CAISR

Center for Applied Intelligent System Research

Annual report 2016

HALMSTAD UNIVERSITY

data stream mining affective computing intelligent systems image/signal processing
patients' states inference from unobtrusive sensors registration of fingerprints
interestingness measures of patterns data mining intelligent environments
biometrics timeseries-analysis classification committees
automotive industry machine learning for automated driving biomedical applications
recognition representation learning reliability analysis norm critical design
robotic mapping research support biometrics recognition connected vehicles
active learning robotics control theory AGV/truck safety anomaly detection
semi-supervised learning classification anomaly detection clustering
autonomous vehicles causal inference recommender systems deep learning
self-organizing algorithms BCI predictive maintenance
mobile robotics reports
computational modelling of behaviors analysis of pathological speech power systems
path planning computer vision change-point and outlier detection
semantic mapping self-organising anomaly detection knowledge representation
predictive and prescriptive analytics on EHRs intelligent vehicles e-health
mechatronics with focus on embedded systems and actuators signal analysis
internal and external relations signal image and video processing applied physics
incorporate expert knowledge in the modelling and make models possible to interpret
speech analysis personalization signal and image processing electrical power systems
multi-robots descriptive autonomous mechatronic systems motion planning
smart homes communication security pattern recognition fuzzy logic
deep neural networks truck safety smart homes
computer graphics modelling of human behaviour patterns big data AGV
situation awareness medical image processing human-robot interaction
signal processing activity recognition electronics feature extraction
joint human-machine learning entrepreneurship SLAM
exploration agreements
unsupervised learning vehicular behavioral modeling health technology
wearable sensors human vision path planning under uncertainty well-being
mechatronics pervasive and mobile computing technology adoption modelling
human motion analysis technology for future care self-organizing models
perception connected health machine learning gender studies
survival analysis funding feature selection
tele-monitoring incorporating expert knowledge into modelling architecture
electrical machines and drives social robotics timeseries-analysis task scheduling
deviation detection signal analysis of human motion image processing
neural networks electronics design and implementation product development
AI cryptology anomaly and novelty detection robot-terrain interaction

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Knowledge Foundation

Opposite page:

A word cloud symbolizing the competence in the research environment at CAISR.

Cover photo:

Sepideh Pashami and Jens Lundström are two of the younger researchers at CAISR. Meet them in interviews in this report.

CAISR

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Annual report 2016

The Directors' statement

In our original plan for CAISR (from 2011) we described the first five years as the "start-up" and "build-up" phases for the profile, and during 2017 we would have established the profile. When looking back we can safely say that we have followed our plan very closely. We are very close to having established the profile – the recruitment of one more professor remains, but this process is well underway. The total research volume is well established above 20 million Swedish kronor, not including the industrial in-kind efforts. The industrial matching and involvement continue to be substantial, showing that we maintain a good focus on relevance and impact.

CAISR today includes well over 40 people, involved in research, industrial and public collaborations, education, and management. CAISR has around a dozen PhD students. CAISR staff members have key roles in Halmstad University's collaboration arenas, and are very active with academy-industry mobility (see more about this later in this report).

In the area of intelligent vehicles there were two visibility highlights during 2016: The Halmstad University student team won the Grand Cooperative Driving Challenge, and a film covering Halmstad University research on intelligent vehicles was presented at the Intelligent Transportation Systems Congress in Melbourne. CAISR was involved in the former by supervising two master theses connected to the team's work – a CAISR adjunct senior lecturer published two papers on the competition setup.

In the area of healthcare technology we see a growing interest in the data mining research within CAISR. We see this increased interest both in the public and the private sector. During 2016 we started a joint PhD project with the Halland Region, plus a joint PhD project with Getinge Sterilization, both in this area. Our young researchers were also granted both EU-funded and Science Council (Vetenskapsrådet) funded projects in healthcare technology.

In summary, just as 2015, 2016 was a very successful year for CAISR members.

Antanas Verikas & Thorsteinn Rögnvaldsson

CAISR **Scientific Agenda**

Aware systems research

The concept of "awareness" is very broad and has many connotations and perspectives. Regarding research on computer systems, two directions exists. One is related to what it logically means to be aware and how to determine if a system is aware or not, and another direction is related to what capabilities are required to be aware. In CAISR, we primarily focus on the second aspect. From a human psychology perspective[1], awareness requires interaction between an agent and the environment to know "what is going on". If we go further into computing systems[2], we need sensory and reasoning mechanism to obtain information or materials that allow understanding and decision-making, either made by humans or by the computing system itself. Computationally aware systems can be also classified by the event to be aware of, for example awareness of humans (where they are, what they do, what they need), awareness of a situation (objects or people are behaving safely or as expected), awareness of the own machine system (the machine is operating correctly without faults), and so on. Based on these considerations, our definition in CAISR of aware systems research is:

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

The goal is thus to construct systems that behave intelligently. The construction of knowledge (going from perception to knowledge) is often represented by the knowledge pyramid[3], shown in Figure 1. The higher a system reaches on the pyramid, the more knowledge it has, and the more aware it can be. A fully aware system will have interaction both upwards and downwards, so for example, feedback from events higher up in the pyramid can affect subsequent choices on lower levels.

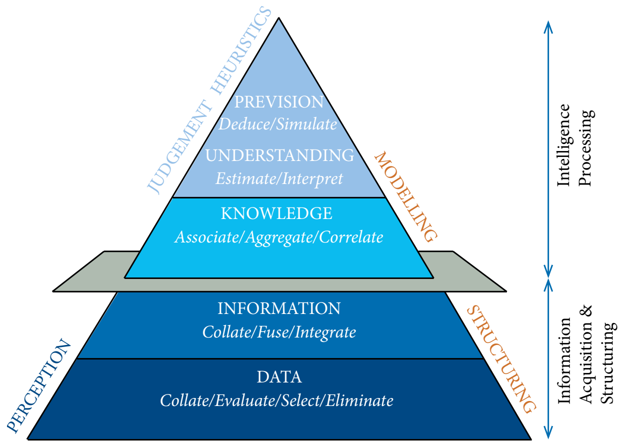


Figure 1. The knowledge pyramid, adapted from Ackoff (1989). "From Data to Wisdom". Journal of Applied Systems Analysis 16: 3–9.

Nevertheless, most research on Machine Learning (ML) and Artificial Intelligence (AI) does not consider the knowledge creation aspects of intelligent systems. Usually, human experts define the problem and task to be performed in significant detail, including data characteristics, representations and models used, constructing an algorithm that replicates the human decision. Such systems are "designed" or "programmed", and may break when the context changes. Another problematic aspect is that many mechanism underlying human reasoning are not well known yet, so it is simply not possible to make autonomous systems work 'just like' humans and implementing some technological equivalent. Likewise, so far relatively little is known regarding the question to what degree, by which means, and with which boundary conditions, human capacities can be extended to technological systems. For this reason, one aim within CAISR is to approach the construction of intelligent systems that can do "life-long self learning", i.e. that require less supervision and are capable to handle surprising situations. In order to do so, the systems must become more "aware" and able to learn on their own. As such, we do not approach problems where all data is necessarily available at the time of design, but where learning takes place over time (e.g. with streaming data).

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

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

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

From the above considerations, there are thus several open research challenges for each of the levels in the knowledge pyramid:

Data at the bottom level is related to the collection of data and how to represent it. Open questions include how to autonomously select what data to collect, and how to assess the present or future relevance of data streaming from all type of sources and with varying degrees of quality. Here, assessing the quality and reliability of a source of data can be a challenge in itself. This is often simplified by largely involving humans in such decisions, but it is clearly a relevant issue to move towards autonomous learning. Other aspects that arise at this level is how to create features that are general, i.e. they are applicable to different tasks and are able to accommodate variations in data quality; and how to aggregate representations of endless data streams (in the "internet of things" era) without needing to save all data, but at the same time without losing richness in the representation.

Information is related to the creation of "events" from the data in the previous layer, answering to questions such as "who", "what", "when" or "how many". This requires data classification, sorting, aggregation and selection. Much ML research is devoted to this stage (e.g. deep learning models), and also AI research (e.g. text and language parsing). Open questions in this level are related to how to cluster and categorize events for current or later use, either autonomously or with only limited interaction with a human (that can provide hints), and in non-stationary changing environments. A significant body of research in this level is also devoted to deviation detection.

Knowledge is related to the creation of "rules" from the information, matching "events" (inputs) to correct responses (targets). For this purpose, it can be necessary to combine information from several sources, which may also imply finding such associations during the process itself, exploiting correlations to reinforce knowledge and/or eliminate unnecessary redundancy, and being able to formulate these associations into rules. The system should also be able to evolve and learn across time due to changes in the information, either temporarily (e.g. seasonal changes) or permanently. A very relevant question is how to incorporate humans in the process, combining human- and machine-generated knowledge (e.g. in the form of text comments) to generate rules. Another question is how the knowledge itself can be represented in a structured way, so it can be used effectively in the upper levels for reasoning and prediction. A requisite to achieve awareness here is the capability of knowledge structures to evolve over time, as mentioned above, while being well-defined, highly-organized, and capable of learning from data and human experts.

Prevision and **understanding** at the top level (sometimes referred to as the "wisdom" layer) is related to answering "what will happen" or "why". For this, an aware system must be able to interpret observations from the layers below and from there, make deductions and extrapolations. The system should be also able to evaluate the consequences of its decisions. This can be for example predicting paths in robotics to avoid collision with other robots or humans, while keeping efficiency in the entrusted task.

A key and common aspect in all levels is uncertainty, which can be propagated upwards and downwards, for example asking to collect additional or alternative data if reliable modelling or prediction is not possible in upper levels. It is also an important issue the human interaction with the system, and how machines and humans can create knowledge jointly, not like traditional ways in which machines are just expected to replicate humans.

Celeste Gabrielli, ERASMUS+ student from Ancona (Italy) uses Halmstad Intelligent Home to assess the credibility of generated data characterizing human activity at home. Celeste (to the left) in discussion with Malin Bornhager (to the right),

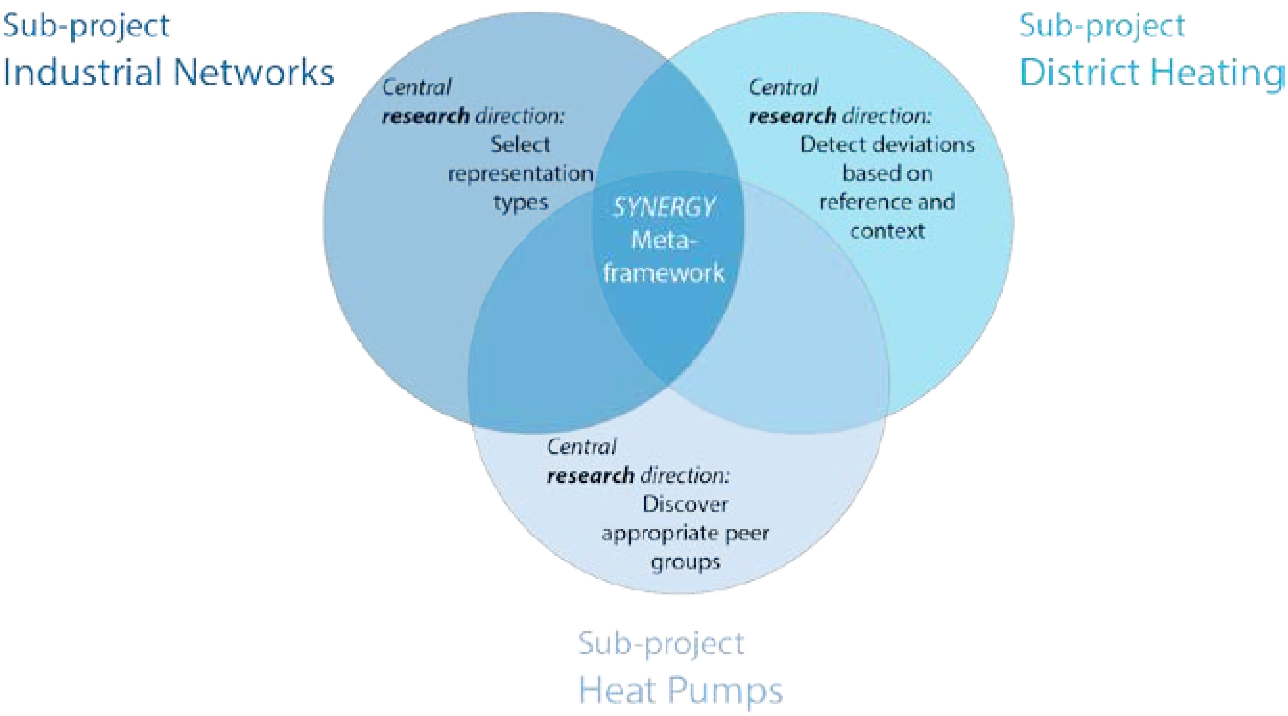
Example **Projects**

SeMI - Self-Monitoring for Innovation

The SeMI project aims at developing a meta-framework for self-monitoring systems. A meta-framework is a set of tools for automated learning that exploits data and expert knowledge from related areas and builds upon rich and diverse domain knowledge.

The first step towards achieving the goals of the project is **finding general and robust representations of data that are useful for more than one task.** The ability of any system to interpret information depends on how this data is represented. In order to develop a general meta-framework, we must develop representations that are applicable to different types of data, and are able to reflect different aspects of the monitored system. SeMI will address this issue by designing suitable interestingness metrics, and building flexible knowledge structures, automatically or semi-automatically through interactions with domain experts. The generality of our solution will be tested in three different domains with different data characteristics.

Given the suitable data representation, within SeMI we investigate **how to perform detection of deviating systems and clustering of events through the use of multiple systems and consensus-based reasoning.** For many industrial systems, multiple similar components are available, and information collected can be used to determine whether some are deviating from the norm. Such deviation detection, however, depends on how components are compared and many challenges arise when components are not identical or operate in different environments. Another issue addressed in the project is what happens when we cannot assume that the majority of systems operate correctly, in which case we must leverage expert knowledge concerning their differences in order to make inferences.



SeMI project consists of three different sub-projects; Industrial networks, District Heating and Heat Pumps. Each one contributes with its own scientific challenge and enables creating the meta-framework.

SeMI

Self-Monitoring for Innovation

In SeMI we also look for how **to match events from different data sources, including human generated knowledge, in an effective way.** Complex systems typically generate multiple kinds of data, in different formats of different size, reliability, granularity and other such properties. For example, operational data from the equipment in use and service records corresponding to maintenance of a particular machine both contain information of great value. The challenge is to automatically combine these sources to provide insight about the whole system. The project will leverage automatically detected deviations with expert input in order to learn how to hone in on relevant information despite uncertainty in the data.

Finally, all the above steps need to be combined to answer **how to reason about health status of machines and components for predictive maintenance purposes?** SeMI aims to address this by developing decision support for experts based on semi-automatic reasoning using the knowledge base of associations that were discovered on the knowledge level, ultimately providing guidelines on **how to create "joint human-machine learning" systems.**

Industrial partners

Alfa Laval · Easyserv Sweden · HEM - Halmstad Energi och Miljö · HMS Industrial Networks · Sydpumpen · Öresundskraft Kraft och Värme

Post doc Liang Dai, Ece Calikus, Shiraz Farouq, both PhD students and professor Sven Werner, in discussion about district heating

SIDUS Air - Action and Intention Recognition in Human Interaction with Autonomous Systems

This project is a national distributed research institute initiative (SIDUS) with the Mobile Robotics & Olfaction Lab at Örebro University (ÖU), the Cooperative Systems Group at Viktoria Swedish ICT (VI), and the Interaction Lab at University of Skövde (HIS). It is directed at studying action and intention recognition in human interaction with autonomous systems that move in shared physical spaces.

The mutual recognition of actions and intentions between humans and the autonomous systems they interact with is absolutely crucial to ensure safety as well public acceptance of such technologies. Public discussions on the topic have been somewhat clouded by associations with science fiction or extreme cases such as military robots or humanoids. But the underlying research issues are in fact fundamentally similar to those technologies leveraging applications that can provide many societal gains in a wide array of areas. The particular research scenarios of this project address human interaction with (1) social/assistive robots in the home, (2) autonomous transport vehicles in industrial environments, and (3) autonomous vehicles in public traffic.

Halmstad University leads the corresponding Work Package of scenario (1). All of these scenarios share the requirements that the autonomous systems must behave in a way that is unobtrusive and transparent to the humans interacting with them, and have cognitive abilities that allow humans to intuitively and effortlessly communicate their intentions and desired actions. In the framework of CAISR research, the project deals with aware intelligent environments, addressing research questions at different levels:

- Data and information: how to reliably detect, localize, recognize and track humans and other objects?
- Knowledge: how to autonomously learn activity patterns of human motion? how to enable reliable communication between humans and autonomous systems?
- Prevision and understanding: how can robots and humans move and interact seamlessly and safely in shared spaces? how can they mutually recognize their actions, intentions, habits, and status, enabling trustful and engaging interaction between them?

Endowing autonomous systems with the ability to perceive user actions and intentions is a key issue for their future acceptance and development. Existing widespread autonomous technologies, such as autonomous lawnmowers or automated transport vehicles, are not successful or accepted primarily because people actually 'trust' them, but rather because they are quite constrained in their range of motion and they simply turn away or stand still when encountering obstacles. Such simple modes of interaction (or lack thereof) obviously have their limitations, in particular where autonomous systems are envisioned to closely collaborate with people. Accordingly, autonomous systems must be endowed with higher level cognitive functions, as this project pursues.

Robots such as Baxter (left) and Sawyer (right) can use a rich variety of sensory and behavioral modalities to seek to recognize human actions and intentions and behave in a way which appears safe and transparent. For SIDUS AIR, a Baxter with a Ridgeback mobile base has been procured.

Photo: Courtesy of Rethink Robotics, Inc.

SA^{3}L - Situation Awareness for Ambient Assisted Living

The project SA^{3}L is about how to design smart environments for residential care applications. These applications are designed to be capable of creating and maintaining a model of residents' natural behaviour over time and space (e.g. **where** is the person and at **which time** and for **how long**?). Examples of residential care services that utilize such models are: *robust recognition of dangerous situations, real-time prediction of activity patterns, automatic activity reports for long-term trend detection,* and *robust answers to user queries*. Such services require learning from residents and user data over time. The ability to learn and adapt over time enables a service that is both more general and also more specific, that is simpler to deploy and more easily accepted. Learning would make it possible to handle a large variation in designs of smart environments, sensor modalities, and individual preferences and behaviours.

Wagner O. De Morais and Jens Lundström discuss how the algorithm for deviation detection is designed.

Research questions

In SA^{3}L, the first challenge approached was how to model human behaviour by using the data generated by sensors distributed throughout the home. Such data can be described as discrete, sparse and with correlation in both time (e.g. similarity in *morning routines* or *weekends*) and space (e.g. bathroom visits having similarity by their *sequence of sensor activations*). In order to find **a general and robust data representation** useful for both prediction of activity patterns as well as deviation detection, a low-dimensional spatio-temporal model based on unsupervised clustering was adopted. Using the adopted techniques similar activity patterns (in both time and space) tend to cluster, which creates *islands* of common behaviour patterns. Further, to employ **autonomous deviation detection** researchers in the project developed methods for learning the probabilities associated with the transitions between clusters of behaviour patterns as well as how long residents spend in a certain clusters. By studying how normal data and artificially created deviations were classified by the developed algorithms researchers could conclude the suitability of the approach.

Another research question that concerns the continuation of SA^{3}L is **how to explain categories** (clusters of behaviour patterns) and by doing so in a human understandable format. The hypothesis is to increase value of decision support to home care staff by allowing a system to convey what normal behaviours are and the interpretation of deviating situations. Currently researchers in the project are evaluating how fuzzy rules can explain normal and deviating behaviours by textual information understandable by users. In this step, hand-made ontologies (from users) are considered to be used in conjunction with the observed data.

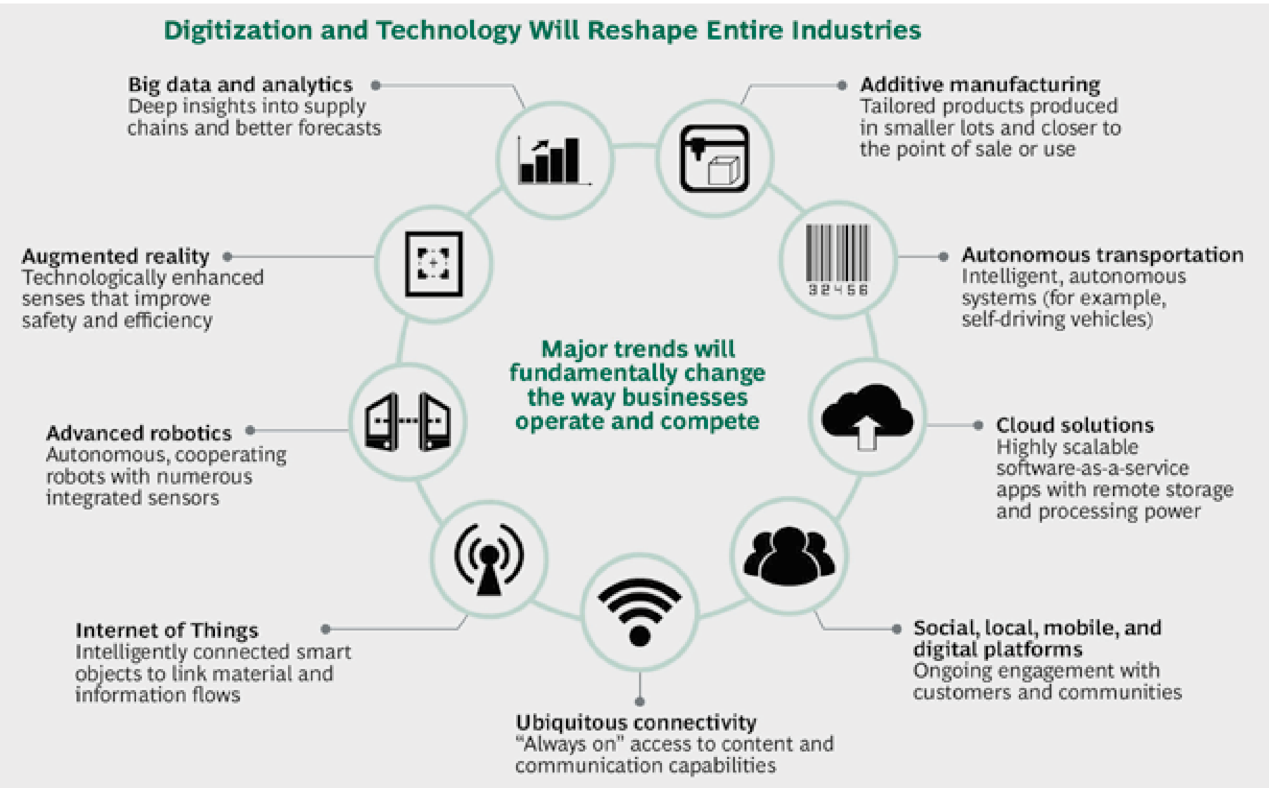
It can be observed from collected data that human behaviour patterns are seldomly static. Therefore researchers in the project are planning to adjust learning models over time using evolving clustering methods for **maintaining categorizations of human behaviour**. Even for this research question the user input is valuable and could be realizable by prompting both home care staff and residents.

CAISR and **The School of Information Technology**

Halmstad University has during 2016 continued concentration of its research efforts on two main profile areas, Health Innovation, and Smart Cities and Communities. Concentration on these two societal challenges allows the University to promote cooperation of researchers representing different subjects and helps creating strong interdisciplinary research teams capable of contributing to solution of the aforementioned challenges. Important contributions to solution of the societal challenges can only be obtained from such interdisciplinary research teams possessing relevant knowledge from various fields and capable of creating new knowledge when working together.

Being in the frontier of the digitalization of society is another prerequisite for being successful in solving the two societal challenges. Over the coming years digitalization will reshape entire industries and sectors, shown in the figure below. According to the Boston Consulting Group (BCG), it is important that both private and public sectors understand that digitalization must be a priority for Sweden aiming to increase the productivity and competiveness of Swedish businesses and public institutions [1].

The School of Information Technology (ITE) plays a leading role in advancing the digitalization agenda at the university. To better reflect technological advancement areas within information technology, to promote cooperation of researchers within ITE, and to facilitate steps from IT related research to the digitalization of society, the ITE adopted a new structure from January 2017. Four important areas of technology relevant for ITE were identified: *Aware Intelligent Systems, Digital Service Innovation, Systems of Cyber Physical Systems,* and *Smart Electronic Systems* and the former four labs of the ITE School were merged into two departments. The *department A* concentrates its efforts on *Aware Intelligent Systems* (the research focus of CAISR) and *Digital Service Innovation*, while *Systems of Cyber Physical Systems* and *Smart Electronic Systems* constitute core areas of the other department.



[1] BCG, Launching a new digital agenda, 2015

The four technology areas range from enabling technology (Smart Electronic Systems), via system solutions (Systems of Cyber Physical System, Aware Intelligent Systems), to value-creating products and services (Digital Service Innovation). A social science research group focusing on use and design of self-monitoring health technologies and autonomous driving (AD) cars was also integrated into EIS during 2016 to reinforce user innovation and user experience design research. It became part of the new department A from January 2017.

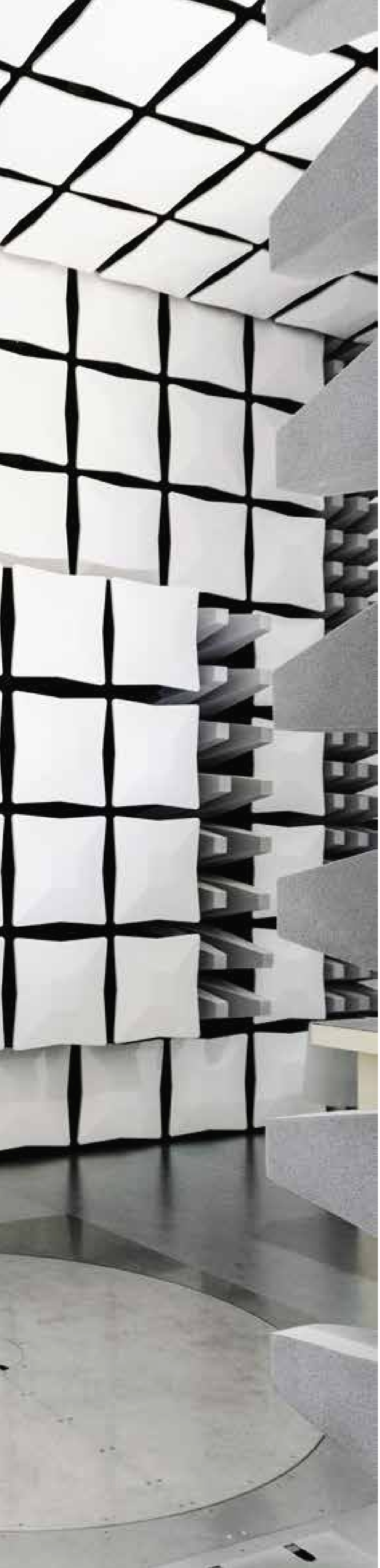
Such a constellation greatly facilitates creation of new knowledge and technology transfer concerning the digitalization of society. For example, it is reasonable to expect that research on aware intelligent systems should lead to digital services and innovations. Such expectations are very well supported by the well-established innovation and coproduction arena, the Centre for Health Technology Halland (HCH), managed by the school of ITE. HCH has already proved to be of great value for the development of the health technology application area of CAISR and continues being an important coproduction and cooperation arena for advancing digitalization within healthcare and wellbeing based on research carried out within *Aware Intelligent Systems* and *Digital Service Innovation* areas.

Presence sensor in a Health Technology application

CAISR strength in machine learning and data mining supported by knowledge of digital service innovations already resulted in a rapidly growing cooperation in research and innovation between the ITE School and Halmstad hospital possessing a unique database of "health data". The health industry is to an increasing extent dependent on personalized and tailor made care, resulting in great need for research on how individual solutions can be developed with greater speed yet preserving robustness and high quality, while being able to adapt to specific user needs (functionality, user goals, business models etc). There is no doubt that data mining and machine learning are of great value in developing such solutions. Digital service innovation researchers have already started taking important steps in exploring the role of digitalization for development of health technologies based on data analysis, which has potential to identify future industry development in health.

Alexander Örning, Halmstad Energi och Miljö AB, Slawomir Nowaczyk and Hassan Nemati, both from CAISR, in discussion about data mining within smart grids.

The school of ITE also manages the Electronics Centre in Halmstad (ECH), a very important coproduction and cooperation arena concerning profiling the university towards health innovation and smart cities and communities (SCC). SCC need enabling technologies, such as sensors, radar systems, small and energy efficient circuits, CCD cameras, accelerometers and electronics. Future digitized innovations, such as autonomous vehicles, advanced health technologies, and smart environments are dependent on research and development of enabling technologies in areas such as advanced sensors, nanotechnology, building methods for extreme electronics integration, extremely energy efficient electronics, efficient use of the limited radio spectrum and reduction of electromagnetic interference. These enabling technologies, of-



The instrument illustrate in the picture is a camera that is used for observation of the DUT (Device Under Test) during Immunity tests at ECH.

ten referred to as Internet of Things (IoT), function as the ”bandwagon” for innovations. Therefore, ECH is an important platform for research, industry collaboration and education that drive innovation of enabling technologies to meet demands on flexibility, safety, reliability, error detection and consequence analysis.

SCC are unimaginable without intelligent vehicles. Intelligent vehicles will certainly be used to provide a variety of services, such as autonomous parking, autonomous taxis, uploading, downloading and sorting of items in warehouses and harbours to name but few. CAISR with its focus on both health technology and intelligent vehicles is very well aligned with the strategic directions of the University and the School.

The Halmstad University GCDC-car *(see page 40)*

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 active in CAISR and the head for the school of information technology. One of the professors is also heading the department where CAISR is placed. This provides a very good overview of teaching, research, cooperation and coproduction. Two younger researchers coordinate activities in two main application areas of CAISR, Intelligent vehicles and Health technology. Issues concerning research, education and coproduction are equally important for CAISR. These issues are continuously raised and discussed during weekly meetings where all the department staff members are present.

Each industrial partner in CAISR is represented in the IAB. The IAB gives advice on the progress and activities from the industrial partners' perspective and takes decisions when new industrial partners want to enter or old partners need to leave. David Johansson from Tappa Service AB was the chairman during 2016 for the CAISR IAB. The IAB meets approximately semi-annually. The RG includes national and international experts representing research and industries relevant to CAISR and gives advice concerning the overall CAISR development. Professor Birgitta Bergvall-Kåreborn and Professor Xin Yao joined the RG in 2016. Members of the CAISR reference group and IAB are listed below.

Industrial Advisory Board

Peiman Khorramshahi	DaraLabs AB
Mats Billenius	NEAT Electronics AB
Emil Hällstig	Fotonic AB
David Lundqvist	Kollmorgen Automation AB
Per-Arne Viberg	Swedish Adrenaline AB
David Johansson	Tappa Service AB
Jacob Arvidson Klint	Toyota Material Handling Europe AB
Andreas Jonsson	Volvo Technology AB
Ervin Omerspahic	Volvo Bus Corporation

David Johansson, Tappa Service AB, head of IAB during 2016

CAISR Reference Group

Robert Evans	Senior software engineer at Google, Mountainview, California.
Charlotta Falvin	Chairman of the board for the Faculty of Engineering at Lund University and for the Lund research park Ideon. Member of the board for several companies.
Christer Fernström	Director and consultant at Fernstrom et Associates in Grenoble, France and the CTO of CommuniTeams in Copenhagen, Denmark.
Birgitta Bergvall-Kåreborn	Professor in Information systems at Luleå University of Technology
Xin Yao	Professor of Computer Science in the School of Computer Science at the University of Birmingham
Magnus Bergquist	Professor in Informatics. Leads the Knowledge Foundation-environment "Research for Innovation" at Halmstad University.

Funding

A total research turnaround on the university side of 18 MSEK (million Swedish kronor) was originally planned for 2016. We reached a research turnaround of about 20.4 MSEK in 2016. Moreover, the university overhead was decreased in 2015 for more than 25% so the research effort (measured in man hours) was considerably higher than our original plan. About 5.1 MSEK of the research funds came from the CAISR KK funds and 5.5 MSEK from Halmstad University. The remainder was attracted from different external sources (see the pie diagram). Thus, the level of external funding exceeds 73%.

CAISR is an industry-guided research center in a university context. Most of research in CAISR is carried out in close coproduction with industry and public sector. The industrial matching funding was more than 6.9 MSEK for 2016. During the period 2012-2016 the industrial (mostly in-kind) funding exceeded 37 MSEK.

A number of new externally funded projects started in 2016 or to be started in early 2017 (see the Table) help us expanding our national and international research and industrial networks.

Financer	Budget 2016	Actual 2016
The Knowledge Foundation	6 500 000	5 252 623
CAISR Industrial partners (in kind)[1]	7 088 000	7 279 395
Other external funding[2]	9 500 000	10 224 233
Halmstad University	5 439 940	5 514 625
Sum total	**28 527 940**	**28 270 876**

1. All in kind contribution have been computed using the standard tariff of 800 SEK per hour (the actual company costs are sometimes larger than this and sometimes less).
2. Funding from other sources (VR, EU, Vinnova, companies…) not matching the Knowledge Foundation CAISR funding

Knowledge Foundation

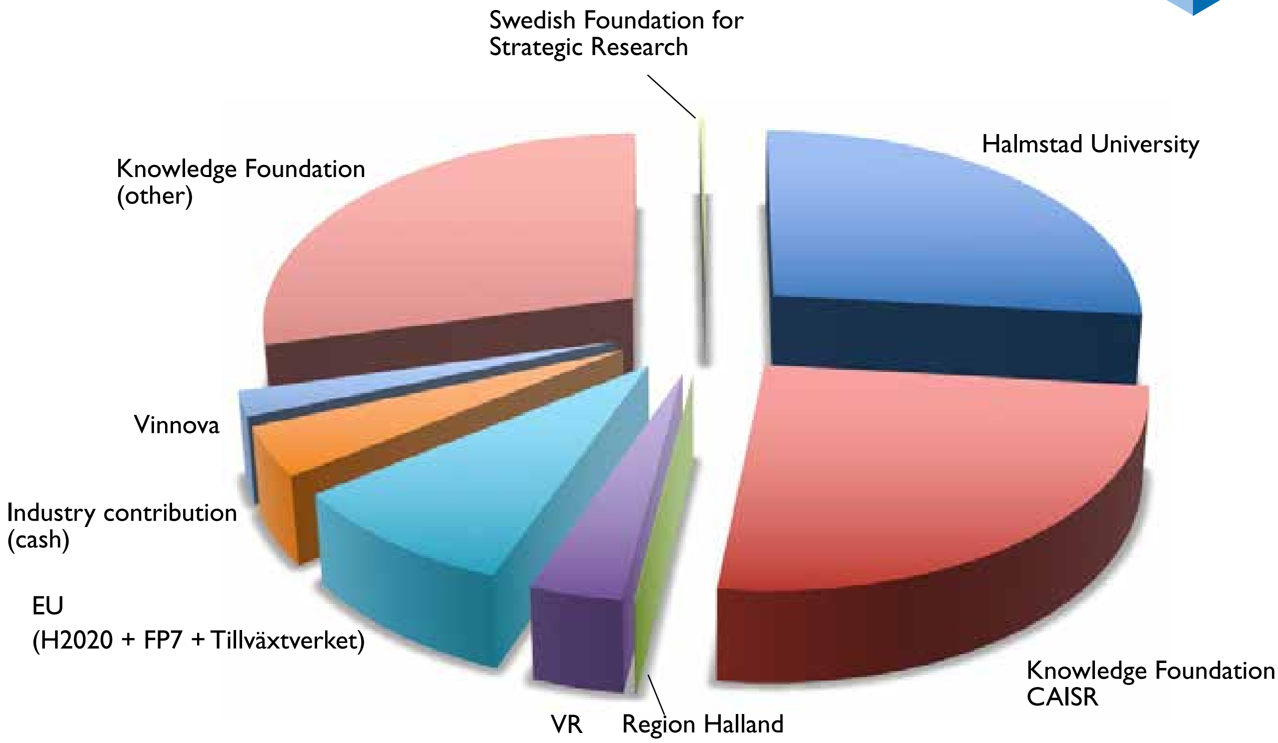
The Knowledge Foundation is the research financier for universities with the task of strengthening Sweden's competitiveness and ability to create value.

The Foundation supports research that is conducted at Sweden's new universities, provided that industry provides a matching amount and actively participates in order to achieve development there as well.

The Knowledge Foundation was established in 1994 and since then it has invested some SEK 9.1 billion in more than 2,500 projects.

The Knowledge Foundation strives to help Sweden's new universities create internationally competitive research environments, work long-term on strategic profiling and increase cooperation between academia, industry, institutes and society. Universities are responsible for a significant portion of knowledge development and research. Many are leaders in their own special areas, cooperate extensively with industry and contribute to strengthening Sweden's competitiveness and creating growth.

> *"The quality of knowledge production is improved when different perspectives take part. Research results become more relevant. Our globalised world is so complex. There are so many competencies and links between them, and an increasingly large proportion of knowledge production is taking place outside academia."*



Funding for CAISR research on the Halmstad University side 2016

Recently funded projects

Project short name	Title	Financier
ARISE	Analytical Root-cause Identification in data Streams for detection of Emerging quality issues	Vinnova
Mobility	Data-Driven Predictive Maintenance for Trucks	Vinnova
PRIME	Predictive Intelligent Maintenance Enabler	Getinge Infection Control AB
SeMI	Self-Monitoring for Innovation (SeMI): Meta-framework for group-based self-monitoring	The Knowledge Foundation
REMIND	The use of computational techniques to improve compliance to reminders within smart environments	EU H2020
Gait	Patient-centred gait assessment tools for mobility impaired patients	Promobilia foundation
HIPACH	Halland Intelligent Patient-Centered Healthcare	Region Halland, EU
Ocular	Ocular biometrics in unconstrained sensing environments	The Swedish Research Council
Active@Work	Personalized decision support to improve physical activity and self-management at work for persons with arthritis.	The Swedish Research Council

Meet researcher **Jens Lundström**

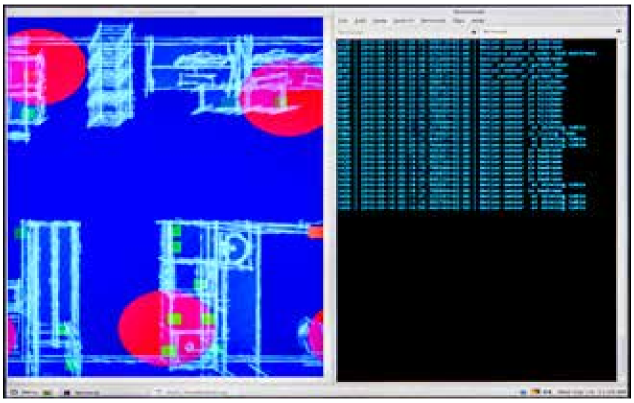
After earning his Master's degree in 2005, Jens Lundström went into business on his own. After four years as a self-employed software developer, he went back to Halmstad University for a postgraduate degree in Information Technology. Today he is an Assistant Professor, and even though he now focuses on research and teaching, he uses his understanding of the corporate world to combine the researcher's view of sustainability and long-term development with a focus on the application of innovations and the use of products for the good of society.

– Going from having my own company to being a researcher here at Halmstad University was not such a big step. The way you work here is based on collaboration, understanding of commercial interests and companies' need for growth. It's about listening, seeing possibilities and linking research to development, says Jens Lundström.
Like his colleagues, he is always looking for funding to realise new ideas and explore new areas of research. But his main focus at present is SA3L, "Situation Awareness for Ambient Assisted Living".

The project is about the Intelligent Home, how to monitor and model people's behaviour in their home environment. This research can be applied in domestic help services and geriatric care, so that the day something happens and the system alerts, you can act immediately, giving assistance, preventing suffering and using public resources where they are most needed.

Simple door sensors for data collection in Halmstad Intelligent Home.

– We are developing methods to detect changes in behaviour through simple sensors and self-learning systems that can alert attention when something is out of the ordinary. With today's home care alarms, you have an alarm with you to activate if something happens. But when it does, you might be unable to call for help. With this solution, the system will alert for you, says Jens Lundström.



Sensors detecting activities in the Intelligent Home. Anything to worry about?

For this innovation to work, you need to collect data over time. In order to have an intelligent system that can detect individual changes in behaviour, the system has to get to know you. This is the strong point of the concept, but also the greatest challenge.

– Integrity for the client is an important question.
Jens Lundström is collaborating with the company Neat Electronics in Löddeköpinge for the project SA3L, and studies have been done in homes of elderly people who have agreed to allowing sensors in their home, and to discuss their thoughts about the technical supervision and security with the researcher.

> *"We are developing methods to detect changes in behaviour through simple sensors and self-learning systems that can alert attention when something is out of the ordinary".*


Jens Lundström

– What I love about the work is the wide range of tasks. One day I'm lying underneath a bed attaching a sensor, having coffee and talking to a participant in the study about their lives and feeling of security at home. The next day I can be deep into analysing data, drawing new conclusions in a project that I will discuss with colleagues at a conference on the third day. I get to do everything.

His goal is to find a dynamic, reliable and smart system that can make people feel and be secure in their home, regardless of age or health situation.

Halmstad Intelligent Home (HINT) is a flat located at the University. Last autumn, a guest lecturer stayed there for three weeks, allowing colleagues to collect data from his everyday life. They have signed a confidentiality agreement that this data cannot be used in research, but there is much to learn from examining the sensors and algorithms at work. The technique of using sensors and algorithms for behaviour modelling in geriatric care is not unique; others are exploring it and Jens Lundström thinks there will be a product in use within a few years.

But he's aiming higher. He wants to go one step further and create a truly dynamic system that won't collapse if somebody moves a bookcase or if a change in medication gives an altered behavioural pattern.

The results of his research will help the collaborating company in taking its products forward. His goal is to find a dynamic, reliable and smart system that can make people feel and be secure in their home, regardless of age or health situation.

– We already have a static system without individual adaptivity, though the users are unique, complex and dynamic. I don't want to create the same kind of static system in a new form.

The vision of Halmstad University is to be an arena for creating value, driving innovation and developing society. Can you apply that vision to your work?

– That basically describes what I am trying to do in my research and in my projects. I think the amount of collaborations that happen here and the clear focus on synergies, from research to development and application, is something quite unique, says Jens Lundström, whose personal driving force is to keep learning new things.

– You are never fully taught. Saying that as a researcher would be biting your own tail. The world is full of unanswered questions.

Jens Lundström

Age: 35

Title: Assistant Professor

Field: Information Technology

Project in focus: SA3L, Situation Awareness for Ambient Assisted Living

CAISR Industrial **Partner**
Neat Electronics AB

Neat Electronics AB (Löddeköpinge), part of NEAT Group, manufactures telecare and telehealth products to support home care and residential care throughout the world. The company was founded 1988 and has since then expanded their business to having offices in Europe as well as their last expansion to Argentina. Today Neat is one of the leading manufacturers of carephones in Europe which enables remote communication between carers and residents by voice, push button alarms and a multitude of sensors.

Research questions in CAISR and relation to Neat

Neat Electronic's products have the important and time-critical functionality to assist people in need; therefore reliability and security of the products are essential features in their product suite. Moreover the products require high usability and intuitiveness, and due to the functionality the devices should not be too complicated to configure or to use. All these requirements make it challenging when transfering innovations from a research stage to development and then finally to a product, especially with a motivation of offering products at a good functionality-price ratio. *"We are however determined to operate in minor incremental steps designed to deliver results that are manageable and which could benefit Neat Electronics' future products."* says Jens Lundström, researcher in CAISR's SA^{3}L project in which Neat is a partner.

Currently, Halmstad University and Neat Electronics are designing future services based on the current wireless sensor network which is sold off the shelf today by Neat. These services connect to the core of CAISR's focus of developing algorithms for situation awareness, which in this project means enhanced care support provided to carers and next-of kins, e.g. sleep and toiletry behaviour summarized in a human readable format. *"For such a platform to be offered to customers, the system needs to be reliable and easy to install, with a low number of sensors."* Mats Billenius from Neat explains. Without self-learning an easy installation and reliability would be difficult due to the numerous ways of installing and configuring sensors as well as accounting for the individual human behaviour over time and space in the home. Instead, by letting a system learn by sensing the surroundings and thereby adjust to inaccurate installations and human behaviours makes the problem manageable but of course still challenging. For this challenge it is about developing methods for the system to autonomously find features that are useful for more than one application, which is a research questions for CAISR found at the Data level. As an example, the data produced by sensors in the bathroom, living room and bed could all be combined and refined to enable services not just for telling a person's location but also sleep patterns and prediction of nocturnal behaviours for deviation detection.

Services which enable carers to have a more complete view of the lives of beneficiaries are promising for future business opportunities but also addresses unsolved research questions. One of these research questions relate to *autonomous deviation detection in non-static environments, which links* to the *Information level* of the pyramid model used for describing awareness. For example, if a system learns one person's individual behaviour, this behaviour shall not be considered as static but as a behaviour that could evolve over time and therefore systems need to adapt to such changes. This is an example of challenges met when developing methods and tools aiming to maintain categorizations (of behaviours) despite the presence of concept drifts (e.g. *a person gradually or suddenly changes behaviour due to an injury*) or seasonal variations (e.g. *behaviour during weekdays in relation to weekends*). These research questions are considered in the SA^{3}L project.

Benefits from working in the CAISR project

One of the benefits of participating in a CAISR project is the connection and availability of researchers and their experience in the problem domain. The competence and past research of Visiting professors Misha Pavel and Holly Jimison are highly related to the challenges that motivate the SA^{3}L project and are therefore planned to be consulted regularly during 2017. Another gain is the access to representatives of municipalities via Health Technology Centre Halland (HCH). HCH serves as a link between research, development and the needs of home care. During 2016 HCH and Neat Electronics conducted a study in which home care staff in the municipalities of Halland were polled for needs in order to create a *catalogue of potential services*. Parts of these services are planned to be implemented at Halmstad Intelligent Home for demonstration.

http://www.neat-group.com/se/en/

Paper in Focus:

Detecting and exploring deviating behaviour of smart home residents

Expert Systems with Applications, 55(15), 2016, 429-440. J. Lundstrom, E. Jarpe, A. Verikas

In this paper, researchers in the SA³L project proposed a new approach to modelling human behaviour patterns for the long-term goal of developing a system for detecting deviating human behaviour in a smart home environment. The approach shows promising results in unsupervised modelling of human behaviour and detection of deviations. Human behaviour/activity in a short time interval is represented in a novel fashion by responses of simple non-intrusive sensors. Deviating behaviour is revealed through data clustering and analysis of associations between clusters and data vectors representing adjacent time intervals (analysing transitions between clusters). To obtain clusters of human behaviour patterns, first, a random forest is trained without using a priori defined teacher signals. Then information collected in the random forest data proximity matrix is mapped onto the 2D space and data clusters are revealed there by agglomerative clustering. Transitions between clusters are modelled by a third order Markov chain.

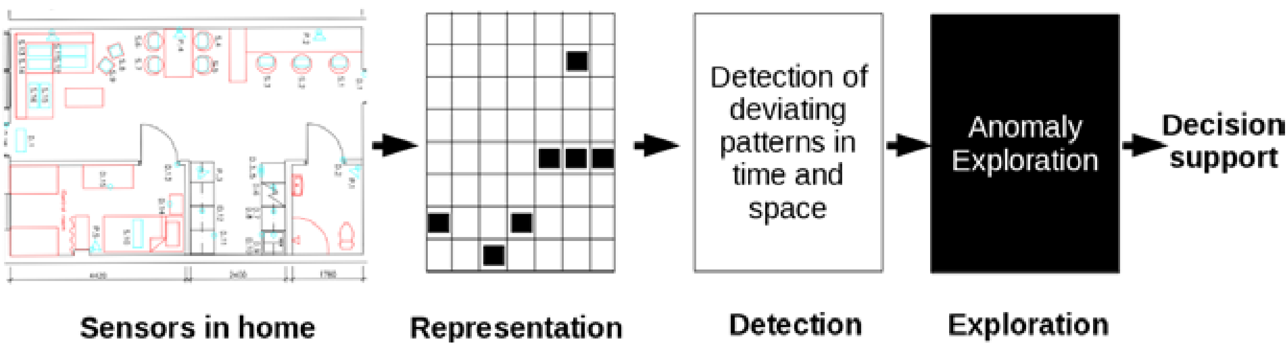
In order to relate deviations to understandable behaviours occurring in the home three types of deviations are considered: deviation in time (*doing a normal activity at a deviating time*), deviation in space (*doing an activity in a deviating way*) and deviation in the transition between clusters of similar behaviour patterns (*shifting between activities in a deviating way*).

The proposed modelling approach does not make any assumptions about the position, type, and relationship of sensors but is nevertheless able to successfully create and use a model for deviation detection–this is claimed as a significant result in the area of expert and intelligent systems. Results show that spatial and temporal deviations can be revealed through analysis of a 2D map of high dimensional data. Moreover, it was demonstrated that such a map is stable in terms of the number of clusters formed.

Future work includes to explain the clusters in terms of prototypes to make an even more understandable model (e.g. *by textual rules as when using Fuzzy rules*).

Highlights

- A new approach to modelling human behaviour patterns (using spatial and temporal information) in smart homes is presented.
- Researchers examined the detection functionality and accuracy of deviating human behaviour patterns such as falls.
- Researchers analysed deviations in space, time and transitions between behaviour patterns.
- Spatial and temporal deviations can be found through analysis of a 2D map of data.



Components of the proposed anomaly detection system

CAISR Industrial **Partner**
Fotonic AB

At Fotonic we believe that 3D cameras are a key enabler for new automation and robotics to create a safer and better world. Therefore we provide robust state of the art 3D cameras together with image processing software. The current product portfolio contains different 3D cameras based on time-of-flight or projected structured light. Main markets today are robotics, logistics, automation and agriculture and other potential markets are medical technology and safety. Fotonic strives to also provide more intelligent cameras where the 3D measurement technology is bundled with image processing software. The output would then be a higher level metric like volume of goods or obstacle position instead of a point cloud consisting of several thousands of 3D coordinates.

CAISR research questions relevant for Fotonic AB

For Fotonic it is interesting how to combine streaming data generated by 3D cameras with real-time image processing to measure, detect, position or track objects. This should also be done at high speed and with high flexibility and reliability. Research topics like data representation (i.e. how to find general and robust representations of data) in multilayer maps and how to autonomously classify and detect objects are thereby important, especially how to maintain such categorizations to application and environmental changes. At Fotonic we want our products to be more intelligent and aware, so the addressed research questions in CAISR are very much relevant.

Benefits from working in the CAISR project

There are many different benefits for Fotonic in the CAISR project. One is to learn more about and get access to new image processing algorithms developed within the research community. The data collected with our 3D cameras in the project helps us to better understand different applications, e.g. how to select what data to collect. By comparing data from different 3D sensors in the project we can also learn more about our strengths and weaknesses, making it possible for us to develop better 3D cameras. Finally the work with safety regulations for autonomous guided vehicles is important as we get a better understanding and could also hopefully affect the regulations in a way that is good for us.

Benefits from being in the CAISR network

Fotonic is a small but rapidly growing company so being part of the CAISR network and cooperating with Universities, other companies and potential customers are very important. During the first part of the project Fotonic has provided cameras and services to other partners within the network. The regular project meetings are a good place to exchange information about for example requirements related to different applications or new available technologies.

http://www.fotonic.com/

Paper in **Focus:**

Upper limit for context-based crop classification in robotic weeding application

Biosystems Engineering, 146(SI), 2016, 183-192. S. Midtiby, B. Åstrand, O. Jorgensen

Knowledge of the precise position of crop plants is a prerequisite for effective mechanical weed control in robotic weeding applications such as in crops like sugar beets which are sensitive to mechanical stress. Visual detection and recognition of crop plants based on their shapes has been described many times in the literature. In this paper the potential of using knowledge about the crop seed pattern is investigated based on simulated output from a perception system. The reliability of position–based crop plant detection is shown to depend on the weed density (ρ, measured in weed plants per square metre) and the crop plant pattern position uncertainty (σx and σy, measured in metres along and perpendicular to the crop row, respectively). The recognition reliability can be described with the positive predictive value (PPV), which is limited by the seeding pattern uncertainty and the weed density according to the inequality: $PPV \leq (1 + 2\pi\rho\sigma x\sigma y)^{-1}$. This result matches computer simulations of two novel methods for position–based crop recognition as well as earlier reported field–based trials.

Highlights

- Derivation of classification limits for context based classifiers.
- Variables weed pressure and the uncertainty of crop plant position.
- Testing of two novel context based crop recognition methods described.
- Predicted upper limit for classifiers agreed well with results from real field data.

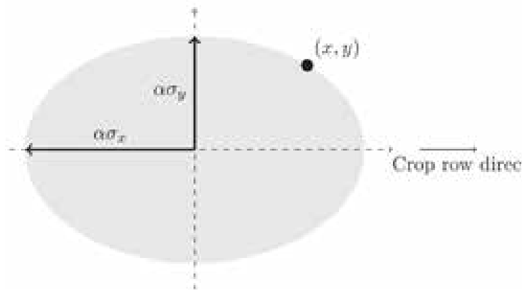


Fig. 1 Given a crop plant at (x,y), the area that should be weed free for obtaining a correct classification is marked with a grey shading. All points in the shaded area have a smaller Mahanolobis distance to the expected crop location than the observed crop at (x,y). Origin is the expected crop plant position.

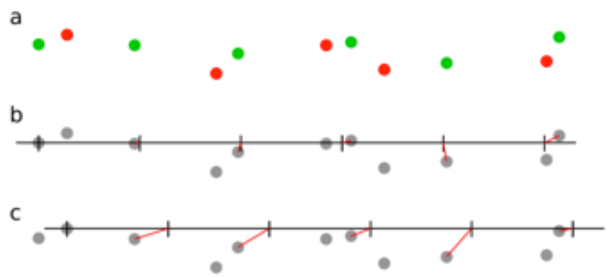


Fig. 2 Two examples of how position scores are calculated, when looking at five neighbour sites (N = 5). Grey circles represent plant locations, the black scale marks expected crop plant locations and the red lines are the distance from an expected crop plant location to the nearest observed plant. The used plant positions are shown in a), green circles represent crop plants and red circles weed plants. In b) the position score of a plant, which belong to the crop-row structure, is visualised. c) is similar to b) but now with a plant outside the crop-row structure.

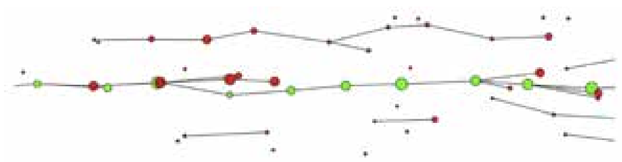


Fig. 3 Example of tree built by the path score method. The circles mark plant positions (crops are green and weeds are red) and their radii are proportional to the assigned position score. Solid lines indicate the neighbouring plant position that is contributing to the current position score.

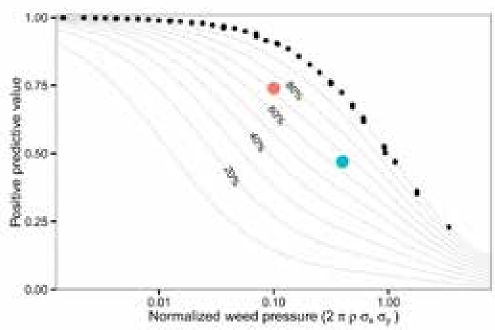


Fig. 4 Visualisation of the predicted PPV as a function of the normalised weed pressure and the crop emergence; emergence percentages are indicated. The black dots are simulation results of the known seeding positions method for recognising crop plants; it is seen to follow the prediction PPV. The two coloured dots are PPV from field experiments.

CAISR Industrial **Partner**
Kollmorgen Automation AB

Kollmorgen Automation is part of Fortive, a fortune 500 company, listed on New York Stock Exchange (FTV) with annual sales of 6 Billion US Dollars. Kollmorgen Automation is a world-leading provider of vehicle automation kits for automated guided vehicles (AGV) and mobile robots. Our NDC Solutions platform includes everything you need for excellent vehicle control of a driverless vehicle —hardware, software, navigation, design- and service tools.

Innovation is fundamental to Kollmorgen Automation and its owner Fortive, together with continuous improvements in quality, delivery and cost. Kollmorgen Automation is part of several research projects, http://ndcsolutions.com/about/#research-projects, and these are part of Kollmorgen's general research and development within vehicle automation kits for automated guided vehicles (AGV). The idea is to regularly come up with new ideas on navigation, hardware, software and services to integrate into the NDC8 platform.

CAISR research questions relevant for Kollmorgen Automation

To meet our customers' future demands for driverless vehicles, it needs to be easy to install an AGV system. The system must be perceived as easy to handle for users and this often requires complex algorithms interpreting the surroundings via sensors in order to help in the best way possible.

We focused on identifying and developing possible solutions to minimize the time to install an AGV system. This can be done in many aspects and one is by using smart solutions allowing the system to be aware of their surroundings. This means, for example, a sensor system that, as autonomously as possible, can construct a suitable representation of the environment (including geometric and semantic information) that facilitates an intuitive setup and short installation times. A research question here is how this information/knowledge should be represented? The representation of the environment also needs to be scalable and flexible (adapt to changes in the environment). A research question here is how to identify interesting and novel events (e.g. changes in the environment), and how to maintain such representations over time?

Another area is that we are focusing on making the system smarter predicting a better flow in the systems and here it is important that we are aware of the surroundings so that the system can take smart decisions dependent on what awaits.

Benefits from working in the CAISR project

We are working together with Halmstad in the SAS2 (Situation aware safety systems) project to further understanding of the challenges described above. Leveraging the awareness (e.g. predicting actions of other agents in the environment) of today's safety systems will not only make the AGV's more flexible but also increase the productivity of an AGV system. Moreover, a system that automatically generates warning fields, based on environmental input (including sematic information) and truck state, will ultimately minimize the time to install an AGV system. A research question here is what level of awareness is needed?

Furthermore, we are contributing with our test facility and AGV's so that the researchers could test and collect data together with our system.

Benefits from being in the CAISR network

Finally, we strongly believe that a close cooperation between the industrial parties and the academy is a necessity in order to be able to deliver breakthrough products, which ultimately is Kollmorgen Automation's commitment to its customers.

http://ndcsolutions.com/

Paper in **Focus:**

Experimental analysis regarding the influence of iris segmentation on the recognition rate

IET Biometrics, 5(3), 2016, 200-211. Hofbauer, F. Alonso-Fernandez, J. Bigun, A. Uhl

In this study the authors look at the detection and segmentation of the iris and its influence on the overall performance of the iris-biometric tool chain. The paper examines whether the segmentation accuracy, based on conformance with a ground truth, can serve as a predictor for the overall performance of the iris-biometric tool chain. That is: If the segmentation accuracy is improved, will this always improve the overall performance? Furthermore, the paper systematically evaluates the influence of segmentation parameters, pupillary and limbic boundary and normalisation centre (based on Daugman's rubbersheet model), on the rest of the iris-biometric tool chain. The authors investigate if accurately finding these parameters is important and how consistency, that is, extracting the same exact region of the iris during segmenting, influences the overall performance.

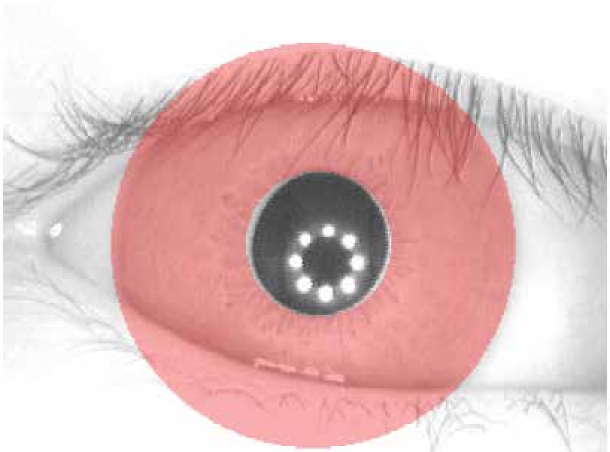
Highlights

- Segmentation is a critical part in iris recognition systems, since errors in this initial stage are propagated to subsequent processing stages. However, the lack of ground truth data for iris segmentation has produced that when evaluating the performance of iris segmentation algorithms, this is mostly done by utilizing the recognition rate, and consequently the overall performance of the biometric system.

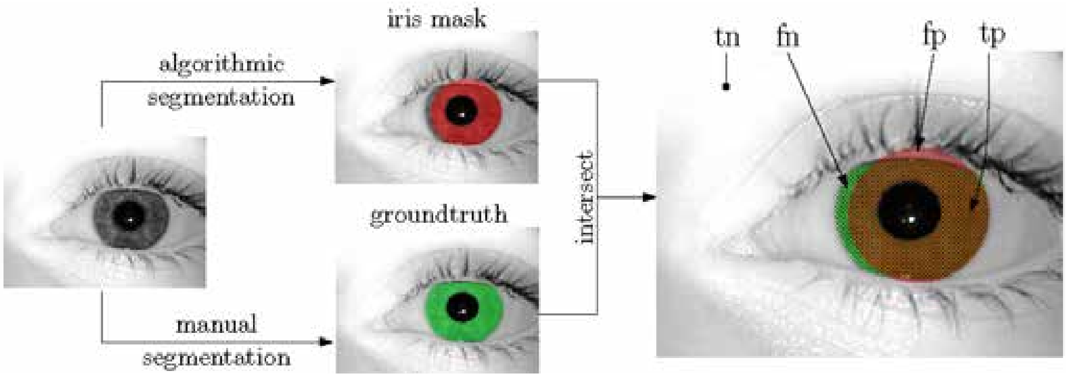
- In order to streamline the development and assessment of iris segmentation with the independence on the whole biometric system, we have generated an iris segmentation ground truth database. We also show a method for evaluating segmentation performance base on this ground truth database and give examples of how to identify problematic cases in order to further analyse the segmentation algorithms.

- Our experiments show that segmentation accuracy is not a reliable predictor of overall iris tool chain performance, i.e. a feature extraction method can produce better overall results even if segmentation is worse. This means that the choice of segmentation and feature extraction should not be made in isolation.

- Regarding segmentation accuracy, we found that it is not required to extract the whole iris image as long as the extracted region is consistent, i.e., the same region is extracted for both matched templates. This is valid under the assumption that the normalisation center is stable and the center point is correctly identified.



Correct outer iris



CAISR Industrial **Partner**

Swedish Adrenaline AB

Swedish Adrenaline AB has two business areas: Sensing of vital signs in the health care sector and innovative sensors for the sports market. These two business areas are implemented in two subsidiaries: *Raytelligence* for sensing in the health technology area and *Innowearable* for sensing in the sports area.

Raytelligence: The RayVS1 radar sensor could play an important role in the future health care. To be able to monitor respiration, heart rate, and motion patterns with one single sensor would be a big leap forward in modern heath care. The fact that the sensor has the form of light bulb makes it interesting from an implementation point of view. All functionality for sensing and communication can be integrated in this device.

Imagine that the RayVS1 is placed in the bedroom of an elderly person. The vital signs can be monitored throughout the night. When any parameter is outside a specified range, measures are taken; e.g. an alarm or a message for subject's relatives. Anomalies can be detected with established algorithms.

Innowearable: is an invention company with the vision to provide new products that enhance the performance of athletes. Examples of products are non-invasive blood lactate concentration level and force measurements in different training scenarios. Machine learning-based algorithms capable of mapping EMG signals sensed from the muscles of an athlete to the blood lactate level is the basis for the products developed at Innowearable.

CAISR Research questions relevant for Swedish Adrenaline

The product development at Innowearable is entirely based on the research results from CAISR. The open research question was "Can we assess the blood lactate concentration level, oxygen uptake rate, and muscle fatigue level using the EMG signals recorded from the muscles of an athlete?" This ongoing work has until now been very successful with encouraging results.

The following questions of the CAISR research agenda are of high importance for the CAISR project as well as for the company in general:

- *How to find general and robust representations of data useful for more than one task?* We are interested in algorithms capable of analyzing data recorded during various exercises, e.g. bicycling, running, skiing. Thus general representation of data is of great importance.
- *How to deal with missing, flawed or erroneous signals coming from EMG or inertial sensors*? Bad connectivity is the most common cause of such signals.
- *How to build accurate models for predicting physiological parameters of athletes using the discovered representations of EMG signals?* Accurate models exhibiting good generalization properties and capable of learning from data is a prerequisite for success of the project.
- *How to represent domain and human expert knowledge to be used in combination with information generated by predictive models?* To provide meaningful feedback to athletes, knowledge of human experts and domain knowledge need to be formalized for efficient use in combination with information obtained from predictive models.
- *How to anticipate the progress of observed physiological parameters of athletes, how to plan actions based on this inference and how to justify the plans*? We believe that such algorithms can be developed in a not so distant future based on tools for semi-automatic interaction between man and machine.

Benefits from working in CAISR

Working in CAISR projects is very important for development of the company. Interacting with CAISR researchers contributes to competence development of the personnel, and provides opportunity to attract bright students for future employment. Being in the CAISR network allows us to learn how to create new businesses based on data mining, and how knowledge extracted from data can be used to advance products and services provided by the company.

We believe that other CAISR partners also benefit from being exposed to other branches of Swedish Adrenaline (e.g. radar sensing).

http://www.swedishadrenaline.com/

CAISR Industrial **Partner**

Toyota Material Handling Europe AB

Toyota Material Handling Europe AB is a member of the global company TMHG, which is the world's biggest supplier of warehouse solutions in terms of material handling solutions. TMHE has in total over 8500 employees and is responsible for the European market including western Russia. Traditionally our strongest product segment is the manual fork lift trucks but a step-change is approaching which will require us to focus on being more of a warehouse solutions provider. Customers search for partners that can improve and support their material handling operation with the skills to reduce cost, increase productivity and offer solutions to enhance the level of safety. This step-change in the market leads to new challenges and possibilities. The traditional products have to be upgraded and we have to widen our offer. Important key-areas for the future are automation and management systems. CAISR is connected to technologies supporting both areas.

CAISR research questions relevant for Toyota Material Handling

Relevant to us is research and development of advanced management and automation systems that can handle the complexity and dynamics of the environment. This means a system that handles changes in the environment autonomously, or with as little interaction of humans as possible. Adaptivity is achieved by the means of streaming data from onboard perception systems on the working vehicles interacting with the environment, as well as interaction with Warehouse Management Systems (WMS) for improved decision making. This means that a system to some extent needs to be aware, e.g. the working vehicles can see and identify objects in the surroundings, predict action/behaviors of other agents and construct knowledge from data. This opens up the possibility to create new systems for positioning/navigation, warehouse inventory, machine operation control, accident prevention and order checks. Advanced systems with connection to the customers WMS-systems could be one of the most important solutions to improve warehouse operations in the future. Important research questions relate to how to select a suitable sensor type and configuration and how does that impact on system performance; how to (semi-) autonomously identify different categories in a warehouse (e.g. humans, trucks, and infrastructure) and how to represent knowledge collected.

Benefits from working in the CAISR project

The main driver for automation is cost reduction. However, flexibility, expanding the operation time 24-7, or reducing the risk for accidents and damages are other strong arguments for automation. The safety standards for automated trucks and AGV's are old and based on 2-D sensor technology. We believe that 3-D cameras and sensors will replace the old sensors, both because the technology is low cost and they can provide better functionality. How to improve the performance of a safety system of a driverless truck by leveraging the awareness (e.g. foresee actions of moving agents) by incorporating new functionalities as identification (humans, trucks, etc.) and tracking and objects/agents are important research questions for us. TMHE needs to be at the front-line in this research to be competitive.

Benefits from being in the CAISR network

In 2011, when TMHE began organizing as a solution provider, we came in contact with the CAISR initiative and were invited to join. The project description and the other industry partners woke our interest to participate. At this point, we have reached several of our goals and the result has made it possible to sharpen the upcoming activities. Beside the project activities we have also created contacts with other business partners, not only within CAISR. These collaborations have created new products and solutions delivered to our customers.

www.toyota-forklifts.se

CAISR Industrial **Partner**

Tappa AB

Tappa was established in Varberg, Sweden 2005 and have since delivered digital wellness solutions across Scandinavia and Germany to thousands of companies and organisations. Based on counting steps and having participants competing with each other on the platform Tappa motivates employees into taking the stairs instead of the elevator or taking the bike instead of the car when commuting to the workplace. In addition to increasing the physical activity for the employees the concept aims towards improving the work environment and increasing the knowledge regarding health from a broad perspective.

CAISR research questions relevant for Tappa

At the "Information level" connecting patterns in physical activity with observations in data without explicitly modelling them.

At the "Knowledge level" understanding trends and patterns in physical activity behaviours.

At the "Understanding and Prevision level" reason on how to predict effects of interventions & rank interventions based on different criteria.

Benefits from working in the CAISR project

Being able to cooperate with high level researchers and test ideas before bringing them to market through own channels. Connect with students and researchers, who give us a view on development and concepts that are important for bringing our product forward.

Two years ago we had the benefit to use a CAISR shared resource, a development engineer. This enabled us to take the step counting mechanism from the CAISR project and integrate the information into existing services provided by Tappa (this is described in the 2014 CAISR annual report). This resulted in an app for step counting on Android phones.

Benefits from being in the CAISR network

Shared knowledge and possibility to discuss matters with companies from both within and outside our branch.

The CAISR network has also led to us being involved in another project at Halmstad University, GODIS, which focuses on psychological models for promoting healthy lifestyles.

https://www.tappa.se

Paper in **Focus:**

Gait Event Detection in Real-World Environment for Long-Term Applications: Incorporating Domain Knowledge into Time-Frequency Analysis

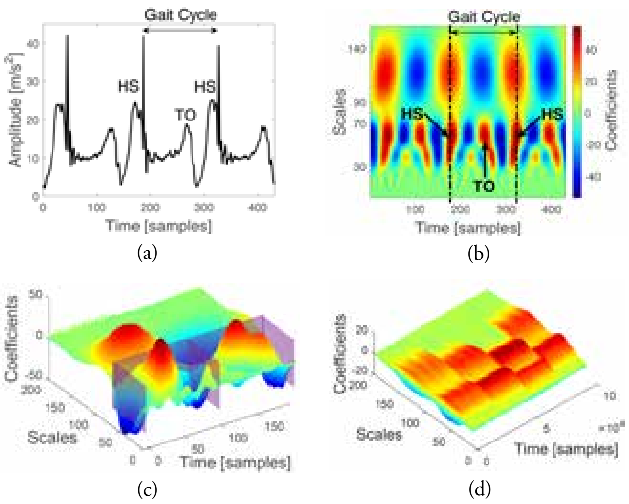
IEEE Transactions on Neural Systems and Rehabilitation Engineering, 24(12): 1363-1372.
Siddhartha Khandelwal, Nicholas Wickström,

Detecting gait events is the key to many gait analysis applications that would benefit from continuous monitoring or long-term analysis. Most gait event detection algorithms using wearable sensors that offer a potential for use in daily living have been developed from data collected in controlled indoor experiments. However, for real-word applications, it is essential that the analysis is carried out in humans' natural environment; that involves different gait speeds, changing walking terrains, varying surface inclinations and regular turns among other factors. Existing domain knowledge in the form of principles or underlying fundamental gait relationships can be utilized to drive and support the data analysis in order to develop robust algorithms that can tackle real-world challenges in gait analysis. This paper presents a novel approach that exhibits how domain knowledge about human gait can be incorporated into time-frequency analysis to detect gait events from long-term accelerometer signals. The accuracy and robustness of the proposed algorithm are validated by experiments done in indoor and outdoor environments with approximately 93 600 gait events in total. The proposed algorithm exhibits consistently high performance scores across all datasets in both indoor and outdoor environments.

Highlights

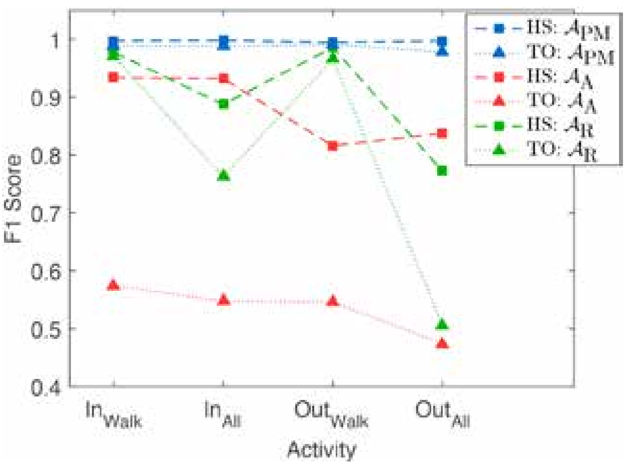
- A novel approach that demonstrates how domain or expert knowledge about human walking can be incorporated into time-frequency analysis.
- The proposed algorithm exhibits high accuracy and robustness in detecting gait events of Heel-Strike (HS) and Toe-Off (TO) from accelerometer signals collected in real-world settings.
- A new approach of evaluating the accuracy of an event detection algorithm is presented by utilizing non-parametric statistical tests.

Figure 1



(a) HS and TO events in one gait cycle of a composite acceleration signal, obtained from the accelerometer attached to the ankle. **(b)** Time-frequency representation (top view) of the composite acceleration signal using Continuous Wavelet Transform (CWT) by the Morlet wavelet. HS and TO events exist in the finer scales while the corresponding gait cycle exists along the coarser scales. **(c)** Spectral-temporal boundary shown as semi-transparent walls, around the HS and TO region in one gait cycle. **(d)** CWT coefficients shift along the spectral axis with changes in gait speed. With faster gait speeds, the event and cycle coefficients shift towards the finer scales.

Figure 2



Mean F1 scores of all algorithms for detecting HS and TO in indoor and outdoor environments. Activities labelled InWalk, InAll, OutWalk and OutAll represent only indoor (flat space) walking, all indoor activities grouped together, only outdoor walking and all outdoor activities grouped together, respectively. Mean F1 score of detecting HS for a particular activity is shown as a square while that for detecting TO is shown as a triangle. F1 score reaches its best value at 1 and worst at 0. Abbreviation APM stands for Proposed Method while AA & AR stand for two other state-of-the-art methods.

CAISR Industrial **Partner**
Volvo Technology AB

Volvo Technology AB is a legal entity within AB Volvo's business unit Volvo Group Trucks Technology. The unit designs and engineers vehicle, powertrain, and main components.The mission is to drive prosperity through transport solutions by being the most desired and successful transport solution provider in the world.

CAISR Research questions relevant for Volvo Technology

Volvo has an interest in questions related to all levels of the CAISR model. The main relevance is towards Volvo's ambition to find and develop technologies for self-driving commercial vehicles.

Data level: How collect the data and transfer it from sensory equipment to computational nodes in a reliable way

Information level: How to process data to extract information on the traffic environment including object contours, speeds and distances

Knowledge level: How to merge data from several information sources both within the own vehicle, other vehicles and the infrastructure

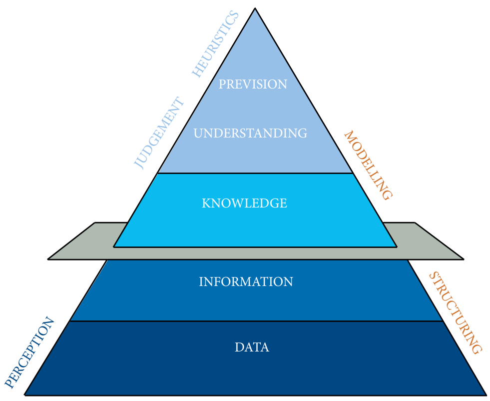
Understanding and prevision level: How to take strategic decisions where to position the vehicle on the road in a safe way

Benefits from working in the project

Volvo see the potential in cooperating with other partners in the CAISR projects. Several partners have experiences from other non-competitive industries, such as AGV systems. This experience can be useful for Volvo both on vehicle technology level, but also in understanding the needs of autonomous fleet customers.

Benefits from being in the CAISR network

Volvo can influence the direction of research to ensure results are useful in the application area of commercial heavy vehicles



How to take strategic decisions where to position the vehicle on the road in a safe way

How to merge data from several information sources both within the own vehicle, other vehicles and the infrastructure

How to process data to extract information on the traffic environment including object contours, speeds and distances

How to collect the data and transfer it from sensory equipment to computational nodes in a reliable way

www.volvogroup.com

Paper in **Focus:**

Predicting Air Compressor Failures with Echo State Networks

Third European Conference of the Prognostics and Health Management Society 2016, Bilbao, Spain, 5-8 July, 2016. PHM Society, 2016. Yuantao Fan, Sławomir Nowaczyk, Thorsteinn Rögnvaldsson and Eric Aislan Antonelo

Modern vehicles have increasing amounts of data streaming continuously on-board their controller area networks. The next generation of equipment monitoring and maintenance prediction solutions for such highly digitised systems will be required to build up knowledge (semi-)autonomously and learn over the lifetime of the equipment. Such an approach towards autonomous fault detection and improving vehicle uptime was proposed by researchers at CAISR. The method, called Consensus Self-Organising Models (COSMO), utilises compressed representation of on-board sensor signals and finds deviations based on the idea of "wisdom of the crowd" and deviation detection; an illustration is shown in Figure 1.

In this paper, Echo State Network (ESN), shown in Figure 2, is employed to represent on-board signal and applied to predict on-road failures caused by air compressor faults in city buses based on COSMO framework. A key feature of ESNs is the ability to encode various characteristics and explanatory factors of signals without external supervisions. Trained upon time series, ESN can model and capture non-linear dynamics of signals. ESN is a special type of Recurrent Neural Networks that is based on a large reservoir of recurrently connected units with its connection strength randomly determined and fixed over time. By learning the mapping from the readout to a teaching signal using a linear or Ridge regression technique, ESNs can be trained very efficiently (much faster than RNNs), which made it suitable to be applied on-board vehicle where computation resources are limited.

Highlights:

- Proposed to train Echo State Networks to learn dynamic behaviour of the air system of heavy duty vehicles based on Wet Tank Air Pressure signal and use trained Networks to present the system.
- Utilised two types of distance measure for comparing different ESN models, as is shown in Figure 3. Analytical distance (grey area in upper plot) integrates the area between two functions. Monte-Carlo distance (grey lines in lower plot) computes l2-norm between randomly sampled reservoir states. Analytical distance works well if all reservoir states are uniformly distributed over the whole space. Otherwise, Monte-Carlo distance can be employed. However, it requires more computation power as well as memory.
- Synthetic experiments showed that ESNs can detect multiple types of faults without providing any additional explicit knowledge regarding inputs, while, part from being compact and robust, histograms need to be calculated over appropriate signals, to detect a specific type of fault.
- Being more robust, compact and resource efficient, histograms perform better than ESNs in detecting serious compressor failures on real data.

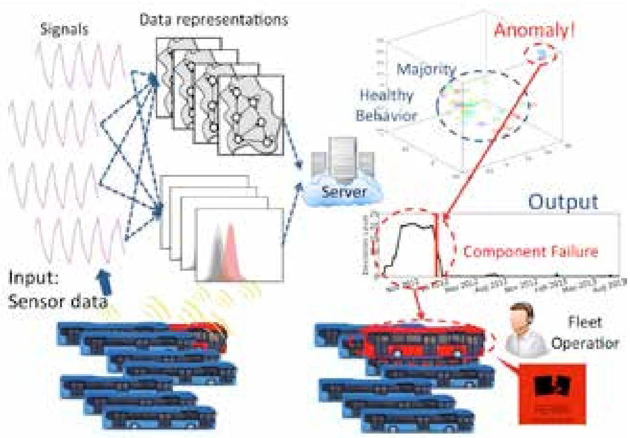


Figure 1 An illustration of Consensus Self-Organising Models method

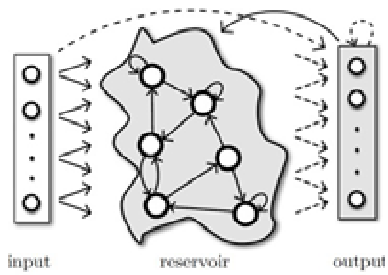


Figure 2 Echo State Network / Reservoir Computing (RC) network. The reservoir is a non-linear dynamical system usually composed of recurrent sigmoid units.

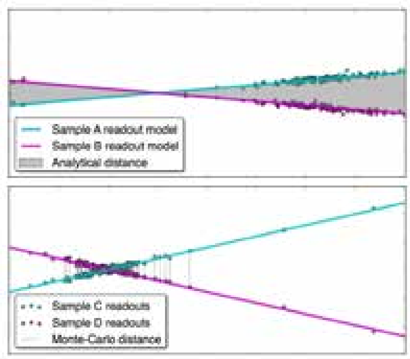


Figure 3 Two distance measures for comparing ESNs.

CAISR Industrial **Partner**

Volvo Bus Corporation

As one of the world's biggest manufacturers of large buses and coaches, Volvo Buses has a responsibility to society. We want to be part of shaping the future, based on our core values of Quality, Safety and Environmental Care. We do it by driving our industry and society forward through innovative solutions that improve everyday life for people and entire cities, today and tomorrow. Volvo Buses is one of the world's leading brands of buses and coaches, operating in more than 140 countries. We are driven by a passion to help create the cities of the future, free from congestion, emissions and noise. Our mission is to help operators and communities offer people safe, clean and efficient transportation to and from work, around the city or across the continent. We do so by striving to be the ultimate provider of sustainable transport solutions.

CAISR research questions relevant for Volvo Bus

Many of the research questions put forward in CAISR scientific agenda have clear applications towards the current and future products and services that are under development in Volvo Buses.

Given the specific challenges of the automotive industry together with perpetual development of computing and communication technology, we continuously need to select which data to collect, store and analyse? Data collection and transfer is expensive in the distributed, mobile setting, but the potential benefits are immense. Based on engineering knowledge within Volvo Group we can do it for the purposes we have identified today, but it would be of great benefit to know how to match the data to various future tasks? New products and services are introduced every day, and they often have hard to predict data requirements. Additionally, what is collected is often difficult to understand: how to describe the purpose of this data? Informal and unstructured descriptions of the available parameters can seriously limit the future opportunities for use of automatic data analysis. Another challenge is how to deal with missing, flawed or erroneous data? Such problems will inevitably happen, and many solutions available today lack the necessary robustness.

In a global organisation like Volvo Buses it is important to understand that the context in which a particular system, be it a vehicle or a workshop, operates is largely unknown in most cases. However, one still needs to know how to detect trends, patterns and anomalies in the collected data. Data created by a system is affected by its external, often unknown, conditions and extracting the actual performance indicators is a challenge. An important data analytics task is assigning categories to objects, and in particular we collaborate within CAISR on how to maintain such categorisations over time and how to quickly detect category changes. For example, there are significant season and geographical variations that affect our vehicles, making it critical that we understand how their operation is expected to change based on such factors.

One of the important research directions we pursue together with CAISR is how to combine diverse data sources. Within Volvo Group there is a lot of data collected, by different people and for different purposes. Some of this data is based on directly recording sensor readings, other input is a result of complex analysis by experts. A lot of new insight can be obtained by bringing all of them together. However, it raises the question of how to handle the combination of information sources that may all be uncertain. Also, given this diversity, how can events from different data sources, including human generated data, be associated? Fundamentally, the purpose is not to automate all the aspects of company operation, but rather to support engineers: how to present knowledge obtained through data mining to domain experts?

The ultimate objective for Volvo Buses is to provide better value for our customers. To this end, we need to understand how to plan actions based on discovered knowledge. Machine learning models find relations and patterns in the data, but how to use those patterns to predict effects of interventions.

www.volvobuses.com/

Benefits from working in the CAISR project

Volvo Group has been developing predictive maintenance solutions aiming to decrease maintenance cost, downtime of vehicles and repair time for several years now. Ensuring that the vehicles are in good condition is also critical for safety and environment. The current project aims to identify components with the highest potential for societal and business impact, as well as to develop a methodology for adapting the predictive maintenance data mining methods for their specific requirements. Collaboration between CAISR researchers and aftermarket experts will lead to new approaches for explaining the reasoning behind the decisions made by machine learning models and, ultimately, to more precise identification of the actual causes for predicted failures.

Benefits from being in the CAISR network

Interactions with several partners within the CAISR network provide opportunities for knowledge exchange and allow us to explore novel directions of research and product development. The work CAISR researchers have done in identifying common threads across various projects gives us valuable insight and deeper understanding of the theoretical foundations underlying the specific problems we face within the automotive industry. Data analytics and machine learning are becoming more important tools for both the product development and aftermarket within Volvo Buses, and we appreciate the opportunity to observe how similar transformations happen in other industries.

Meet researcher **Sepideh Pashami**

After studying at Teheran University and earning her PhD at Örebro University, Sepideh Pashami came to Halmstad University in May 2015.

Here, she is involved in several projects that focus on analysing big data, making sense of the data by means of statistical machine learning, predicting effects and understanding not only what happens when you change certain factors in a process, but also why it happens.

Currently, she spends one day a week at Volvo AB researching "Data-Driven Predictive Maintenance for Trucks", a project financed by Vinnova.

– The aim is to predict the maintenance needs of a truck, before they happen. The collaboration between Halmstad University and Volvo Group on predictive maintenance has been going on for a long time, and there are existing solutions. The goal of this project is to improve the prediction accuracy and reduce the number of false alarms, says Sepideh Pashami, explaining that reducing the false alarms even by a small percentage can have a huge and visible impact when the solution is applied on a large scale for all the Volvo trucks.

- I am also working on another project with Volvo Group, focusing on early detection of the quality issues targeting a group of vehicles instead of individual trucks for predictive maintenance.

Causal inference workshop at RISE SICS. There is a close collaboration between Juhee Bae (from Skövde university), Sepideh Pashami (from Halmstad university) and Anders Holst (from RISE SICS) on causal inference part of the BIDAF project.

Sepideh Pashami is involved in one more theoretical project about analysing big data, combining different sources of information, handling streaming data, and providing interactive functionality to communicate easier to end-users.

– The goal of this project is to develop general methodology, which can address big data challenges and later be used in different domains. The areas of the research include machine learning, distributed algorithms, uncertainty management, data fusion, causal inference and visualisation, says Sepideh Pashami, explaining that the results of this project can be complementary to the applied project discussed previously. A massive amount of streaming data is generated in a large number of trucks. By combining various data sources from trucks and real-time analysis of data, for example, we would be able to create more advanced maintenance solutions, predicting needs of maintenance in trucks while they are on the road.

> *Sepideh Pashami has been given a chance to create her own signature, as a young researcher through her work.*

– One of the research directions, which I am pursuing in this project, is working with causal inference which means analysing the causes and effects of a process in order to draw conclusions that can eventually take into account the effect of changes in underlying mechanism. We are trying to go beyond answering predictive questions, explaining the predicted result by understanding the underlying causes and effects. This is very well consistent with the goal of the research programme CAISR, which is going from data to wisdom, reaching the highest level of understanding.

And where are you now?

– Right now, we have left the data and we are on the second step, which is information. But I would like to go even higher, to the knowledge and understanding levels.

The reason Sepideh Pashami chose to work at Halmstad University was to move toward the field of Data Analysis for real world problems.

Sepideh Pashami

– Halmstad is a very good place for me to continue in that direction. The goal of the lab is to collaborate closely with the industry. It is a great experience for me as a young researcher. I learn how to align the research needs with the needs of the industry. I learn about how companies work and what they expect of us. I think all parties benefit from such collaboration.

> *The goal of the lab is to collaborate closely with the industry. It is a great experience for me as a young researcher. I learn how to align the research needs with the needs of the industry. I learn about how companies work and what they expect of us. I think all parties benefit from such collaboration.*

There are also collaborations between researchers.

- In CAISR, we try to align individual research with the overall goal of the lab, which is creating an aware intelligent system. Due to having a common goal in the lab, we are able to collaborate within the research environment Embedded and intelligent systems (EIS), says Sepideh Pashami, who is planning to collaborate with her colleague and Assistant Professor Jens Lundström.

– We are both interested in learning representations from data. Jens collects data from the smart home and we work with the data collected from vehicles. He wants to predict the status of people's health and we want to predict the status of the vehicles. There are differences but also similarities that make it interesting to work together. The KK environment creates possibilities for creating synergies through research and collaboration, similarities, even if we do different things.

Sepideh Pashami has been given a chance to create her own signature, as a young researcher through her work.

– Since Halmstad is not a very big university, you have the ability to grow fast as a researcher, with a lot of support from your colleagues.
This is something I have found here and it is unique, to be given this opportunity to create my own research.

Sepideh Pashami
Age: 32
Title: Postdoctoral researcher
Field: Data Mining, Machine learning
Research in focus: Data-driven predictive maintenance for heavy-duty vehicles

Mobility between industry and academy

nuTonomy ⇧

During his Guest Professor period, Karl Iagnemma co-founded nuTonomy, a start-up company that is developing software for self-driving cars. nuTonomy has offices in Boston, MA (USA) and Singapore, and has a fleet of autonomous vehicles that are being tested daily in those cities. nuTonomy's core expertise lies in the areas of perception, mapping, motion planning and decision making, and fleet management for fully autonomous vehicles operating in urban settings. nuTonomy has raised investment capital from leading investors such as Samsung, Highland Capital, and others.

⇦ Data-Driven Predictive Maintenance for Trucks

This Vinnova Mobility project focuses on developing a data-driven approach to improve existing predictive maintenance solutions in collaboration with aftermarket customer service organization within Volvo Group. As a part of the project, Sepideh Pashami spends one day each week at the company.

- This means that I extend my network and transfer knowledge between academia and industry. Two of my intensions are to improve my knowledge of various data sources available at Volvo Group, and to advance the existing solution for predictive maintenance as a challenging application-driven research area. Overall, I expect the time I spend at Volvo Group will help me develop my career, strengthen the connection between CAISR and Volvo Group as well as improve the competitive advantage of Volvo trucks, says Sepideh.

On the photo, from left: Parivash Pirasteh and Sepideh Pashami from the university, also Klas Thunberg, Henrik Ydresko and Magnus Löwenadler from Volvo Group.

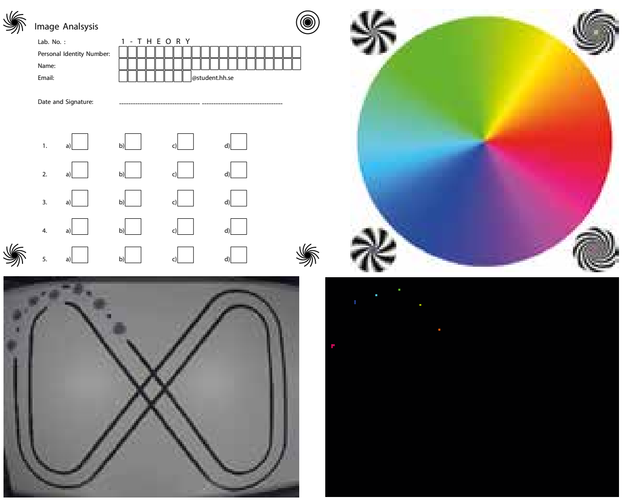
Force Fiction ⇨

Force Fiction AB started 2008 after a student thesis project called “Power Assisted Wheelchair”, initialized within the technology transfer project “teknIQInnovation” at Halmstad University and supervised by professor Ulf Holmberg, who today devotes his full time to the company. The company has developed into an innovative technology company, which through the use of advanced control strengthens a person’s force, with the help of a motor. They combine a person’s own strength and a motor’s power and thus create assistive power without using joysticks, buttons or gears. During the last years the focus has been mainly on power assistance within health technology and bicycles. This enables a better quality of life for people who need help with transportation. Tommy Salomonsson at CAISR is engaged in the company.

BigSafe Technology ⇩

This is a family business offering consultancy services in risk analysis and management, including by technical means. Its clients comprise nuclear power plants in Sweden and Finland, and SMEs. Its competence comprises statistical methods e.g. failure trees, as well as sensing methods; e.g. automatic localization and identification by vision (for information see www.bigsafe.se).

Easily detectable Spiral Code, allowing simultaneous localization and identification of visual beacons for robot navigation and communication is an own, promoted technique. Here, cameras can robustly localize rotation and scale invariant labels at sub-pixel precision accuracy, at the same time as the labels can be decoded (who/what), automatically and fast. The technique is also used in Halmstad University education, e.g. to provide frequent feedback to students on their learning by automatic correction of weekly quizzes. Josef Bigun is engaged in the company.



Autoliv Research ⇩

Nicholas Wickström, Associate professor at CAISR, is on part time leave working for Autoliv Research. At Autoliv Nicholas does his work in a group which performs research on machine learning for autonomous driving applications.

Autoliv is the world’s largest automotive safety supplier with sales to all the leading car manufacturers in the world. Autoliv has around 65000 employees operating in 27 countries, all aiming to save more lives in traffic.

Licentiate exam

Saeed Shahbandi Gholami

Semantic Mapping in Warehouses

Abstract

This thesis and appended papers present the process of tackling the problem of environment modeling for autonomous agent. More specifically, the focus of the work has been semantic mapping of warehouses. A semantic map for such purposes is expected to be layout-like and support semantics of both open spaces and infrastructure of the environment. The representation of the semantic map is required to be understandable by all involved agents (humans, AGVs and WMS). The process of semantic mapping is desired to lean toward full-autonomy, with minimum input requirement from human user. To that end, we studied the problem of semantic annotation over two kinds of spatial map from different modalities. We identified properties, structure, and challenges of the problem. We have developed representations and accompanied methods, while meeting the set criteria. The overall objective of the work is "to develop and construct a layer of abstraction (models and/or decomposition) for structuring and facilitate access to salient information in the sensory data. This layer of abstraction connects high level concepts to low-level sensory pattern." Relying on modeling and decomposition of sensory data, we present our work on abstract representation for two modalities (laser scanner and camera) in three appended papers. Feasibility and the performance of the proposed methods are evaluated over data from real warehouse. The thesis concludes with summarizing the presented technical details, and drawing an outline for future work.

Main supervisor:	Dr. Björn Åstrand, Halmstad Univetsity
Co-supervisors:	Dr. Roland Philippsen, Prof. Antanas Verikas, Halmstad University
Discussion leader:	Dr. Martin Magnusson, Örebro University
Examiner:	Prof. Tony Larsson, Halmstad University

Licentiate exam

Yuantao Fan

A Self-Organized Fault Detection Method for Vehicle Fleets

Abstract

A fleet of commercial heavy-duty vehicles is a very interesting application area for fault detection and predictive maintenance.With a highly digitized electronic system and hundreds of sensors mounted on-board a modern bus, a huge amount of data is generated from daily operations.

This thesis and appended papers present a study of an autonomous framework for fault detection, using the data gathered from the regular operation of vehicles. We employed an unsupervised deviation detection method, called Consensus Self-Organising Models (COSMO), which is based on the concept of 'wisdom of the crowd'. It assumes that the majority of the group is 'healthy'; by comparing individual units within the group, deviations from the majority can be considered as potentially 'faulty'. Information regarding detected anomalies can be utilized to prevent unplanned stops.

This thesis demonstrates how knowledge useful for detecting faults and predicting failures can be autonomously generated based on the COSMO method, using different generic data representations. The case study in this work focuses on vehicle air system problems of a commercial fleet of city buses. We propose an approach to evaluate the COSMO method and show that it is capable of detecting various faults and indicating upcoming air compressor failures. A comparison of the proposed method with an expert knowledge based system shows that both methods perform equally well. The thesis also analyses the usage and potential benefits of using the Echo State Network as a generic data representation for the COSMO method and demonstrates the capability of Echo State Networks to capture interesting characteristics in detecting different types of faults.

Main supervisor:	Prof. Thorsteinn Rögnvaldsson Halmstad University
Co-supervisor:	Dr. Sławomir Nowaczyk Halmstad University
Discussion leader:	Dr. Erik Frisk University of Linköping
Examiner:	Prof. Antanas Verikas Halmstad University

Some Highlights

January to June

Hassan Nemati was granted the "best paper award in the poster session" in the "8th Asian Conference on Intelligent Information and Database Systems (ACIIDS 2016), Da Nang, Vietnam, 14–16 March, 2016"

The GCDC 2016 was an innovative and competitive demo event held on the A270 highway between Helmond and Eindhoven in the Netherlands. Ten European teams competed in the early summer. The challenge was a combination of vehicle automation (making it self-driving) and vehicle-to-vehicle and vehicleto-infrastructure communication. The Swedish team from Halmstad University won the first prize, followed by the German team KIT AnnieWay and the Swedish KTH truck team. Above: Team Halmstad at AstaZero, where the team members for example tested the car in full automatic mode following another communicating vehicle at a set distance.

CAISR Industrial Advisory Board (IAB) met on June 7 for a workshop regarding the CAISR Scientific Agenda. In addition to meeting the CAISR staff (above) the IAB also got an opportunity to meet the winning team in the Grand Cooperative Driving Challenge (below).

CAISR internal workshop March 31. Jens Lundström and Anita Sant'Anna in discussions about the CAISR scientific agenda.

The 9th IAPR International Conference on Biometrics (ICB-2016), was held in Halmstad, June 13-16. The conference is the premier forum for the presentation of new advances and research results in the field of biometrics.

Region Halland including the hospitals in the county are cooperating with Brigham and Women's Hospital/Harvard Medical School in Boston. More than 60 attendees from the university, Region Halland and the partners in the US, met on June 15 to discuss how to use Big data to improve effectiveness and quality of healthcare.

Celeste Gabrielli, ERASMUS+ student from Ancona (Italy) performing a smart environment simulation at Halmstad Intelligent Home with Malin. Celeste visited Halmstad University for a week during her ERASMUS+ stay at Ulster University, 2016.

SeMI
Self-Monitoring for Innovation

The synergy project SeMi got funding from the KK-foundation. The project consists of six industrial partners and the university. The project started in October and lasts for four years.

July to December

Halmstad Embedded and Intelligent systems research (EIS) took part as an exhibitor with a video, at the 23rd ITS (Intelligent Transport Systems) World Congress, October 10 to 14 in Melbourne. The congress gathered more than 11000 delegates. Above: Matthew Gormly, cameraman and Thorsteinn Rögnvaldsson. Below: Antanas Verikas in an interview about the research at CAISR.

Bob Evans gave a seminar on Health Innovation, on August 18. He specially talked about how PACO, a personal analytics companion tool, can be used for programmatic data collection and adaptive interventions and about data mining health care data.

The CargoANTs team after the EU final demo at Stora Holm test track, August 29

Saeed Shahbandi Gholami presented his Licentiate thesis "Semantic Mapping in Warehouses" on September 23.

The reference group gathered together with CAISR staff October 31 and also with the Industrial advisory board on November 1. To the left: Pelle Wiberg, Swedish Adrenaline and Christer Fernström, chair of the Reference group. To the right Reference group members Bob Evans and Birgitta Bergvall-Kåreborn in discussion with Sepideh Pashami at the poster session.

Monika Ringvik, Director, and Urban Wass Senior Vice President, both in the area of Research & Innovation Policy at Volvo Group, visited the university at December 13. Here together with Thorsteinn Rögnvaldsson.

Álvaro Freitas Moreira from Federal University of Rio Grande do Sul in Brasil, visited Halmstad University during three weeks during the autumn. Professor Moreira is doing research in robust programming languages, and he visited Halmstad to strengthen the collaboration between the two universities within a Linneus-Palme exchange program. During his stay he lived and acted as a test person in the Halmstad Intelligent Home and helped our researchers to collect real data from a resident during a longer period.

Yuantao Fan presented his Licentiate thesis "A Self-Organized Fault Detection Method for Vehicle Fleets" on December 16.

On November 3 researchers at CAISR informed bachelor students about current research at the lab.

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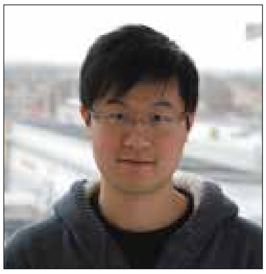

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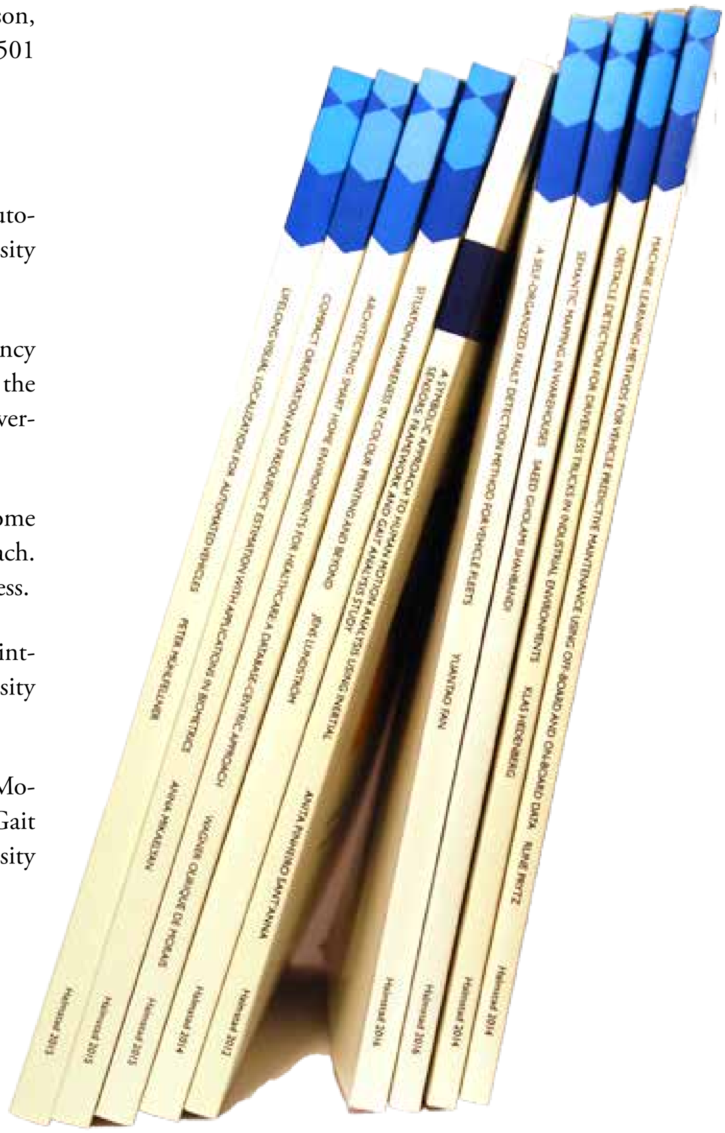

CAISR

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

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

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

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