine learning and AI --> applied in Robotics and autonomous agents...
- Now (Data Science): signal processing, machine learning and AI --> applied in data science, e.g. developing predictive models for vehicle maintenance in automotive industry. Now I'm working at Volvo Group Advanced Analytics and AI.

Nicholas Wickström



I have for a little over two years been working in the automotive industry. Currently with perception for autonomous driving at Zenuity. Zenuity is a joint venture started between Autoliv and Volvo Cars, with the main objective to take the next steps in improving safety for passenger cars. Zenuity was established in 2017 and has now grown to 700 employees, distributed over development offices in Gothenburg, Munich and Detroit as well as tech hubs in Santa Clara and Shanghai.

At Zenuity I work in a product area, *Cruising and highway autonomous driving*, which develops driver support systems that you will find in the newest Volvo V60, as well as the next generation of automated systems for highway driving.

I lead a subarea in Vision together with two colleagues with internal teams in Gothenburg and Munich and external teams in Stockholm and Ukraine. In total, around 100 people are involved in our vision development. As a product owner I have the responsibility to prioritize the technical work and make sure that we develop the right components, to the right quality level. The development teams take end to end responsibility for the software developed.

Nicholas Wickström, Product owner Deep learning/Computer vision at Zenuity

Start up
VectorizeMove AB

The way you walk can reveal current and future health problems. Siddhartha Khandelwal, a former PhD student at CAISR, suggests the use of wearable sensors for analysing movement. This can potentially result in early detection of for example Parkinson's disease, dementia, multiple sclerosis and other neuro-physiological disorders. The same method can also be used for early disorder detection in horses.

Siddhartha Khandelwal started the company VectorizeMove during 2018 to commercialise the research results. In December, he was selected to be among the 20 best business ideas in the country in competition with 300 contributions in Venture Cup 2018.

Siddhartha Khandelwal, at Venture Cup

Many of our body systems, such as the cardio-vascular system and the neuro-physiological system, intimately collaborate to help us move. If one of these systems is affected by an illness, it will be reflected in the way you walk. The manner of walking or running is called gait and is typically analysed in specific gait clinics. Siddhartha Khandelwal, who presented his doctoral thesis on March 14, 2018, proposes a solution on how a person's gait can be measured outside of these controlled labs:

"Gait analysis is a critical component of assessing neuro-physiological disorders, patients undergoing rehab or athletes with leg injuries. However, the analysis is currently performed under strictly controlled conditions and protocols. The results of my research are a step in the direction of providing the benefits of gait analysis to patients in their daily lives; thereby increasing the amount of information that is available for creating better support systems and plans for rehabilitation".

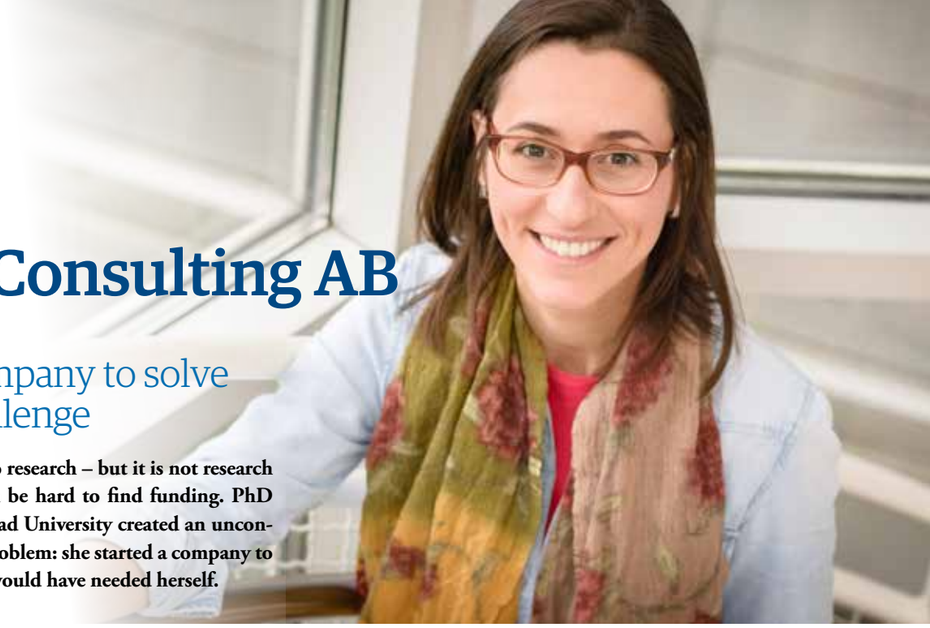
Research results will become a product

Siddhartha Khandelwal's research focuses on detecting gait events from wearable sensors on different parts of the body. This can be done in a home environment, by the patients themselves. The sensor data is translated to a unique pattern that shows the quality of the movement by comparing it with a 'normal walking' template. This continuous collection of information in a real-life setting is unique and can hopefully help patients, physiotherapists and doctors with a better and more informed rehabilitation process.

After starting the company VectorizeMove, Siddhartha Khandelwal is developing the gait analysis system into a product. The Venture Cup award at the end of 2018 was a great acknowledgement to everyone involved in the research and the company.

"During 2019, we will double-up our drive and efforts to create better services to significantly improve the rehabilitation of both humans and animals", says Siddhartha Khandelwal.

VectorizeMove want to significantly improve rehabilitation of humans and animals.



Start up
Viniam Consulting AB

She built a company to solve a research challenge

Data collection is pivotal to research – but it is not research in itself. This means it can be hard to find funding. PhD Anita Sant'Anna at Halmstad University created an unconventional solution to the problem: she started a company to create the service that she would have needed herself.

It's been seven years since Anita Sant'Anna presented her thesis in Information Technology on how to monitor patients motion patterns by using sensors to get a clearer picture of their illness or rehabilitation. After that, as a researcher in CAISR, she wanted to develop methods to help people with osteoarthritis to make healthier choices. The core concept was to provide patients with feedback and suggestions at the exact right time, with the help of artificial intelligence and an activity tracker such as a "fitbit". In behavioral psychology, this is called "just-in-time adaptive interventions" and is related to the more well-known concept of "nudging".

But to do this, she needed massive amounts of data. She found herself facing a threshold that was difficult to pass.

– To collect the data, I needed to build a technical infrastructure. To do this, I needed funding. But it was challenging to raise enough funds to collect data, before we were building anything interesting with that data, explains Anita Sant'Anna.

Anita Sant'Anna describes it as "data collection limbo". Without a system to collect and store big amounts of data, researchers resort to simplifying their projects and research questions to something that can be done with any limited amount of data which can be accessed quickly.

– I realized that if I had this problem, others probably have the same problem. That is how my company came about.

Anita Sant'Anna started Viniam Consulting, where she now works half-time. The company is building a generic infrastructure for data collection in research projects. Instead of looking for grants for this, she finances her business by providing a service to others who already have grants.

– When people get big grants, they normally develop a specific platform that works only for that study. I will go the opposite way; make a platform on which each researcher can create their own study. This should allow more researchers to start doing pilot projects for a lower cost, says Anita Sant'Anna.

So far, she has been targeting bigger research groups that might have a bit of spare grant money and would like an infrastructure built for them. Occasionally, she gets an enthusiastic phone call from a researcher who has heard a colleague talking about her concept. But as in the early days of any small company, the work is challenging. She learns as she moves along, relying on support, experiences and suggestions from other startups and from a few private investors. A research nurse at the Sahlgrenska hospital has been involved in looking for potential clients. A fellow startup developing an app for mental health is collaborating with her to raise funds for a test pilot. A friend of a friend put her in contact with a programming team in Pakistan.

– It's been a learning journey for myself, starting out with a vision but needing to work out the practical details. I have been lucky to be able to build such a great personal network, says Anita Sant'Anna.

Once the data collection system is in place, she is looking forward to using it in her own research. Her idea is to develop something like a virtual coach or analyst, to send feedback or instructions to patients to improve their experience and their health.

However, Anita Sant'Anna doesn't think she will ever go back full time to academia. Today she divides her time between her company and a position as research coordinator at the Center for Health Technology Halland. Her job is to create more connections between the Center and researchers at CAISR and in other programs and projects at Halmstad University.

– I quite like the energy and speed with which things change in the startup world. The inertia in academia is something I can find a little frustrating sometimes. This is more of what I like, personally. After this is finished, I will probably move on to the next thing, and the next, and the next…

Start up
Raytelligence AB

-The world is facing a change in demographic situation where a diminishing part of the population shall support a growing group of elderly. In addition to this we see rising numbers of life style related diseases such as dementia and cardiovascular diseases, says Pelle Viberg CEO and CTO at Raytelligence AB.

Swedish Adrenaline was formed in 2013 with the mission to develop new electronic products for the Sport and Health markets. The fact that these markets differ very much resulted in 2015 in the founding of two subsidiaries to Swedish Adrenaline, namely, Raytelligence and Innowearable. Innowearable is devoted to Sport Electronics and Raytelligence is focused on microwave sensors for the healthcare- and industrial markets. In 2015 Raytelligence received a grant from Sweden's Innovation Agency - Vinnova to develop a radar sensor for vital sign monitoring. Raytelligence showed in 2016 the first version of the 60 GHz sensor for vital sign monitoring, and a cloud service was also demonstrated. In 2017 the sensor RayVS1 was certified for home use. This year the first industrial client was signed for development and delivery of sensors to the road construction market as well as signing a partnership with a major Swedish IT-provider to the e-Health market. The Raytelligence team is a blend of people with competence ranging from industrial design to radar signal processing.

The system offers monitoring of vital signs, that is respiration pattern and respiration rate. Moreover, the sensor can capture and alert onmotion and presence/absence of one or more persons in a room. From the caregiver's point of view this means that nightly supervision can be done more efficiently. From the patient's point of view, it means that he/she can feel safe at night without being unnecessarily disturbed.

-Raytelligence offers a solution for monitoring elderly in their homes. With this technology can supervised and secured homecare be offered as an alternative to nursing home, which means higher quality of life and independence for the elderly, says Pelle.

Technology

The RayVS1 is the first radar sensor that will give the full benefit from the 7 GHz bandwidth in 60 GHz ISM band. All the capabilities of the sensor contribute to a unique capturing of respiration, heart rate and motion patterns

The sensor has a quad-core processing platform that allows advanced signal processing to be performed on the sensor itself.

The RayVS1 is capable of measuring the following parameters:

- Range (sub mm accuracy)
- Small movements (20 µm)
- Position of target (+- 65 degrees)

The sensor has the ability to detect the position of multiple targets in the proximity of the sensor.

For security applications it is sometimes desired to measure the physical condition of a person. The RayVS1/I is able to detect respiration in addition to position of a person.

On December 6 Pelle Viberg was invited guest at Innovation Jam. Rebecca Sellergren lead the talk.

Pelle Viberg was awarded the prize for the Innovator of the year 2018 at "Halmstads näringslivsgala". The motivation from the jury: The Innovation Prize 2018 goes to Pelle Viberg and the company Raytelligence for an innovation that combines the collection of health data with the help of radar technology and the use of artificial intelligence - a key factor in future care.

Innovation is in the pipeline, it meets a large and well-known need and has a growing global market. The company has a strong link to research at Halmstad University and the profile area Health Innovation.

Photo: Destination Halmstad

The miniaturization of radar technology means that we have been able to shrink the technology, which means that we can implement completely different applications than before. And when you go higher and higher in frequency, we can see even smaller objects and movements. Together this means new opportunities. Our special field is that we build a fairly high level of service, where we also use another new technology - machine learning. These two techniques work well together, and we try to find patterns in this very complex data stream. This means that we can obtain information from this that is difficult or impossible to obtain with only camera or radar.

Pelle Viberg, CEO and CTO

PhD Graduation

Siddhartha Khandelwal

Gait Event Detection in the Real World

Abstract

Healthy gait requires a balance between various neuro-physiological systems and is considered an important indicator of a subject's physical and cognitive health status. As such, health-related applications would immensely benefit by performing long-term or continuous monitoring of subjects' gait in their natural environment and everyday lives. In contrast to stationary sensors such as motion capture systems and force plates, inertial sensors provide a good alternative for such gait analysis applications as they are miniature, cheap, mobile and can be easily integrated into wearable systems.

This thesis focuses on improving overall gait analysis using inertial sensors by providing a methodology for detecting gait events in real-world settings. Although the experimental protocols for such analysis have been restricted to only highly-controlled lab-like indoor settings; this thesis presents a new gait database that consists of data from gait activities carried out in both indoor and outdoor environments. The thesis shows how domain knowledge about gait could be formulated and utilized to develop methods that are robust and can tackle real-world challenges. It also shows how the proposed approach can be generalized to estimate gait events from multiple body locations. Another aspect of this thesis is to demonstrate that the traditionally used temporal error metrics are not enough for presenting the overall performance of gait event detection methods. The thesis introduces how non-parametric tests can be used to complement them and provide a better overview.

The results of comparing the proposed methodology to state-of-the-art methods showed that the approach of incorporating domain knowledge into the time-frequency analysis of the signal was robust across different real-world scenarios and outperformed other methods, especially for the scenario involving variable gait speeds in outdoor settings. The methodology was also benchmarked on publicly available gait databases yielding good performance for estimating events from different body locations. To conclude, this thesis presents a road map for the development of gait analysis systems in real-world settings.

PhD Defense facts
Title
Gait Event Detection in the Real World
Author
Siddhartha Khandelwal
Main supervisor
Nicholas Wickström, Docent, Halmstad University
Co-supervisor
Thorsteinn Rögnvaldsson, Professor, Halmstad University
Opponent:
Brian Caulfield, Professor, University College, Dublin, Ireland
Grading committee:
Maria Lindén, Professor, Mälardalens University
Jorunn Helbostad, Professor, NTNU, Norge
Isac Skoog, Docent, Linköping University

Your walk talks

The way you walk can reveal current and future health problems. New research from Halmstad University suggests the use of wearable sensors for analysing your movement. This can potentially result in early detection of for example Parkinson's disease, dementia, multiple sclerosis and other neuro-physiological disorders.

Many of our body systems, such as the cardio-vascular system and the neuro-physiological system, intimately collaborate to help us move. If one of these systems is affected by an illness, it will be reflected in the way you walk. The manner of walking or running is called gait and is typically analysed in specific gait clinics. In a recently published thesis, Siddhartha Khandelwal from the School of Information Technology at Halmstad University, proposes a solution on how a person's gait can be measured outside of these controlled labs:

– Gait analysis is a critical component of assessing neuro-physiological disorders such as Parkinson's disease, patients undergoing rehab or athletes with leg injuries. However, the analysis is currently performed under strictly controlled conditions and protocols. The results of my research are a step in the direction of providing the benefits of gait analysis to patients in their daily lives; thereby increasing the amount of information that is available for creating better support systems and plans for rehabilitation.

Research results will become a product

Siddhartha Khandelwal research focuses on detecting gait events from wearable sensors on different parts of the body. This can be done in a home environment, by the patients themselves. The sensor data is translated to a unique pattern that shows the quality of the movement by comparing it with a 'normal walking' template. This continuous collection of information in a real-life setting is unique and can hopefully help patients, physiotherapists and doctors with a better and more informed rehabilitation process.

– We have tested the system under very dynamic conditions, such as different walking and running speeds, surfaces and inclinations, and it showed excellent accuracy in detecting gait events. This proves that it is ready for use in real-world applications, says Siddhartha Khandelwal.

To the right: Test person equipped with wearable sensors for data collection.

PhD Graduation Saeed Gholami Shahbandi

Interpretation and Alignment of 2D Indoor Maps: Towards a Heterogeneous Map Representation

Abstract

Mobile robots are increasingly being used in automation solutions with notable examples in service robots, such as home-care, and warehouses. Autonomy of mobile robots is particularly challenging, since their work space is not deterministic, known a priori, or fully predictable. Accordingly, the ability to model the work space, that is robotic mapping, is among the core technologies that are the backbone of autonomous mobile robots. However, for some applications the abilities of mapping and localization do not meet all the requirements, and robots with an enhanced awareness of their surroundings are desired. For instance, a map augmented with semantic labels is instrumental to support Human-Robot Interaction and high-level task planning and reasoning.

This thesis addresses this requirement through an *interpretation and integration of multiple input maps into a semantically annotated heterogeneous representation*. The heterogeneity of the representation should to contain different interpretations of an input map, establish and maintain associations among different input sources, and construct a hierarchy of abstraction through model-based representation. The structuring and construction of this representation are at the core of this thesis, and the main objectives are: a) modeling, interpretation, semantic annotation, and association of the different data sources into a heterogeneous representation, and b) improving the autonomy of the aforementioned processes by curtailing the dependency of the methods on human input, such as domain knowledge.

This work proposes map interpretation techniques, such as abstract representation through modeling and semantic annotation, in an attempt to enrich the final representation. In order to associate multiple data sources, this work also proposes a map alignment method. The contributions and general observations that result from the studies included in this work could be summarized as: i) manner of structuring the heterogeneous representation, ii) underlining the advantages of modeling and abstract representations, iii) several approaches to semantic annotation, and iv) improved extensibility of methods by lessening their dependency on human input.The scope of the work has been focused on 2D maps of well-structured indoor environments, such as warehouses, home, and office buildings.

PhD Defense facts
Title
Interpretation and Alignment of 2D Indoor Maps: Towards a Heterogeneous Map Representation
Author
Saeed Gholami Shahbandi
Main supervisor
Björn Åstrand, Docent, Halmstad University
Co-supervisor
Antanas Verikas, Professor Halmstad University Dr. Roland Philippsen (former Halmstad University)
Opponent:
Patric Jensfelt, Prof., KTH Royal Institute of Technology
Grading committee:
Amy Loutfi, Professor, Örebro University Kalle Åström, Professor, Lund University Filip Malmberg, Docent, Uppsala University

Autonomous mobile robots have the capacity to help us with many service tasks, such as home care assistance or moving goods in a warehouse. Saeed Gholami Shahbandi's research suggests methods for enabling robots to better understand and become more aware of their surroundings.

When a mobile robot is given the capacity to detect the surrounding environment – everything from walls to obstacles such as humans or a chair – it can create its own map. This robotic map can be developed by adding layers of information from a variety of sources such as cameras and laser scanners. These types of enriched maps, that integrate additional knowledge into robots' internal representation of their surroundings, are called semantic maps and is one important piece of the puzzle in creating efficient and trustworthy autonomous mobile robots.

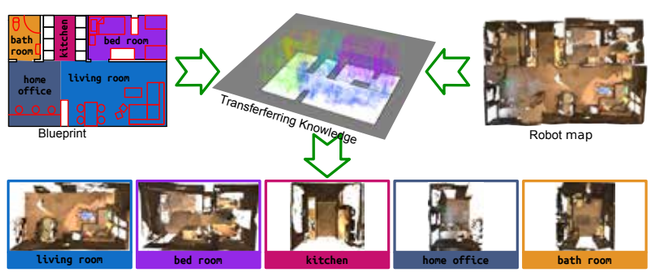
"In a workspace where robots and humans operate side by side, it is important that the robots are 'well-behaved' and aware of their surroundings. Semantic maps are one means of providing this enhanced understanding to the robot", says PhD student Saeed Gholami Shahbandi at the School of Information Technology at Halmstad University.

Improve human quality of life

In his research, Saeed Gholami Shahbandi proposes map interpretation techniques through modelling and semantic annotation, in an attempt to enrich the final robotic map.

"Robotic mapping is a well-advanced field of research, relying and benefiting from a lot of different improvements in robotics, machine learning and computer vision. Such a rich discipline of research has made it possible to develop methods that can handle challenging environments such as warehouses, office buildings or homes."

"I look forward to seeing this line of research improve human quality of life further and that robots will be accessible for everyone in their everyday life. I hope I will have the privilege to extend my contribution in this field", says Saeed Gholami Shahbandi.

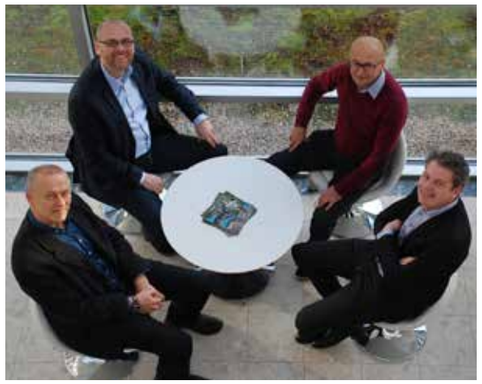


Semantic maps are created by adding layers of information from the surroundings. Here is one example from Halmstad Intelligent Home (HINT) – a realistic smart home environment for research at Halmstad University – where Saeed Gholami Shahbandi has used information from for example sensors and cameras to generate an enriched robotic map.
Illustration: SAEED GHOLAMI SHAHBANDI

Organization

CAISR Management

CAISR is managed by the CAISR director with support from the academic management group, the industrial advisory board (IAB), the reference group (RG), and a project coordinator overseeing details regarding reporting, coproduction and information management. The academic management group consists of the professors in CAISR, the head for the department where CAISR is placed, and the head for the school of information technology. This provides a very good overview of teaching, research, cooperation and coproduction. The two application areas, healthcare technology and intelligent vehicles, are discussed in two coordination groups.



The management group in 2018 - Antanas Verikas, Thorsteinn Rögnvaldsson, Josef Bigun and Magnus Clarin

Industrial Advisory Board

The CAISR management is supported by the industrial advisory board (IAB), where each industrial partner in CAISR is represented, and a reference group. A key contribution of the industrial partners to CAISR is their involvement in the strategic planning. Between October and December 2018 we organized a set of workshops on where to go next with CAISR and the industrial challenges. All industrial partners in CAISR, also those who are partners outside of the so-called core CAISR profile, were invited to present their challenges and discuss possible project directions from that. The results from these workshops will be developed further in the first quarter of 2019 into a coherent set of projects from 2020 and onwards.

The IAB give advice on the progress and activities from the industrial partners' perspective and take decisions when new industrial partners want to enter or partners need to leave. David Johansson from Tappa Service was the chairman during 2018 for the CAISR IAB. The IAB meet in relation to the reference group meetings.

Industrial representatives and CAISR staff in a workshop regarding CAISR Future Direction

The Reference Group

The CAISR reference group serves an important function in the development of the profile; being a sounding board for the CAISR management group. The group represents different perspectives: international and national industry, as well as international and national academic research, related to intelligent systems. The reference group members meet and review the CAISR achievements and activities 1-2 times per year, providing advice and feedback on the progress. Each meeting is typically two days long. The latest meeting was in November 2018.

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.

Robert Evans

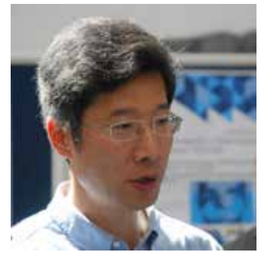
Senior software engineer at Google, Mountainview, California.

Christer Fernström

Director and consultant at Fernstrom et Associates in Grenoble, France and the CTO of CommuniTeams in Copenhagen, Denmark. Head of Reference group.

Xin Yao

Chair Professor at Department of Computer Science and Engineering, Southern University of Science and Technology, Guangdong, China. Professor of Computer Science in the School of Computer Science at the University of Birmingham.



Fredrik Heintz

Associate Professor of Computer Science at Linköping University. Director of the Graduate School for the Wallenberg AI, President of the Swedish AI Society (SAIS), and a member of the European Commission High-Level Expert Group on AI. Photo: Mikael Hansson

Catarina Coquand

University Director at Halmstad University. PhD in Computer Science. Former Dean for the Faculty of Technology and Society at Malmö University. Before that head of the Department for Computer Science and Engineering at Chalmers University of Technology and University of Gothenburg (a shared department).

Funding

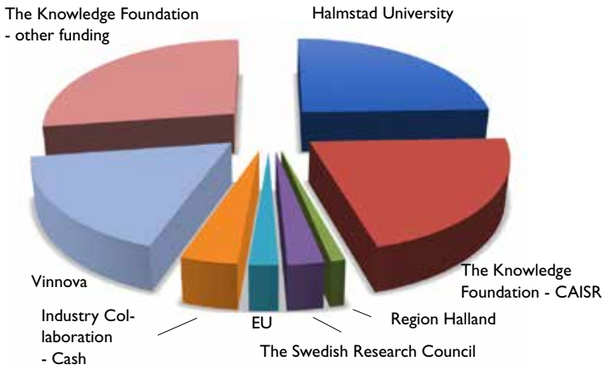
The annual research turnover 2018 in CAISR was 25.7 MSEK (million Swedish kronor) on the university side (i.e. not including industrial in-kind efforts). The industrial matching (in-kind) effort during 2018 equaled 4.0 MSEK, and the total industrial matching to CAISR during the period 2012-2018 exceeds 47 MSEK.

For 2018, about 6.3 MSEK were direct research funds from Halmstad University; the rest were external funds (mostly research grants but also some cash contributions from companies). Thus, CAISR had an external funding ratio of about 76%. The major part of the external funding comes from the Knowledge Foundation: 5.5 MSEK directly for the CAISR profile and about 7.0 MSEK for other projects funded by the Knowledge Foundation, giving a total of about 12 MSEK from the Knowledge Foundation. The sources of the different external funds to CAISR (on the university side) are illustrated in the pie diagram. The bar chart shows how CAISR's total research turnover has developed between 2012 and 2018.

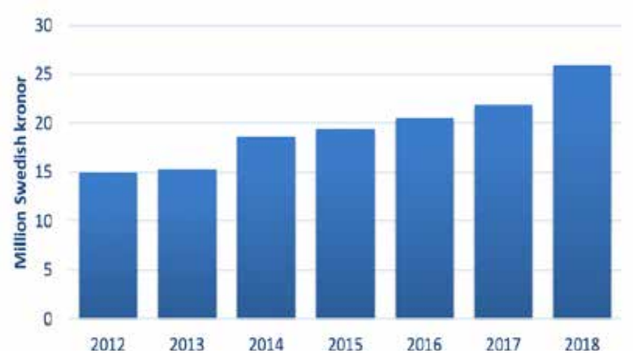
Financer	Budget 2018[1]	Actual 2018
The Knowledge Foundation	4 470 563	5 528 484
CAISR Industrial partners (in kind) [2]	6 202 000	4 082 577
Other external funding[3]	13 000 000	14 082 103
Halmstad University	6 500 000	6 336 960
Sum total	**30 172 563**	**30 030 124**

1. The budget shows what we planned in 2011 for the year 2018.
2. All in kind contribution have been computed using the standard tariff of 800 SEK per hour.
3. Funding from other sources (VR, EU, Vinnova, companies... not matching the Knowledge Foundation

Funding on the University side 2018



CAISR total research turnover



CAISR Staff
researchers

Bigun, Josef
Prof., Doctor
Professor signal analysis
josef.bigun@hh.se

Computer Vision, human vision, pattern recognition, biometrics, image processing, signal analysis, machine learning, AI

Dougherty, Mark
Docent, doctor
Professor Information Technology
mark.dougherty@hh.se

Acoustic analysis, smart sensors, medical informatics, decision support systems, forensic science, ethics of AI

Ohlsson, Mattias
Prof., Doctor
Professor machine learning
mattias.ohlsson@hh.se

Machine learning, deep learning, neural networks, medical informatics, medical decision support

Pavel, Misha
Prof., Doctor
Guest Professor
misha.pavel@hh.se

Computational modelling of behaviors, technology for future care, patients' states inference from unobtrusive sensors.

Rögnvaldsson, Thorsteinn
Prof., Doctor
Professor computer science
thorsteinn.rognvaldsson@hh.se

Neural networks, self-organizing models, predictive maintenance.

Verikas, Antanas
Prof., Doctor
Professor pattern recognition
antanas.verikas@hh.se

Classification committees, feature selection; semi-supervised learning, fuzzy logic, analysis of pathological speech.

Byttner, Stefan
Docent, Doctor
Associate professor
stefan.byttner@hh.se

Self-organizing algorithms, interestingness measures of patterns and joint human-machine learning.

Nowaczyk, Sławomir
Docent, Doctor
Associate professor
slawomir.nowaczyk@hh.se

Data Mining, knowledge representation, joint human-machine learning, self-organising anomaly detection, big data.

Wickström, Nicholas
Docent, Doctor
Associate professor
nicholas.wickstrom@hh.se

Signal analysis of human motion, incorporateing expert knowledge in the modelling, and making models possible to interpret.

Åstrand, Björn
Docent, Doctor
Associate professor
bjorn.astrand@hh.se

Mechatronics, perception, mobile robots, semantic mapping, AGV/truck safety.

Aksoy, Eren Erdal

Doctor
Assistant Professor
eren.aksoy@hh.se

Computer Vision, Cognitive Robotics, Machine Learning, Imitation Learning, and Autonomous Systems

Alonso-Fernandez, Fernando

Doctor
Associate professor
fernando.alonso-fernandez@hh.se
Biometrics recognition, image/signal processing, computer vision, machine learning and pattern recognition.

Berck, Peter

Doctor
Post doc
peter.berck@hh.se

Predictive maintenance, data mining, machine learning, deep learning.

Bouguelia, Mohamed-Rafik

Doctor
Assistant professor
mohamed-rafik.bouguelia@hh.se
Active learning; classification; data stream mining; anomaly and novelty detection; big data; predictive maintenance.

Clarin, Magnus

Doctor
Dean, School of Information Technology
magnus.clarin@hh.se

Health technology, e-health, data mining, applied physics, signal analysis.

Cooney, Martin

Doctor
Researcher
martin.cooney@hh.se

Social robotics, recognition, human-robot interaction, well-being

Dikmen, Onur

Doctor
Senior Lecturer
onur.dikmen@hh.se
Statistical machine learning, change-point and outlier detection, predictive maintenance, causal inference

Englund, Cristofer

Doctor
Associate professor
cristofer.englund@hh.se

Machine learning for automated driving, vehicular behavioral modeling, connected vehicles, situation awareness.

Etminani, Farzaneh

Doctor

kobra.etminani@hh.se

Data Mining, Healthcare informatics, anomaly detection, big data.

Järpe, Eric

Doctor
Associate professor
eric.jarpe@hh.se

Change-point and outlier detection, smart homes monitoring, communication security, cryptology.

Khandelwal, Siddhartha

Doctor

Human motion analysis, wearable sensors, signal processing and incorporating expert knowledge into modelling.

Khan, Taha

Doctor
Post doc
taha.khan@hh.se

Computer Vision, image and signal analysis of human motion, speech analysis, machine learning, medical informatics.

Khoshkangini, Reza

Docent, Doctor
Postdoc
reza.khoshkangini@hh.se

Artificial intelligence, machine learning, data mining and decision making

Lundgren, Lina

Doctor
Associate professor
lina.lundgren@hh.se

Human motion, biomechanics, health technology

Lundström, Jens

Doctor
Assistant professor

Representation learning, anomaly detection, intelligent environments, modelling of human behaviour patterns.

Muhammad, Naveed

Doctor
Post doc
naveed.muhammad@hh.se

Autonomous robot perception and navigation

de Morais, Wagner

Doctor
Research Engineer
wagner.demorais@hh.se

Smart environments, ambient intelligence, Ambient Assisted Living, edge computing, mixed reality

Pashami, Sepideh

Doctor
Assistant professor
sepideh.pashami@hh.se

Predictive maintenance, causal inference, representation learning, machine learning, data mining.

Pirasteh, Parivash

Doctor
Post doc
parivash.pirasteh@hh.se

Machine learning, data mining, recommender systems, personalization.

Shahbandi Gholami, Saeed

Doctor

Machine learning, pattern recognition, robotics and semantic mapping.

Sant'Anna, Anita

Doctor
Associate professor
anita.santanna@hh.se

Wearable sensors, human motion analysis, tele-monitoring, e-health, signal processing, data mining, joint human-machine learning.

Sepideh Pashami presenting projects within predictive Maintenance at the Reference Group Meeting at November 6

CAISR Staff
PhD Students

Galozy, Alexander

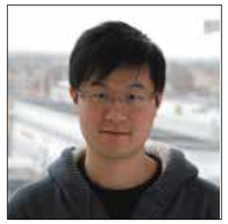
Dipl.-Ing(FH), M.Sc.
Doctorial Student
alexander.galozy@hh.se

Data mining, machine learning, reinforcement learning, deep neural networks, predictive health

Ali Hamad, Rebeen

M.Sc.
Doctoral student
rebeen.ali_hamad@hh.se

Transfer Learning, manifold learning, human behavior patterns, smart homes.



Fan, Yuantao

Lic.Tech
Doctoral student
yuantao.fan@hh.se

Anomaly detection, unsupervised learning, data mining, predictive maintenance.

Ashfaq, Awais

M.Sc.
Doctoral student
awais.ashfaq@hh.se

Descriptive, predictive and prescriptive analytics on EHRs, medical image processing, neural networks and deep learning.

Farouq, Shiraz

M.Sc.
Doctoral student
shiraz.farouq@hh.se

Machine learning, signal processing.

Calikus, Ece

M.Sc.
Doctoral student
ece.calikus@hh.se

Data Mining, big data, predictive maintenance, deviation detection, joint human-machine learning.

Hernandez Diaz, Kevin

M.Sc.
Doctoral student
kevin.hernandez-diaz@hh.se

Computer Vision, biometrics, pattern recognition, machine learning, image processing, signal analysis

David, Jennifer

M.Sc.
Doctoral student
jennifer.david@hh.se

Mobile robotics, intelligent vehicles, multi-robots, path planning, task scheduling.

Nemati, Hassan

Lic. Tech
Doctoral student
hasmas@hh.se

Data mining, machine learning, reliability analysis, power systems.

del Moral, Pablo

M.Sc.
Doctoral student
pablo.del_moral@hh.se

Machine learning, predictive maintenance, survival analysis, time series analysis, data stream mining.

Recena Menezes, Maria Luiza

M.Sc.
Doctoral student
maria.menezes@hh.se

Intelligent systems, smart homes, BCI, affective computing, signal analysis, data mining, machine learning.

CAISR Staff
lecturers, technical and administrative personnel

Hertz, Anne-Christine

B.Sc.
Coordinator
anne-christine.hertz@hh.se

Biomechanics, health technology, e-health, product development

Börjesson, Emma

B.Arts.
Coordinator
emma.borjesson@hh.se

Product development, health technology, gender studies and norm critical design.

Munther, Thomas

M.Sc.
Lecturer
thomas.munther@hh.se

Electronics, Electronics Design and Implementation, Control Theory, Electrical Power Systems, Electrical Machines and Drives

Chen, Kunru

M. Eng.
Research Engineer
kunru.chen@hh.se

Fault Detection, Signal Processing, Usage Analysis, Deep Learning, Data Mining

Ong, Linda

M.Sc.
Visiting research engineer

Health technology, wearable sensors, signal and data analysis, social robots and interaction

Carlsson, Roger

Research Engineer
nils_roger.carlsson@hh.se

Neural networks, Machine Learning

Salomonsson, Tommy

M.Sc.
Lecturer
tommy.salomonsson@hh.se

Mechatronics with focus on embedded systems and actuators. Autonomous mechatronic systems.

Engström, Arianna

M.Sc.
Research Engineer

Data mining, public health, machine learning, e-health

Thörner, Roland

M.Sc.
Coordinator
roland.thorner@hh.se

Research support; Internal and external relations, funding, agreements, reports.

van Esch, Johannes

B.Sc.
Research Engineer Data Mining
johannes.van_esch@hh.se

Data management, Software Development, Intelligent systems, smart homes, embedded systems

CAISR Publications 2012–2018

JOURNAL PAPERS

2018

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Knowledge Foundation

The Knowledge Foundation funds research and competence development at Sweden's new universities. The Foundation was established by the Swedish government in 1994, and the Foundation's overall mission is to strengthen Sweden's competitiveness.

The Knowledge Foundation has the following objectives:

- to support the exchange of knowledge and skills between the business sector on one hand, and universities, higher education institutions (HEIs), and research institutes on the other.
- to fund research at smaller and mid-sized HEIs and Sweden's new universities (founded after the foundation was formed) in special profile areas.
- to promote information technology.

The Knowledge Foundation achieves these objectives by helping young universities build internationally competitive research environments, work long-term on strategic profiling and increase the cooperation between academia, industry and institutes. The Foundation funding programs are all characterized by a long-term perspective and requirements for co-production with industrial partners.

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. 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.

HALMSTAD UNIVERSITY

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

Halmstad University, School of Information Technology, March 2019