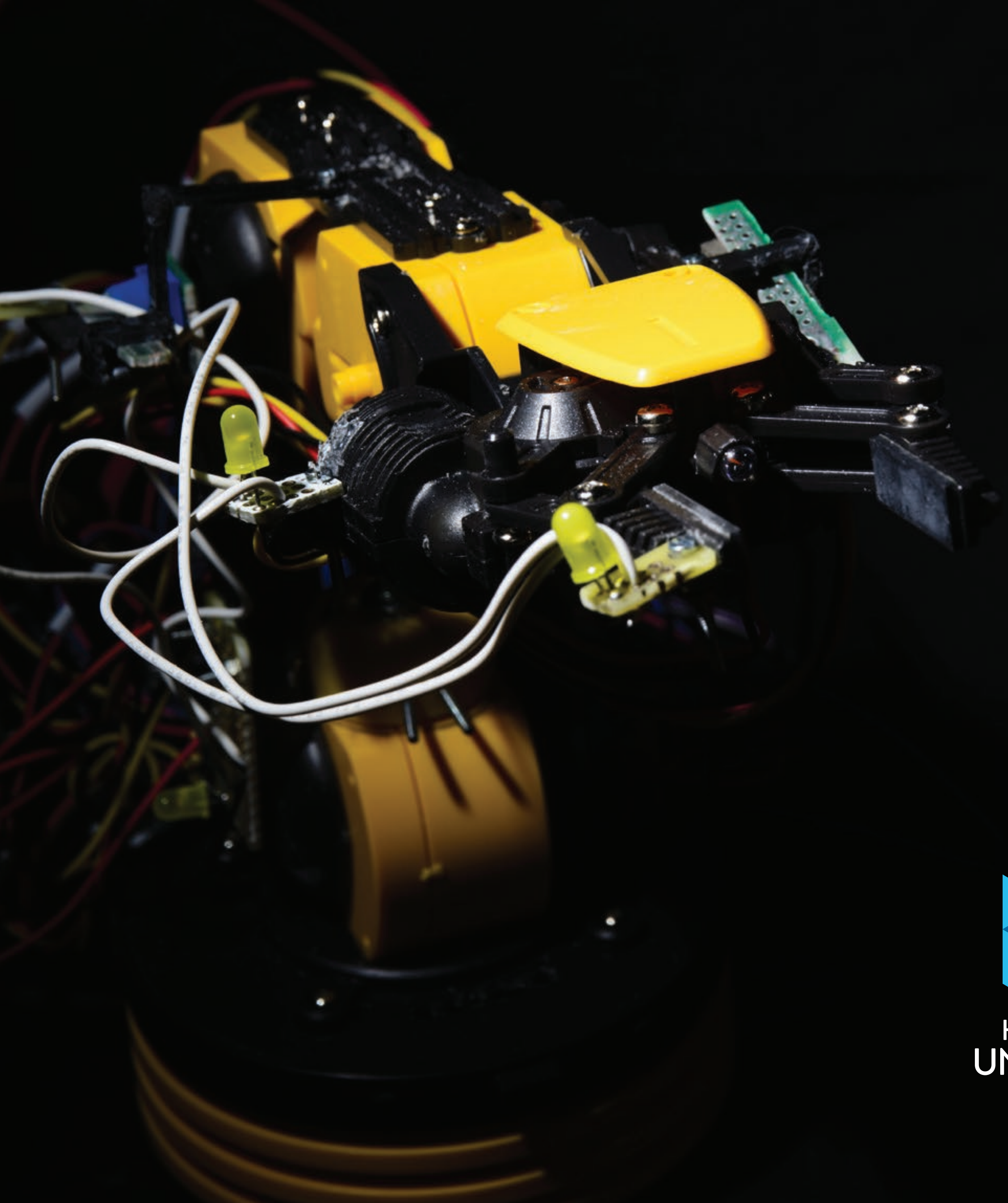
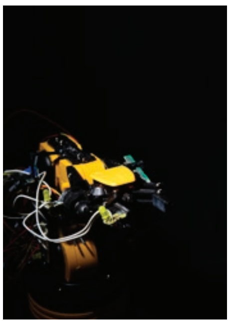
CAISR

Center for Applied Intelligent Systems Research

Annual report 2014



HALMSTAD UNIVERSITY



Cover Photo

With a whirring of motors, a modified toy robot arm spins playfully into position in this picture. Researchers at CAISR engaged in mechatronics, machine intelligence, and signal processing are investigating interactivity, planning, and tracking for various robots. One application will involve integrating robots into an intelligent environment, toward helping people in the event of an emergency.

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Knowledge Foundation

Preface

The Knowledge Foundation (Swedish: KK-stiftelsen) supports young Swedish universities in building up profiled and strong research. A key tool for this is the "KK-profile": a long-term funding for the systematic establishment of an internationally competitive research environment within a limited, well defined and industrially relevant area. The environment shall contribute to the University's strategic research and education development, and to the industrial partners' development and competitiveness. The industrial partners contribute with at least as much in effort to build up the profile competence and produce the research results.

"Coproduction" is the key word, i.e. close collaboration between academic research and industrial development, with clear roles and responsibilities. This is something that both academia and industry gain from. A recent report[1] shows that coproduction projects result in a higher industrial staff education level and significantly increased productivity in the companies that participate, compared to similar companies in a control group. The same report also shows that the academic research environments increase their productivity and that the research results are of high quality. Another recent report [2] contains an analysis showing that about half of Sweden's productivity growth over the last decade is connected with the increase of academically trained staff in the industry, which demonstrates the long-term power of fostering strong academic environments with close connections to industry.

CAISR is a KK-profile. We receive 36 million SEK (Swedish Kronor) from the Knowledge Foundation during the period 2012-2019. The research is also funded by Swedish industry partners, by Halmstad University, and by external grants from the Swedish Research Council, Vinnova (Sweden's Innovation Agency), and the EU programs.

Our goal is to build up a strong research, education and innovation environment in intelligent systems, with extensive national and international networks and with research projects funded by a variety of research agencies. All three responsibilities (research, education and innovation) are emphasized as important parts of a complete academic environment. CAISR is a central part in Halmstad University's master program in embedded and intelligent systems, and in the new "civilingenjör" education that started in 2014. CAISR is also the center for the university's PhD education in signal and system engineering. The CAISR researchers are active in several coproduction research projects with industry that have led to patents and new products.

We have now passed the first three years of CAISR with a strong development. We are looking forward to the halftime evaluation of CAISR during 2015.

Thorsteinn Rögnvaldsson
Director of CAISR

1 DAMVAD, Samproduktion för tillväxt – Resultat och effekter av forskningsfinansiering (2014). Available from http://www.kks.se/om/Lists/Publikationer/DispForm.aspx?ID=189

2 Johan Eklund, "Högre utbildning, matchning och ekonomisk tillväxt", in (Braunerhielm and Eklund, eds.) En fungerande arbetsmarknad, Swedish Economic Forum Report 2014 (2014). Available from http://entreprenorskapsforum.se/2014/11/20/en-fungerande-arbetsmarknad-nyckel-till-innovation-och-kunskapsdriven-tillvaxt/

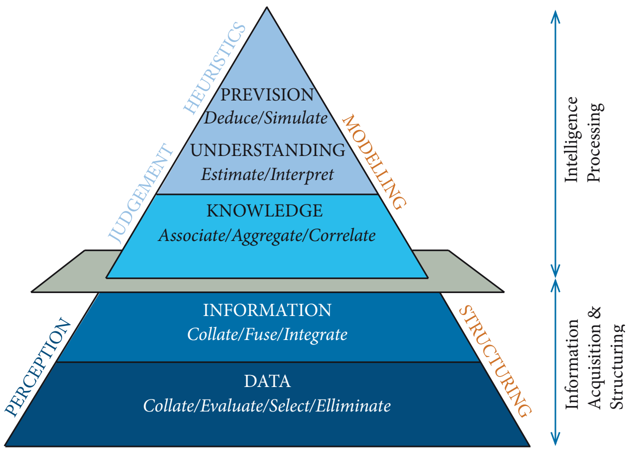
Aware systems at your service

The overall common research theme for CAISR is aware intelligent systems. The goal with artificial intelligence (AI) research and development is to construct systems that behave intelligently and transform the way we live and work (Machine Learning is included in AI). However, AI solutions tend to be brittle; they break when the reality deviates from what was anticipated by their designers. The standard paradigm in AI is supervised learning, i.e. assume that human experts are available to define the task that the system should perform and teach it to replicate this and as best as possible generalize from the examples. Obviously, this assumption never holds in real life. It is impossible to have human experts that can label a huge corpus of data. Furthermore, things change. This limits the applicability of supervised AI.

Our aim is to go beyond this and approach the construction of AI systems that work in a variety of situations. Real life is complex but real life is where we want our systems to operate. In order to do so, the systems must become more "aware" and able to learn on their own. If a system is to be able to adapt to changing circumstances, it must be aware of the circumstances. Furthermore, new data is generated continuously and we need systems that can, in an autonomous fashion, deal with this deluge of data.

Awareness refers to being higher in the so-called knowledge pyramid (see the Figure on the right), having moved up from experiencing sensor sensations to the levels of integrating them into knowledge and understanding. Awareness also refers to self-organizing, the ability to learn and act autonomously, and to an awareness control loop with monitoring → recognition → assessment → learning → monitoring, and so on, endlessly, building up knowledge, becoming aware.

A good and highly relevant application example is the assisted living environment for elderly (ambient assisted living). In its simplest form is it just collecting sensor data and transferring them to a human for interpretation and dialogue, e.g. a remote controlled mobile robot with a smartphone or an emergency alarm system (with a button to push). In a slightly more advanced form it is equipped with sensors (motion, door, heat, smoke, etc.) and can issue an alarm based on predefined rules for the sensor readings. In an even more advanced form can the system learn the signal patterns from the sensors when the inhabitant is at home feeling well and alarm when the observations deviate from this. In this latter example is the system situation aware and has learned this in a self-organized way, unloading tedious monitoring work from human personnel. With time can observed abnormality be associated with particular events (e.g. visitors) and a knowledge base be built up. An even more advanced version also has cameras and can detect where humans are, can react to human signals and interact with the human (e.g. checking that everything is ok, and issuing simple alarms). Here the system exhibits a human-aware ability. Going even further up the knowledge triangle can mean that the system is able to interact with the inhabitant and provide cognitive training and "keeping company".



Adapted from Ackoff & Russell (1989). "From Data to Wisdom". *Journal of Applied Systems Analysis* **16**: 3–9.

> If a system is to be able to adapt to changing circumstances, it must be aware of the circumstances.

Application and Scientific areas

Application Areas

The industrial partners are active in two application areas: intelligent vehicles and health care technology. These are two application areas where aware systems will be important and have a large societal importance.

Health care technology. The health of the elderly and a growing elderly population are major societal challenges. Overweight, an inactive population and poorer health is another. Aware intelligent systems is a key technology for meeting this challenge, e.g. through social (aware) robots and smart (aware) environments that support peo-ple in their life. Aware systems can be used to motivate and coach not so old people to live a healthier and more active life, so that their life quality later is improved, e.g. through "life logging" apps or smart exercise equipment. Technology development transforming this sector and creating new business opportunities.

Intelligent vehicles. More efficient and safer transportation and logistics opens up new opportunities for trade and business. Efficient and reliable transportation means opportunities for people to work and live a rewarding life. Smarter cars allow persons with disabilities to have a more mobile life. Smarter cars lower the problem with traffic congestions. Smarter vehicles decrease the number of injured and killed in traffic. Smarter transport vehicles mean lower costs for operating them. Aware intelligent systems is a key technology to achieve this.

Scientific Areas

CAISR is built around research groups in three scientific areas: signal analysis, mechatronics and machine learning.

Signal analysis is the extraction of meaningful information from signals. This is often digital images but it can also be signals from other sensor modalities (sound, lasers, radars, accelerometers, etc.). The purpose can, e.g., be to identify an object or a person, understand what a person is doing, evaluate how she/he is doing it, or localize an object or a person in an environment. One line of our research is on visual intelligence as articulated in texture, motion, and shape analysis. This involves developing tools based on, e.g., symmetries, orientation and frequency maps. Another line of research is on processing accelerometer data in wearable sensors for long-term gait analysis.

Mechatronics is the joint disciplinary subject in the intersection between machine engineering, electronics, computer and systems engineering. Mechatronics includes, e.g., control theory, computer science, signal processing and sensor technology. Today's vehicles and robots are excellent examples of complex mechatronic systems. Our research here focuses on perception, specifically for semantic mapping, and some on motion planning in complex scenarios. We also work with human-robot interaction, e.g. for understanding human intentions.

Machine learning is about designing algorithms that enable machines to develop knowledge, from data and/or from interaction with humans. Typical algorithms here are random forests, support vector machines, deep learning with neural networks, and algorithms for clustering. Key questions in our research are the analysis and recognition of patterns and how decisions can be taken from this. We focus much on deviation detection in data streams, automatic creation and evaluation of features for data streams, and how to combine different data to enable long-term learning in real-life scenarios.

Funding and goals for 2014

We had set a number of goals for 2014. We met or exceeded most of them but not all. Our original plan was to reach a total research turnaround on the university side of 17 MSEK (million Swedish kronor) for 2014. We ended up with more than 18 MSEK, well above plan. Of this came about 5.8 MSEK from the CAISR KK funds and 5.5 MSEK from Halmstad University. The remainder was a mix of different funding sources (see details below). About 70 % of the research funds on the university side came from external competitive research grants (including the CAISR KK-grant). We designated 300 kSEK of the university funds specifically to developing courses for the PhD education.

Our original plan included being an official partner in one major research project funded within the EU framework program no later than 2014. We achieved this with the CARGO-ANTs project. Our plan also included giving a CAISR workshop during 2014. The Health Technology workshop took place in September (see more details later in this report), and gathered several key stake holders in Health Technology and nicely showcased our research.

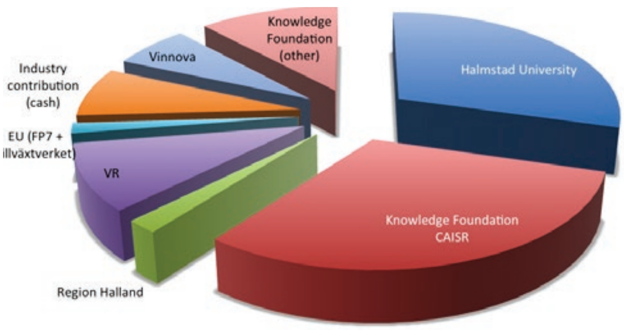
We target to publish at least one Journal paper per 1.25 MSEK research expenditure and equally many peer reviewed conference papers. Furthermore, a significant fraction of these should be in high status Journals or at leading conferences. However, maintaining a high publication output has turned out to be a surprising challenge during the start-up period of CAISR. The number of published Journal papers dropped in 2013, compared to previous years, and even though we put special focus on this during 2014 the output remained low. The activity in writing and submitting papers definitely increased 2014 but only four Journal papers were published in print, with an additional three published electronically ahead of print. There are many submitted papers in review so the number of Journal papers is expected to grow significantly in 2015. The increased activity in writing papers was evident in the number of peer reviewed conference papers, which ended up being 31 in 2014 (the number of peer reviewed conference papers were 13 in 2013 and 15 in 2012). We published a total of 79 peer reviewed scientific papers during the first three years of CAISR, which on the whole is an acceptable number but the percentage of Journal papers is too low.

Of the 20 Journal papers published (in print) during 2012-2014 are two classified as "level 2" and 18 "level 1" in the Norwegian DBH system[1] , i.e. 10% of our publications have been in the top 20% leading scientific Journals[2] . Of the 59 peer reviewed conference papers published during 2012-2014 are six at conferences ranked as "A*" or "A" in the Australian CORE system[3] , i.e. 11% of the papers were presented at "highly visible and well known" conferences in the field of computing research and education (CORE). Our ambition is to double these ratios over the coming years.

The amount of teaching by CAISR staff in 2014 equaled about 6.5 full time equivalents, which is a bit better than our plan. The CAISR staff supervised 12 Bachelor and 7 Master theses, and two of the Master theses resulted in scientific publications. We taught, or co-taught, 34 courses during 2014, of which 85% got "good" or "very good" student reviews.

On the whole the development has been good so far, in line with or exceeding plan except for the output of Journal publications.

Funder	Budget 2014	Result 2014
Knowledge Foundation	5 848 535	5 773 837
CAISR industrial partners[4]	4 624 980	5 898 135
Other external funding[5]	7 300 000	7 384 730
Halmstad University	4 187331	5 509 461
Sum total SEK	21 960 846	24 566 163

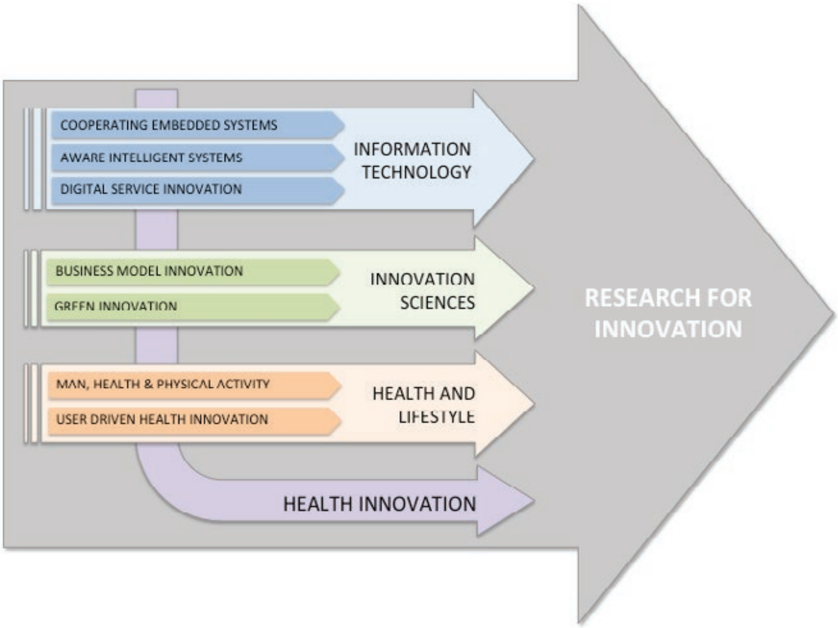


Funding for CAISR research on the Halmstad University side

1 https://dbh.nsd.uib.no/publiseringskanaler/Forside
2 The ranking is determined by the Norwegian Association of Higher Education Institutions.
3 http://www.core.edu.au/index.php/conference-rankings
4 All in kind contribution have been computed using the standard tariff of 800 SEK per hour.
5 VR, EU, Vinnova, companies et cetera

KK-environment

Halmstad University is one of the three universities in Sweden that has qualified to become a Knowledge Foundation - Environment, which was granted by the Swedish financier for universities – The Knowledge Foundation. This means that the foundation, on a long-term basis, invests in the University's research within the University's key areas: Information Technology, Innovation Science and Health Sciences. Crucial to all research projects within the Knowledge Foundation Environment is the collaboration with business and commerce, known as co-production. This means that companies are actively engaged in research projects together with the University's researchers and account for part of the financing. The research contributes to the general development of knowledge in society and provides a research basis to undergraduate education.



Research work at Halmstad University is characterised by the ability to cross boundaries, i.e. researchers from different fields working together to find new ways to understand and solve complex problems. One example is the research field of health innovation, where knowledge in areas such as technology, health, education, and healthcare are united in exciting, new ways.

The 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 8.4 billion in more than 2,400 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."[1]

Madelene Sandström, CEO, The Knowledge Foundation Photo: Försvarets Forskningsinstitut

Stefan Östholm, Head of Operations, The Knowledge Foundation

1 http://kks.se/om/SitePages/In English.aspx

CAISR Reference group

The CAISR reference group members serve a very important function in the development of the profile, being a sounding board for the CAISR management group. The group represents different important perspectives with a good understanding for state-of-the-art research and development. They have extensive experience from international and national industry, as well as international and national academic research, related to intelligent systems. Furthermore, one of the group members is the program manager for Halmstad University's Knowledge Foundation-environment "Research for Innovation".

The reference group members meet and review the CAISR achievements and activities 1-2 times per year, providing advice and feedback on the progress. Each meeting is typically two days long, where the reference group meets the CAISR staff, the PhD students, and the industrial partners, with presentations, lab visits, and dialogue sessions.

Charlotta Falvin

Charlotta Falvin, has a Master of Science in Business and Economics from Lund University. She is known as an excellent business developer, company manager and creator of cooperation between academy and industry. She was awarded an honorary doctorate from the Faculty of Engineering at Lund University in 2011. She is currently Chairman of the board for the Faculty of Engineering at Lund University and for the Lund research park Ideon, , as well as board member of e.g. Doro AB, Chamber of Commerce and Industry of Southern Sweden and Axis Communications. She has previously been e.g chairman of the board for Teknopol AB, board member of Anoto and CEO of TAT (The Astonishing Tribe).

Robert Evans

Robert (Bob) Evans is a senior software engineer at Google. His current work is dedicated to augmenting human intelligence and quality of life by providing tools to support analysis and exploration of daily experience. For the past four years of his time, Bob has been working on an open source, free platform called Paco. Paco allows individuals and behavioral scientists to easily create and conduct behavior studies and interventions on mobile phones. It is being used both inside and outside Google in a wide range of behavioral science research. His previous experience include being a senior research engineer at Agitar Software, R&D engineer level IV at Borland, Chief Architect at Fujitsu Software Corporation, and CEO and lead developer at GetTheNet Inc.

Christer Fernström

Christer Fernström is director and consultant at Fernstrom et Associates in Grenoble, France and the CTO of CommuniTeams in Copenhagen, Denmark. His current work involves technology transfer of research, and the development of community-based Web services. From 2005 to 2009 he was the Manager of Strategy and Planning at the Xerox European Research Centre reporting to the Centre Director. During the same period he was also in charge of co-ordinating company-wide research programmes on technologies and methods to support new service offerings. This work spanned across the research centres in Grenoble, Webster/Rochester and Palo Alto (PARC), and involved about 80 people. Prior to his role as the Manager of Strategy and Planning Christer was a research area manager at Xerox, leading a team of some 20 researchers in the area of contextual and ubiqutuous computing. Before joining Xerox he worked for the Cap Gemini research centre, where he headed research on workflow and also worked to develop European-wide service offerings in workflow. He has managed several EC-funded European projects, and was the Technical Director of a major European project in Software Engineering, the Eureka Software Factory.

Misha Pavel

Misha Pavel is a Professor of Practice jointly appointed between College of Computer and Information Sciences and the Bouvé College of Health Sciences at Northeastern University. Dr. Pavel came from a position of a Program Director of Smart and Connected Health in Boston. Previously he served as chair of the Department of Biomedical Engineering and as Director of the Point of Care Laboratory at Oregon Health & Science University. His earlier academic appointments included positions at New York University and Stanford University. His current research is at the intersection of multilevel computational modeling of complex behaviors of biological and cognitive systems, behavioral informatics and augmented cognition. His most recent efforts are focused on fundamental science and technology that would enable the transformation of healthcare to be proactive, distributed and patient-centered. He has a Ph.D. in experimental psychology from New York University, an M.S. in electrical engineering from Stanford University, and a B.S. in electrical engineering from the Polytechnic Institute of Brooklyn. Misha Pavel is a Senior Member of IEEE.

Bertil Svensson

Bertil Svensson, leads the Knowledge Foundation-environment "Research for Innovation" at Halmstad University, where he has also been the founding manager of the Centre for Research on Embedded Systems (CERES) as well as the first dean of the School of Information Science, Computer and Electrical Engineering. He is professor of Computer Systems Engineering at Halmstad University since 1998 and at Chalmers University of Technology since 1991. He earned his Master's and PhD degrees from Lund University. He was a member of the Scientific Council for natural and engineering sciences in the Swedish Research Council 2004 - 2009. He has authored or co-authored more than 100 scientific papers in journals and full-paper reviewed international conferences and contributed to seven books. His research interests are mainly in embedded systems, parallel and reconfigurable computer architecture, as well as in intelligent systems.

Lars Niklasson

Lars Niklasson, is pro vice chancellor for Jönköping University. He is professor in computer science and managed the establishment of a Knowledge Foundation funded research platform for "learning systems", which later developed into the Information Fusion KK-profile at University of Skövde. He has supervised several PhD students as well as organized and co-organized many scientific conferences. He has been on the executive board for Gothia Science Park in Skövde between 1999 and 2013, when he moved to the University of Jönköping.

Industrial partners

DaraLabs AB

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

Kollmorgen Automation AB

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

NEAT Electronics AB

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

Optronic Partner dp AB

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

Swedish Adrenaline AB

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

Tappa Service AB

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

Toyota Material Handling Europe AB

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

AB Volvo

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

CAISR organization

In order to maintain focus on both academic development and application expertize is CAISR organized in a matrix structure, with academic research and application areas as the two dimensions. The academic management group consists of the three professors in CAISR plus the head for the school of information technology. One of the professors is also manager for CAISR and another is heading the lab where CAISR is placed, with overview of all teaching, administration and research duties in the lab. This makes it very easy to take decisions with a complete overview of teaching and research and to allocate resources where needed. The two application areas are coordinated by two researchers, who each head discussion groups for their respective application areas where also projects that are outside CAISR but within the application areas are invited. These groups meet biweekly to discuss the project portfolio and progress from the perspective of their application area. CAISR also has a project coordinator who oversees details regarding reporting, coproduction and information.

The academic management group, the application area coordinators, plus the CAISR project coordinator meet monthly to discuss general CAISR issues. Some of these are also raised and discussed during the weekly lab meetings where all the lab staff members are present.

The CAISR management is supported by the industrial advisory board (IAB), where each industrial partner in CAISR is represented, and a reference group (see separate presentation). The IAB give advice to CAISR on the progress and activities from the industrial partners' perspective and they take decisions when new industrial partners want to enter or old partners need to leave. Jonas Rahm from Kollmorgen is the chairman for the CAISR IAB. The IAB meet every time CAISR has a reference group meeting, i.e. approximately semiannually, and give input to the CAISR management and to the reference group.

Halmstad University started Health Innovation as a University-spanning research, education and innovation theme during 2014. The CAISR coordinator for health technology is part of the management group for this Health Innovation theme.

CAISR academic management group: Antanas Verikas, Magnus Hållander, Josef Bigun and Thorsteinn Rögnvaldsson.

Industrial Advisory Board

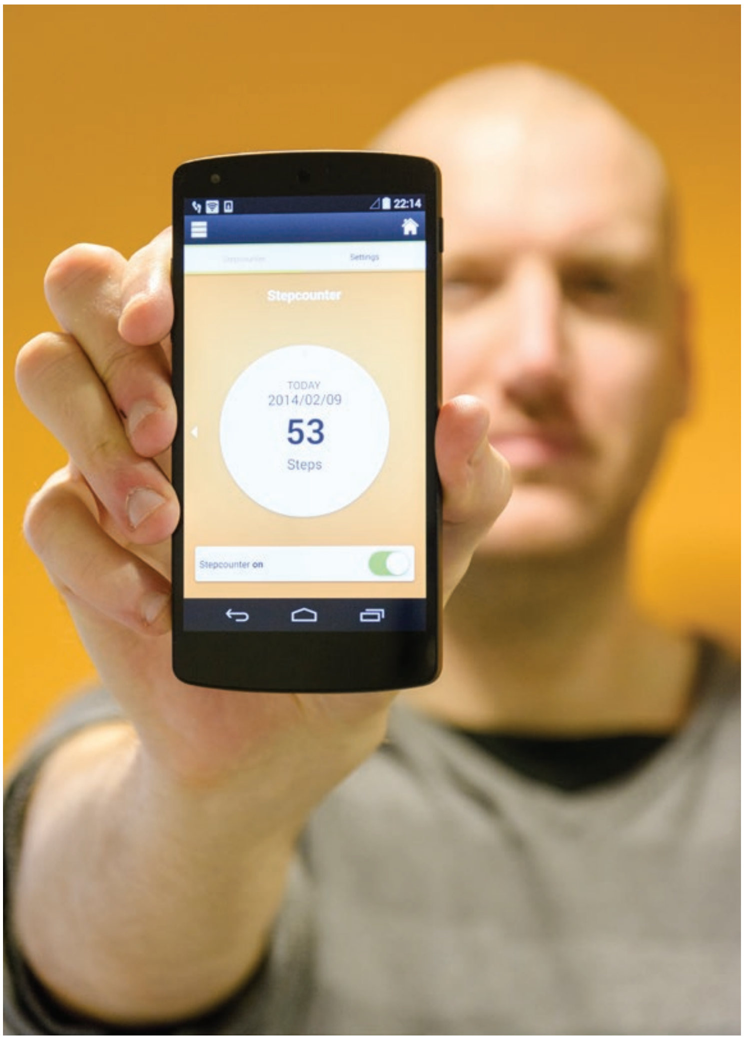
DaraLabs AB	Peiman Khorramshahi
Kollmorgen Automation AB	Jonas Rahm (chairman)
Neat Electronics AB	Lars Nyström
Optronic Partner dp AB	Emil Hällstig
Swedish Adrenaline AB	Per-Arne Viberg
Tappa Service AB	David Johansson
Toyota Material Handling Europe AB	Jacob Arvidson
Volvo Group Advanced Technology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

Bridging the "Valley of death"

The "Valley of death" is a term sometimes used to denote the gap between research and innovations, to illustrate the difficulty with bringing research based products to the market. In an attempt to bridge this gap, CAISR has allocated resources for a development engineer jointly with the industrial partners. The cost is divided equally between the industrial partners and the CAISR research center, to emphasize the engineer's role to have one foot in each camp. The engineer works closely with the researchers in CAISR, as well as with the industrial partner, to transform the outcome of the research and bring it closer to a product.

The first product on the market based on this procedure is available on the market since December 10, 2014. The product, an app for smart phones, which counts steps integrates with the step counting competitions arranged by Tappa. Versions exist on the app stores for Android as well as for iPhone.

Research results from the HMC2 project were used, to ensure robustness for sensor placement, e.g. in purse, pocket or carried in hand. Identifying the events in walking, heal-strikes and toe-offs, from motion sensors is the specialty of our PhD student Siddhartha Khandelwal. This ground truth information about the events in walking was used in the development and for validation.



Above: Mattias Enervall showing algorithms transformed into an app

The engineering resource was Mattias Enervall, a former computer engineering student from Halmstad University, who shared the time between CAISR and the Tappa development team in Varberg. One major part of the work was to construct the step counting mechanism and the other major part was to integrate the information into the existing services provided by Tappa. Transforming the algorithms into an app can sometimes be challenging, especially for the less standardized Android platform where many vendors provide hardware with different specifications. This type of insight shows the importance of co-production, the identification of the need for finding signal processing algorithms that can adapt to changes in sampling rate.

The work was performed over a time period of six months in 2014 and upon the completion of the app, Tappa recruited Mattias to their development team in Varberg where he primarily will work with development of future apps. This addition of technical competence to Tappa also leads to an increased ability to co-produce research-driven innovations in the collaboration between Tappa and CAISR.

Awareness through semantic maps

In two different projects, AIMS and Vasco, we are developing a system, through which an *awareness* of the surrounding environment is embedded in a *semantic map*. Such a system requires:

– *Situation awareness* through different types of sensors, data fusion and employment of novel methods for interpretation of information.

– Maintaining practicability by means of *flexibility* and *adaptability* for handling a variety of environments and sensor data.

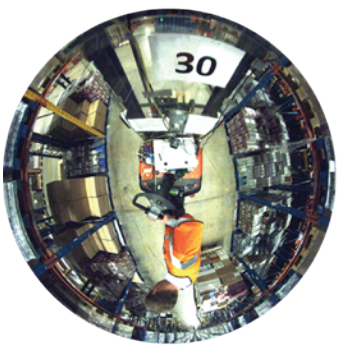
The objective behind *semantics* is to elevate a robot's understanding by linking its model of the world to human related meanings. Semantics vary by context, such as human-robot interaction, and object semantics for manipulation. In general, a robot cannot acquire semantics unless there is a link between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

The purpose of the AIMS Project is to make autonomous systems and AGV:s operating in a warehouse setting more intelligently, by extending their functionality with a system for automatic inventory and mapping of goods. A crucial ingredient for effective management of logistics and inventory, especially for autonomous fleet of trucks working in the same space as humans and human-operated devices, is a map combining metric and semantic information of the warehouse as foundation for addressing the articles. Acquiring the skills of situation awareness, flexibility and adaptability demands accomplishment in different disciplinary areas:

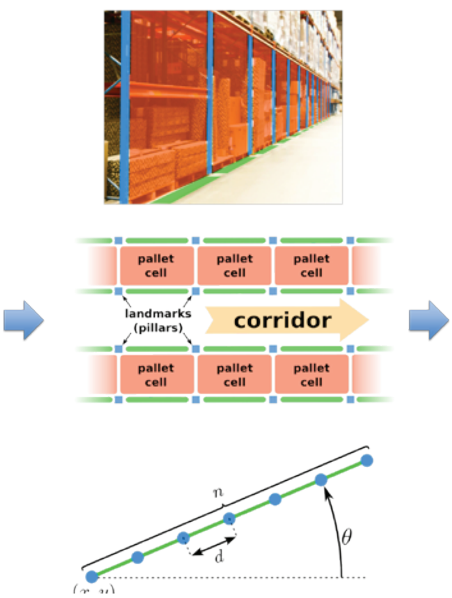
– *Mapping and semantic annotation*, both as a foundation of the semantic map for addressing articles (goods), infrastructure (e.g. pallet rack) and trucks in the environment, and to provide an automatic surveying and layout design for initial installation of the system.

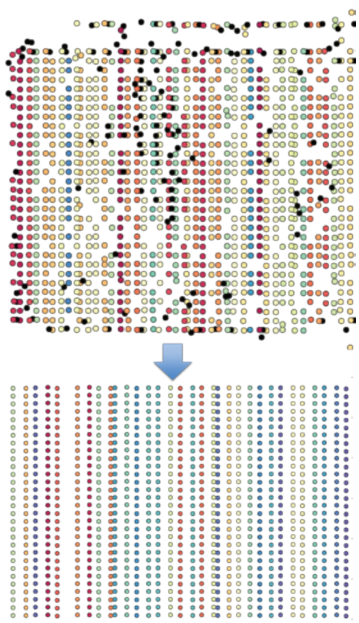
– *Inventory list maintenance*; a dynamic map maintenance approach in order to keep track of the inventory, linked with the warehouse management system.

– *3D-perception*; serving the objectives of obstacle avoidance and articles quantity estimation for inventory list.



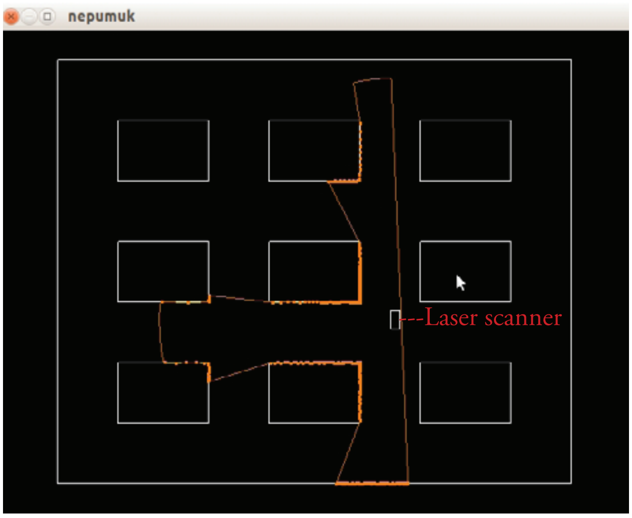
Infrastructure map - pillar map



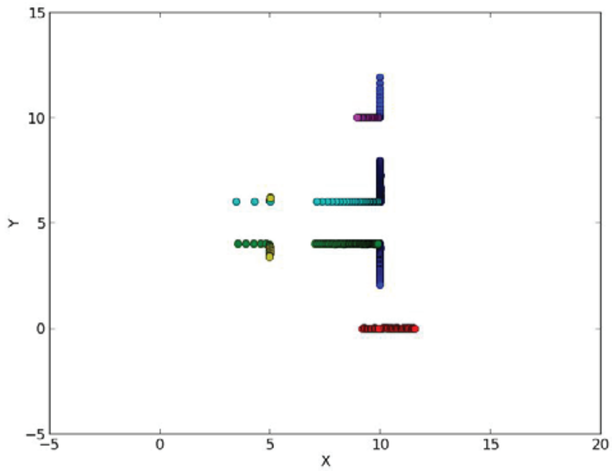


The Vasco Project is aimed at the development of software tools and algorithmic methodologies for robot-aided construction and annotation of *semantic maps* for *situation awareness* in work-yard type environments. These maps are to be used for planning and execution of tasks where the degree of automation can range from assisted manual control to autonomous operation in shared work-yards, such as harbors, quarries, or construction sites. With the focus on the human-interaction, the system should work in a shared autonomy situation and facilitate exchange of information between the users and the system for better modelling and labelling of the work-site. A key question is how best to bring the human into the loop, i.e. how to enable human operators to interactively annotate and modify maps, define work-site constraints and task goals.

Container storage in a harbor - a typical environment in the Vasco Project



1. The figure shows the simulation of a robot moving in a container storage area with a mounted laser scanner having 180 degree field of view.



2. Shows the point cloud received as input in that frame, colors represent the clusters each point is associated with after passing through the feature-extraction algorithm.

Project Partners

Automatic Inventory and Mapping of Stock (AIMS) is a collaborative project between Kollmorgen, Optronic, Toyota material Handling Europe and Halmstad University. The project is a part of Centre for Applied Intelligent System Research (CAISR) funded by the Knowledge Foundation.

Vasco Project is collaboration between Volvo Group Trucks Technology, Advanced Technology and Research and Halmstad University under the framework of CAISR.

Taking transportation systems to the next level

The continuous growth in global trade justifies the expectation that transport will continue to grow in the future. Economic growth is also strongly correlated with increased transport. The structure and operations of European container transport industry is facing new challenges, such as increasingly stringent environmental regulations as well as capacity bottlenecks at ports and hinterland connections. In essence, the handling of freight has to become significantly more effective across the range, from the smallest individual scale to voluminous container flows.

The Cargo-ANTs project (Cargo Handling by Automated Next Generation Transportation Systems for Ports and Terminals) envisions to bring cutting-edge insights from autonomous robotics research to bear on the above challenges.

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

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

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

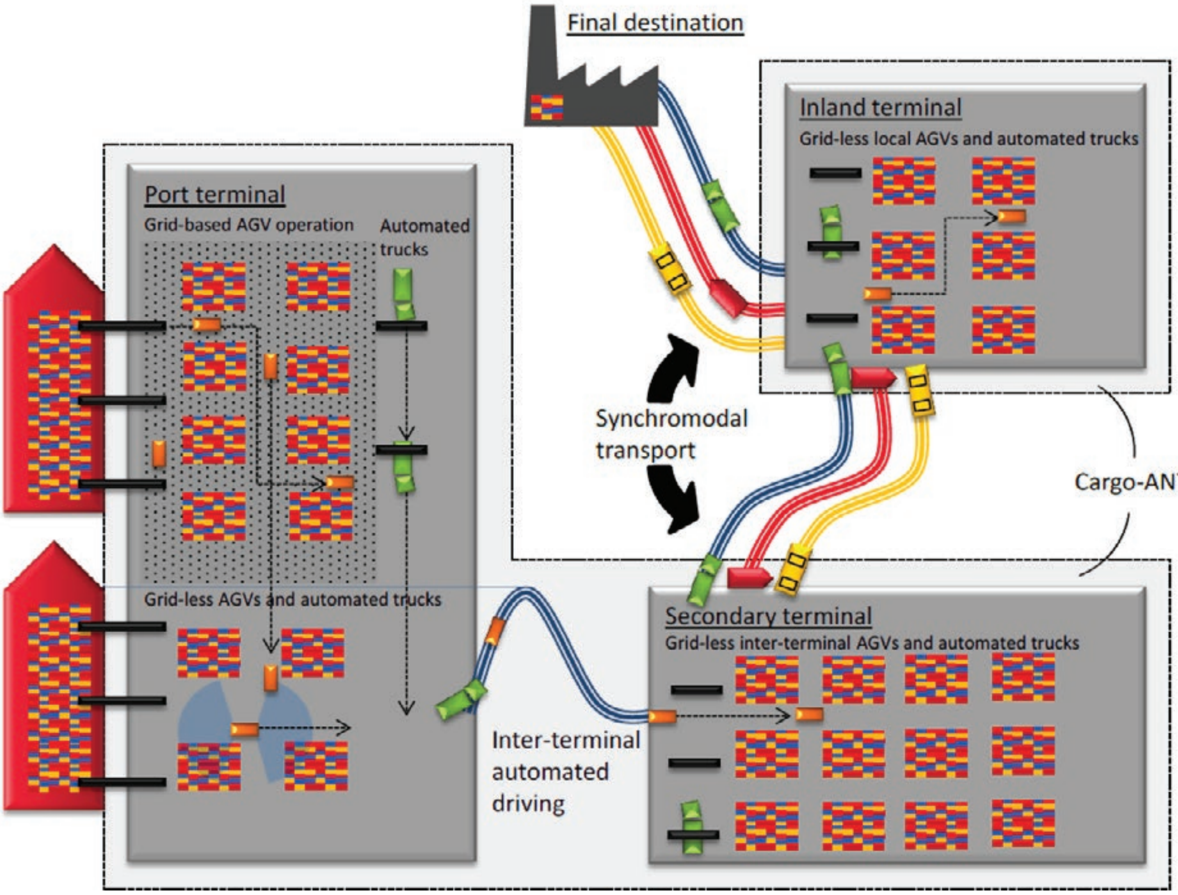
CAISR collaborates to solve the above issues in the project ANTWaY (Automated Next generation Transport Vehicle for Work Yard application). ANTWaY aims to create a driver driven truck that can transform into a fully-autonomous vehicle once it enters a warehouse. This truck should be able to interact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

Thus, in a typical scenario an ANTWaY equipped truck travels towards the warehouse on a public road. Once it reaches the site it is coupled with the site control systems and the truck becomes fully autonomous. In case of any blockade on the way the truck will be able to plan for an alternate path and maneuver to reach its loading/unloading location. Having an autonomous truck will help with reverse and park assistance, safe and fuel efficient maneuvering as well as reducing queues among other benefits.

The Projects

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

ANTWaY is funded by FFI. It started on May 2014 and runs for 3 years. The partners of this project include AB Volvo, Kollmorgen, Chalmers Tekniska Högskola and Halmstad University. In this project CAISR expects to gain insights into the methodologies, formulations, and approaches that best bridge the gap between state-of-the-art research in motion planning, automatic scheduling, and interaction design.



Cargo-ANTs concept that aims to optimize freight transportation by combining grid-less smart AGV operation in terminals and beyond fenced spaces, and AT operation in terminals and in inter-terminal driving.

Typical Cargo-ANTs scenario with AGVs in operation.

Fleet-based vehicle diagnostics

The amount of goods that is being transported is expected to increase by 50 percent over the next 20 years. The road infrastructure will not grow equally much, and therefore the efficiency of the operation will need to increase significantly. An important requirement for achieving timely transport at a low cost is that vehicles are well-maintained and in good condition. This can only be achieved by continuously monitoring the health status of a vehicle and communicating with off-board services for maintenance planning.

The main purpose of our research in this area is to develop algorithms that allow vehicles to describe their own operation and detect when deviations from the norm occur. By using data mining across many data streams available onboard a modern truck or bus, and by comparing discovered relations across the whole fleet, both faults and component wear can be discovered early and continuously monitored in a self-organized way. Since modern vehicles are too complex to be accurately modelled as a complete system, we take advantage of the fleet aspect, focusing on differences in operation between similar individuals.

Our goal is to make the vehicles more self-aware, and to be able to discover when something is wrong on their own. The primary diagnostics paradigm today starts with human experts listing all possible faults, and specifying which signals should be used to distinguish between them. Our system continuously mines the on-board sensor streams, looking for interesting relations in the data. Parameters of discovered models are then sent to the central server or to other vehicles in the fleet. We compare them and match observed deviations against available reference data, building a repository of information about faults and their symptoms.

When one of the group members starts to deviate from the normal behaviour, it is reflected in the differences between data models obtained from individual vehicles. Even when all the vehicles operate correctly over a period of time, there is some natural variability of individual characteristics, external conditions and minor differences in usage. This causes the models to form a more-or-less regular cloud, as seen in the top plot. The shape and size of this cloud depends on all those aspects. A broken truck, however, consistently separates itself from the fleet, as seen in the bottom plot. In this case the effects of the fault are much larger than the natural variability of the data.

During over three years of data collection and analysis we have shown that a self-organizing, unsupervised system like this one can reduce the number of unplanned stops. The adaptive nature of our approach allows it to evolve with the fleet, always focusing on the relevant faults. It is not tied to any particular component, and we have been able to predict faults related to engine, air compressor, exhaust system, wheel speed sensors, and more.

Such a self-aware system is especially beneficial for rare or non-critical faults, since it offers a cost effective complement to engineered diagnostics, and can also be used to increase knowledge about vehicles' usage.

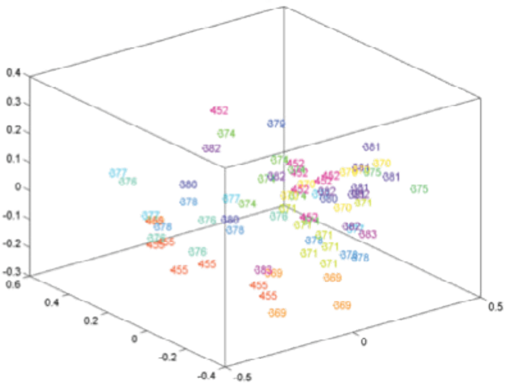
Service Development

One of the unique aspects of our research in this area is that all of the projects have included a service development part. In addition to the development of data analysis tools and algorithms, we have tried to identify possibilities for service innovation through business analysis, workshops and interviews with different stakeholders. There is no doubt that improving vehicle uptime and providing better predictive maintenance is important, but the exact business model associated with it still needs to be developed.

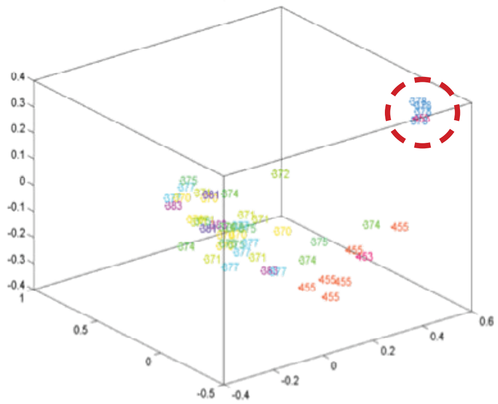
Partners

In this area we have collaborated with several different partners, both industrial and academic ones:

- Volvo Group Trucks Technology
- Volvo IT
- Recorded Future
- Chalmers University of Technology
- Svenska Innovationsinstitutet



Daily models representing different buses, collected over one week, with all buses in good condition.



Daily models representing different buses, collected over one week, with one bus experiencing engine problems.

Data sources

The projects have access to many different data sources, including:

- On-board data (both high frequency sensors measurements on different components in the vehicles, as well as aggregate statistical information about usage and external condition, etc.)
- Off-board data (history of repairs and maintenance, vehicle specification, warranty claim information, etc.)
- Public data (news articles, twitter, marketing information, sales statistics).

Projects

Within this research area we have been involved in several individual projects, each with its own particular focus, but sharing the overall goal:

ReDi2Service project consisted of development of a data collection system, installation in a bus fleet, collection and analysis of data and combining data from various sources to enable new diagnostic algorithms. The solutions have been tested on data from real city buses collected over a period of 3 years. We have shown that it is possible to use the self-organizing approach to predict several different kinds of faults, ranging from jammed engine cylinders to malfunctioning wheel speed sensors.

InnoMerge project focused on business models and reverse innovation for emerging markets. We have collected data on a prototype truck in India to test different algorithms for predictive diagnostics, load estimation and driver profiling.

In4uptime project investigates how different vehicle-related data sources can be combined in order to improve maintenance planning. For this purpose, a big data analytics platform will be developed for evaluating and fusing data of different types, different origins, and created for different purposes.

Profiling of truck drivers and estimating their impact on fuel consumption

The number of embedded computers on-board vehicles is continuously growing and the data they generate is becoming more and more widely accessible. Our goal is to use available data to extract useful information that can lead to better fuel efficiency. In particular, we focus on ways to quantify, and ultimately improve, driver performance.

In order to achieve that, first of all, we have to consider that the field is uneven, i.e., that driving conditions as well as vehicle characteristics are different for each mission. A driver that uses more fuel than normally for a particular route may very well be performing better, depending on other factors such as cargo weight, traffic, weather, etc.

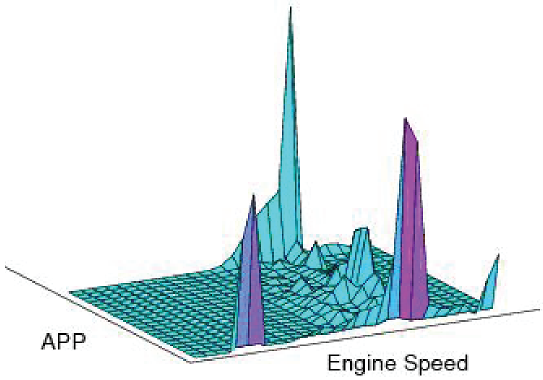
Therefore, one approach is to find a way to normalize fuel consumption based on those conditions. We would then be able to compare drivers in a meaningful way. Another approach is to identify driver behaviors, for example specific maneuvers executed at specific times, that lead to decrease or increase in fuel consumption.

We are also interested in methods for driver and vehicle profiling, i.e., in determining strengths and weakness of the individual. For example, a driver can be very proficient in heavy traffic highway driving, but less good on hilly roads. Such information is valuable for targeted driver training. Another direction is to take the passage of time into account, and to analyze how driver behavior changes over several years, as the driver becomes more experience or, over a single shift, more tired.

We consider two approaches at the moment. The first attempts to model the fuel consumption of individual vehicle by calculating so called Base Value (fuel consumption at a constant speed on a flat road) and modeling the effect of various driver decisions.

The second addresses directly the driver and how his actions influence vehicle performance. We model that using APPES maps (Accelerator Pedal Position – Engine Speed). In those maps it is possible to identify different modes of vehicle operation (idling, full throttle, coasting, etc.) and to quantify different parameters of driving style.

Both approaches can be used to train drivers, to give them real time alerts or to detect vehicle faults.

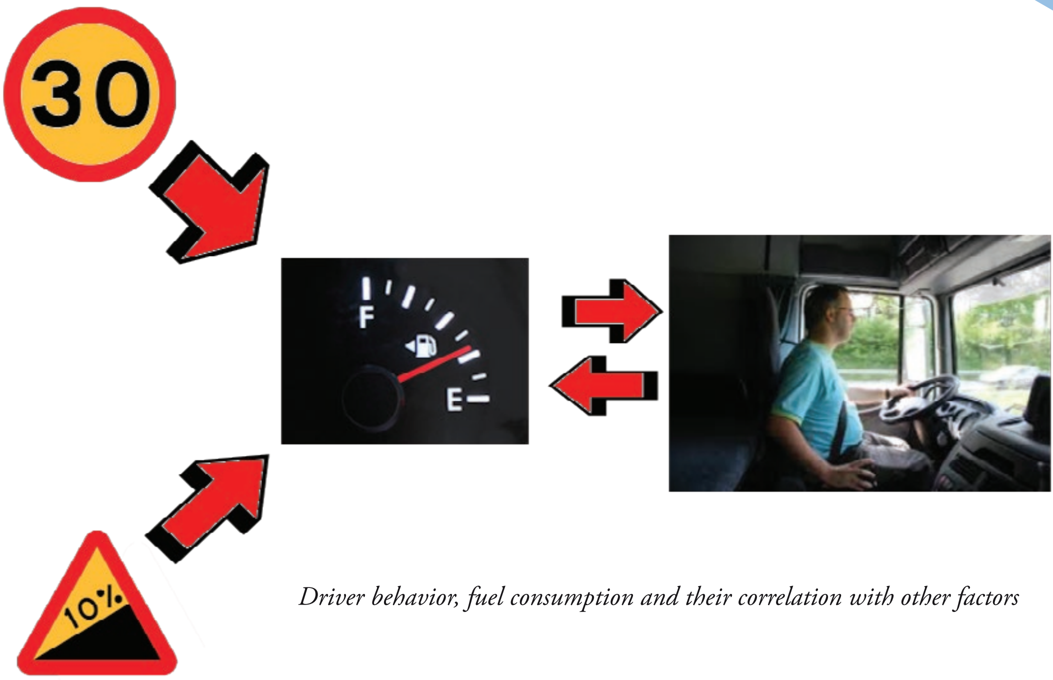


This histogram represents driver intention and behavior. We can identify four regions that correspond to four distinct situations, i.e. the 3 dominant peaks and the middle region. The distinct regions correspond to neutral gear, rolling in gear, driving and full throttle. The amount of time spent in each region as well as transitions between regions could be used to classify driver behavior.

V2V

The data collected on-board can now be exchanged between vehicles using wireless technology on the road, making it possible to benefit from data collected by other vehicles. Learning Fleet is set to take on the task of making use of V2V (vehicle-to-vehicle) communication to increase traffic safety and decrease fuel consumption of its trucks using on-line, real time algorithms.

By collecting data in real time, from a large fleet of vehicles, Learning Fleet can adjust the driving strategy of its vehicles as well as inform drivers about conditions in the future. The type of data collected varies and can include information such as weather conditions, traffic, special events, e.g. traffic accident, road works, etc.



Driver behavior, fuel consumption and their correlation with other factors

Data

We are working with data collected using CAN (controller area network) from trucks in their daily operation. There are two sources for our data. One is the European project EuroFOT that ended in June 2012, where Volvo Group a was partner. The other is an internal Volvo Group project, CuFF (Customer Fuel Follow-Up), still ongoing. In other words, we are taking advantage of available data and using it for a new purpose.

There are differences between the data originating from the two projects, but overall we have access to over 100 different signals, collected at 10 Hz, summing up to 100 TB. This includes video, as well as high accuracy fuel sensors.

Awareness

Self-Aware
We aim at a system that can understand its own operation, and to compare it both to its own past performance, as well as to behavior of other, similar systems. When dissimilarity occurs, it needs to understand the reason. For example, is higher fuel consumption caused by traffic conditions or is there some internal reason for it, e.g., underinflated tires?

Situation aware
We aim at a system that is capable of understanding the factors that comprise the current situation, and figuring out which of them are relevant. This includes not only measured data, but also historical information, including historical decision making. By analyzing the current situation and comparing it to previous similar situations, the system shall decide a course that has the highest chance of leading to both increased traffic safety and vehicle efficiency.

Human aware
We aim at a system that can analyze driver behavior, and can understand the reasons for various decisions the driver makes. Especially in the context of driver coaching, it is not enough to indicate inefficient actions, or to demonstrate the correct ones. It is equally important to provide the driver with a convincing explanation of the difference.

It's hidden in the way we move

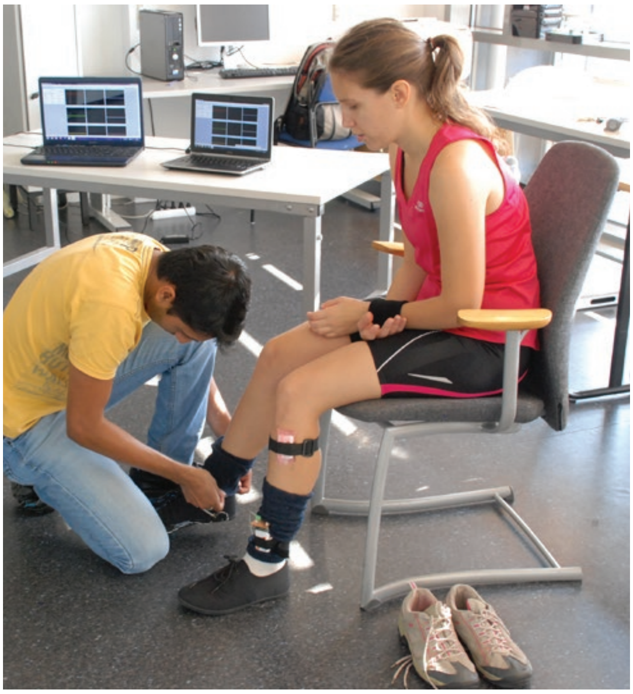
Our movements are a complex product of our neuro-muscular system. Part of our movements is reactive or automatic, but a large part of our movements depends on cognition or conscious thought. As we age, simple activities such as walking start demanding more and more attention. One curious effect of this is that an older person may stop walking while they talk to someone.

Movements are also affected by changes to the structure or physiology of our neuro-muscular system, the brain, and the skeletal system; which could be caused by age, injury, or degenerative conditions.

As changes to the function of our bodies cause changes in our movement, so can the changes in our movements be used as an indicator for changes in our bodies. This means that by measuring movements and quantifying how much they deviate from expected patterns we can estimate changes in the normal function or physiology of our neuro-muscular system.

Movement analysis techniques have great potential to impact individuals and society as they provide a means for non-invasive, non-obtrusive, continuous, and inexpensive health monitoring. Technologies such as video imaging, Kinect (depth-camera), inertial sensors (accelerometers and gyroscopes), and surface electromyography (sEMG) have been successfully used to observe and analyze movements.

The use of wearable inertial sensors, such as accelerometers, already present in many commercial smart watches and activity monitors, enables new forms of health monitoring. Not only can such tools monitor overall physical activity but they can also track changes in movement patterns that may indicate a decline in health or the onset of a more serious condition. Decreased walking speed, decreased arm swing or rigidity of movement, for example, can be indicative of health issues and should prompt a medical evaluation. In such cases, movement analysis can be used as a screening tool for further medical evaluation.
This technology must still develop and mature before it can become wide-spread and common practice. Some of the challenges derive from the fact that not two people walk or move in the exact same way. Therefore methods must be robust enough to cope with the natural variability present in our movements but, at the same time, sensitive enough to detect small changes that may be relevant. Another challenge is that measuring movements during planned experiments in the lab is very different from measuring unsupervised activities during normal daily living. Therefore, methods should be able to cope with unpredicted situations and previously unseen activities. In order for such techniques to have a clinical impact, much work is also needed to validate measurements against medical evaluations for specific health conditions.



Data collection in the HMC^2 project.
Above: Preparation of test person for walking and running indoor and outdoor
Opposite page
Top: Position of accelerometers on various parts of the body and force sensors embedded in the shoes
Right: Test person conducting fatigue test.

Technology

Accelerometers are commonly used sensors for movement analysis. They are very small and consume little power, making them easy to embed in clothing or other commodities such as smart phones.

HMC²

The project "Human Motion Categorization and Characterization" aims at developing wearable devices and methods for movement analysis. Among the contributions of this project are the use of surface electromyography and accelerometers to estimate fatigue while bicycling, and the development of robust methods for gait analysis in uncontrolled environments.

MoveApp

The project "A movement analysis application for the Mobile Health Platform" aims at developing a self-management platform for Parkinson's Patients. The main contributions of this project relate to using inertial sensors to monitor the severity of motor symptoms and data analysis tools for decision support.

Finding regularities in people's home

- Veronica?
- Veronica...are you there?
- Are you in need of help Veronica?

The time just has just turned 3 a.m. and John, a home care phone operator, is not able to get a response from Veronica who lives alone in a small house just outside city center. Two minutes before the call, Veronica pressed the red button on her wrist which triggered an automatic call to the home care headquarter where John is working.

*John classifies the call as a **silent alarm** (due to the lack of response) and notifies the closest of eight cars doing nightly supervisions in the ordinary housing of elderly people in a small city in Sweden. The caregivers in the car, Lisa and Carl, are currently in another resident's home but leaves urgently to rush to Veronica's home.*

Today, the described situation is not unlikely at all, silent alarms is a well-known problematic situation for caregivers carrying out nightly supervisions. Through the use of existing care phone technology and the excellent expertise of the staff, residents and relatives are able to feel safe and secure during the night. Residents are usually visited one to three times per night by the caregivers. The visits are based on schedule and, if no alarm is received by John, each resident is revisited within a duration of a few hours. However, at most of these visits, the resident is in bed, sleeping and doing well. This duration between visits makes the night problematic for some residents: What happens when residents fall into a dangerous situation in-between supervisions carried out by caregivers? The project Situation Awareness for Ambiewnt Assisted Living (SA³L) is about developing methods and tools for detection and interpretation of potentially dangerous situations in the homes of elderly people.

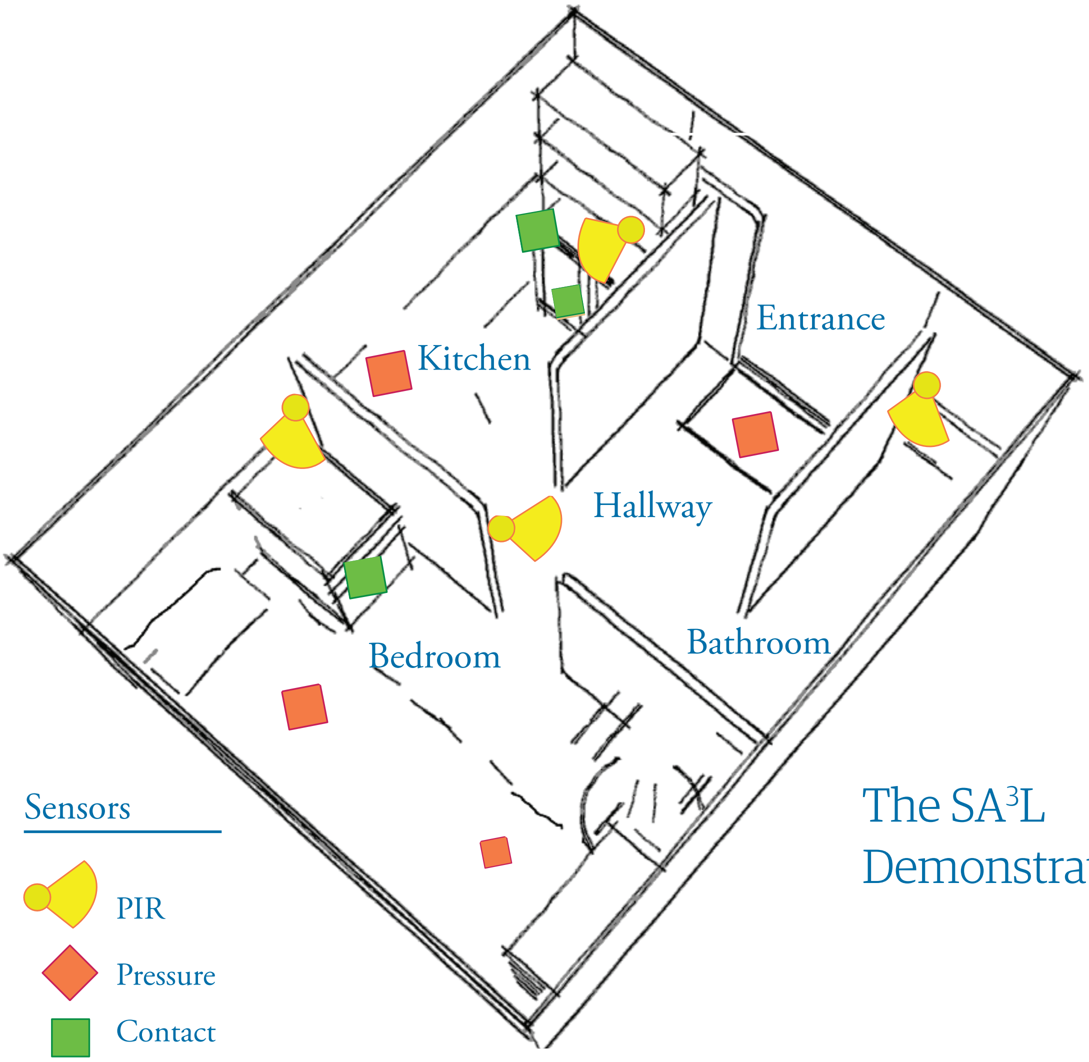
Examples of dangerous situations during night are falls, wandering and residents leaving the home. These situations are inherently difficult to generalize and specify due to the diversity of homes, behaviours and the numerous ways of deviating. Thus, a system for detecting deviations based on manually specified rules is very difficult to build and maintain. Therefore, in SA³L the problem of detecting dangerous situations is based on machine learning methods for learning the normal activity patterns in the home. These patterns are thereafter used to interpret and compare forthcoming activity patterns. This is an approach that decreases the need for manually specified rules. Besides automatic detection of deviating situations, such a system could also assist in interpreting silent alarms such as in the case of Veronica.

Lisa and Carl arrives at Veronicas' home, they enter the home and find Veronica sleeping in her bed. The urgent situation is under control. However, this is not the first time Lisa and Carl is in this situation in the home of Veronica. Yet, a silent alarm is always urgent and must be dealt with accordingly.

This project sees a benefit in combining prior knowledge and data-driven knowledge using smart home sensors. Using a future intelligent alarm system the caregivers would be able to operate on a more informed basis and react on events rather than only by schedule and on ordinary care phone alarms.

> Thus, a system for detecting deviations based on manually specified rules is very difficult to build and maintain.

Examples of equipment used in the project



The SA^{3}L Demonstrator

Research focus

In SA^{3}L we develop methods and tools for:

- Detecting deviations in activity patterns acquired from smart home sensors.
- Answering queries (e.g. where is the person?)
- Generalizing over different homes and individuals.
- Processing online data streams.
- Period: 2012-11-01 - 2018-12-31

Data collection

Seven elderly people in Halmstad have (or have had) the sensor technology in their homes during 2014. The aim is to collect data in order to build and validate the models used to identify individuals' normal activity patterns. The subjects' ordinary security alarm, visits by night patrol and care are not affected. The research has been approved by the The Regional Ethical Review Board in Lund.

The SA^{3}L demonstrator

A demonstrator has been set up in order to communicate, test and evaluate the ideas and results related to the project. The demonstrator was first shown at the Health Technology Workwshop at Halmstad university September 23rd, 2014. The demonstrator will be of great importance in further development of methods and tools.

The SA^{3}L demonstrator and Dr. Jens Lundström

Human machine interaction in motion with motion

Human machine interaction (HMI) is becoming increasingly important. We want to communicate in ways similar to that of human to human interaction, but to get a machine to mimic human behavior has proven extremely difficult. We also hope to get the most out of everyday equipment such as microphones and cameras in our smart phones and tablets: the most common and cheap sensors for digital equipment these days. While we use more sensors for our interaction (smell and touch to name a few), audio and visual input seem to be the most important ones for relaying every day messaging. So why can't we get our increasingly smarter devices to interact with us more naturally? Well, we can!

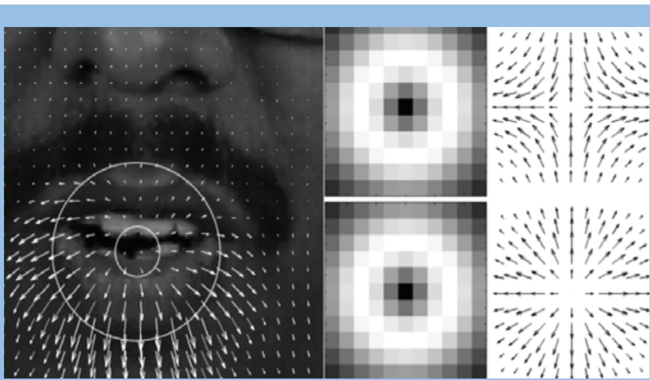
We aim for a more natural form of human machine interaction in this project. We wish to make the machine aware of the smallest of noticeable motions, as occurring from the user. These motions may be over a face, or due to hands and arms moving across a camera view. Two direct questions we wish to address are how gestures, over the face as well as the rest of the body, can be detected and efficiently encoded for interactions of the future.

Some of the applications are just cool in themselves, such as the notion of virtual objects being interacted with for some extended work place, projected in an intelligent home for example. Many scenes from science fiction movies are sure to come to mind (For those so inclined, consider the more recent Iron Man movies, with Tony Stark's virtual workplace).

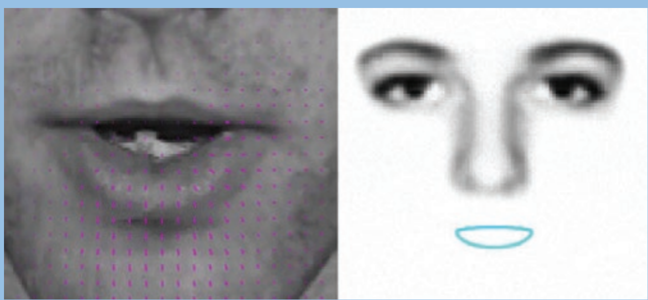
Our greatest hopes, however, lie within health-care and aids for the disabled. We imagine those who have recently become restricted in motion and communication ability. Perhaps so severe that only motions of some parts of the body is possible, and speech no longer an option. Stroke patients and quadriplegics (those who lost use of both arms and legs) are perhaps the most clear cut examples. With the systems we are creating today, we will allow for humans with the very minimum of motion ability, to interact with digital assistance systems. As a very first exposure to this technology, we envision the newly disabled to have simple games, where small head and/or eye movements are the main mode of interaction. Being able to play a game like Tetris, when your entire body will not respond to your will, may be an option to medication for those unfortunate who struggle in recovery. Not only providing mental relief from a disabling trauma, such life-enriching activities may be the source of new social interactions, and training of new motor skills.

Apart from health care, the same principal technology has applications to lip-reading and facial expressions analysis. Picking up on the tiniest changes in a human's facial motions, we hope to decode a deeper form of information in communication. A human whose voice is weakened, either by background noise or by speech impediments, may still be able to mimic the words. While full-scale lipreading is very difficult, the combination of degraded sound and partial decoding of lips provide better speech recognition than decent audio alone. Audio-visual communication is very important, but the video-conferencing systems never made the breakthrough so many anticipated 20 years ago. One of the reasons is the choppy, and slow communication transfer. Seeing your peer at a frame-rate of 1 image per second is a very unnatural form of interaction. If small, facial motion parameters (such as mouth opening, lips widening) can be estimated very quickly, then these limited parameters can be transmitted, and relayed to the user in a natural way. Even looking at a smoothly animated character as you speak will improve the communication medium… assuming that the animated characters lips are synchronized with the audio in real-time.

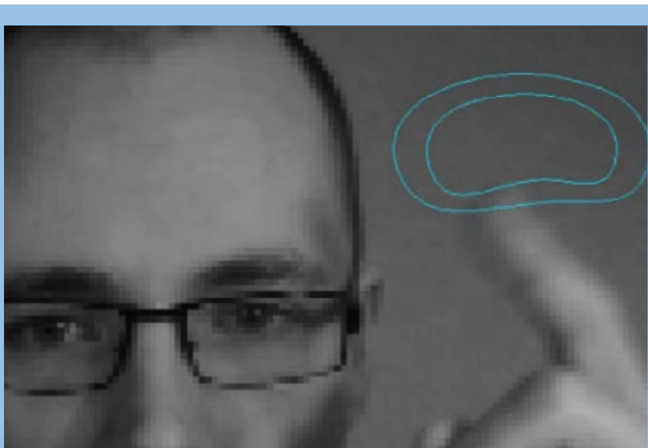
> Picking up on the tiniest changes in a humans facial motions, we hope to decode a deeper form of information in communication.



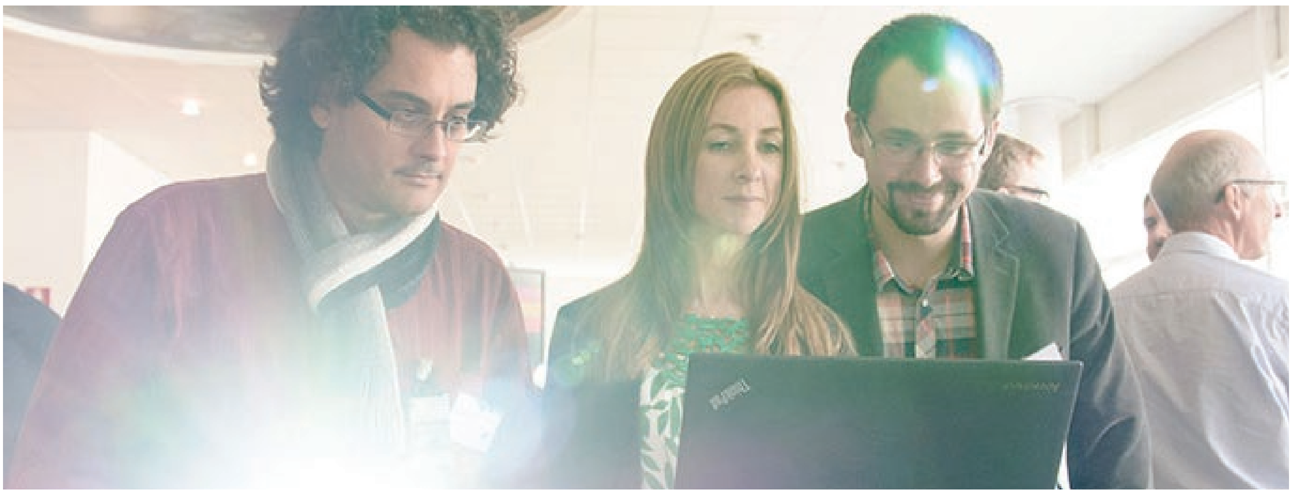
How do we humans encode the changes over a face, and use it to our advantage? We can achieve lipreading, and facial analysis by estimating motion, and encoding it at the same time. This form of “filtering” approach holds great promise for HMI applications and aids for the disabled.



Video conferencing can be rethought, and we aim for something more. On one hand, animated characters can be generated in real-time. On the other hand, the same parameters of speech that we estimate, can be used for active noise reduction. The simplest such noise reduction is to notice when the user’s lips are not moving, and then shutting the microphone off. Much more powerful options are available for the future of combined audio-visual communication.



Interactive virtual objects, for fun and practical design/computer interaction. The picture is of our object: “the squiggle”, which easily runs on a mid-range mobile phone or tablet. The squiggle can be moved around in the video, and placed over the face and mouth. This opens for a combination of hand gestures and lips/facial gestures for machine interaction.



It is written all over your face

The face holds the richest visual information regarding identity, emotional state and messaging. Even infants a few minutes of age show preference to track a human face further than other moving non-face objects. Not in vain, our human visual system stands for 50-70% of all our brain processing, with a specific area of the brain dedicated to face processing. Nowadays, face analysis is being driven by the trend and popularity of social networking sites, the prevalence of mobile smartphone applications and the availability of low cost cameras. Media giants such as Apple, Google or Facebook are including face recognition in their products.

At a first glance the tasks of face detection and recognition may not seem so overwhelming, considering how easy they are solved by a human. However, contrarily to what can be seen in movies or TV series, it is only possible with current technologies if we control the environment in which facial images are obtained, usually requiring a fixed and simple background, frontal view, or special illumination. Analysis of the iris is even more difficult due to its smaller size, with commercial solutions usually requiring to position the eye in front of the sensor (normally at ~20-40 cm) and working with near-infrared lightning, which makes the acquisition more expensive.

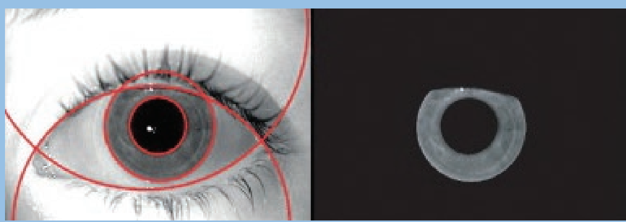
Biometrics "on the move" is currently one of the hottest research topics in this area, with a focus on increasing user convenience by acquiring face and other biometric data "at a distance" as a person walks by detection equipment , or by using their own devices or cameras. Research at Halmstad University in this area is concerned with enabling the analysis of the face or any of its constituent parts (eye, mouth, etc.) with cheaper sensors found in devices of common use, such as smartphones or webcams. This poses important research challenges to solve, since the major limitation of current commercial systems is the degree of control and cooperation required during the acquisition. A primary consequence that we expect is facilitated user interaction by enabling the use of data acquired in a wide range of operational conditions and scenarios. This would drastically reduce cooperation level required, providing more comfort and convenience in the human-machine interaction and influencing user acceptance positively.

> Biometrics "on the move" is currently one of the hottest research topics in this area

Periocular recognition

Periocular refers to the region in the immediate vicinity of the eye including the eye, eyelids, lashes and eyebrows. Although face and irises have been extensively studied by the research community, the degree of control and cooperation required during their acquisition has led to the emergence of the periocular region as a promising trait for unconstrained biometrics. With a surprisingly high discrimination ability, the periocular region can be easily obtained with existing setups for face and iris, and the requirement of high user cooperation can be relaxed. An evident advantage is its availability over a wide range of acquisition distances even when the iris texture cannot be reliably obtained (e.g. low resolution, blinking or closed eyes, off-angle poses, inappropriate illumination) or when portions of the face are occluded (e.g. close distances).

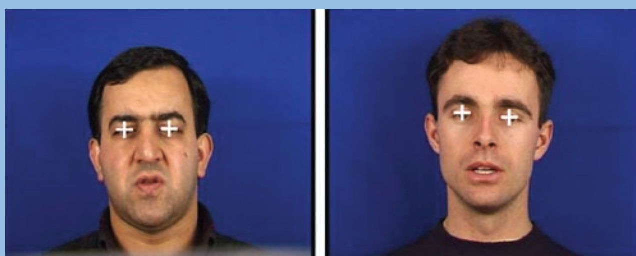
Within CAISR, we have developed several algorithms for periocular recognition, with our developments being among the most competitive in the research literature. It has been also shown by researchers that periocular is better than face under extreme blur or down-sampling, or that periocular is much more suitable than the iris texture with sensors working with visible light (such as digital cameras). This shows the potential of this modality in scenarios where the full face of the iris texture cannot be reliably obtained.



Detection of face parts

Most face detection and recognition systems require a full face, so their performance is negatively affected if parts of the face are occluded. However, face occlusion can happen in many scenarios, for example when the camera is too close. It is even more evident in criminal scenarios, where it is likely that the perpetrator masks part of its face.

Contrarily to existing methods, we are implementing a bottom-up approach, which consists of detecting separately the different facial landmarks (eyes, mouth, etc.). We postulate that this is more effective when the full face may not be available, allowing to perform the detection and the recognition based on the available parts. For this purpose, we are using symmetry features. Such features encode how much of linear symmetry and how much of a certain type of other symmetries (e.g. parabolic, rectangular, circular, spiral, etc.) exist in a local neighbourhood in an image. The combined evidence of the presence of such symmetries in a local neighbourhood is used as a feature for the detection of facial parts.



The whole world uses recycling, how about forensics?

Human fingerprints were considered a reliable source of information for a long time. Experience of generations, stories from books and movies creating an impression of magic story in the lines, defining our identities.
Nevertheless, the prints found at crime scenes are not as perfect as one would hope. Left in a speck of blood or dust; maybe smudged if left in a hurry or by accident, they are far from being clear and unique.

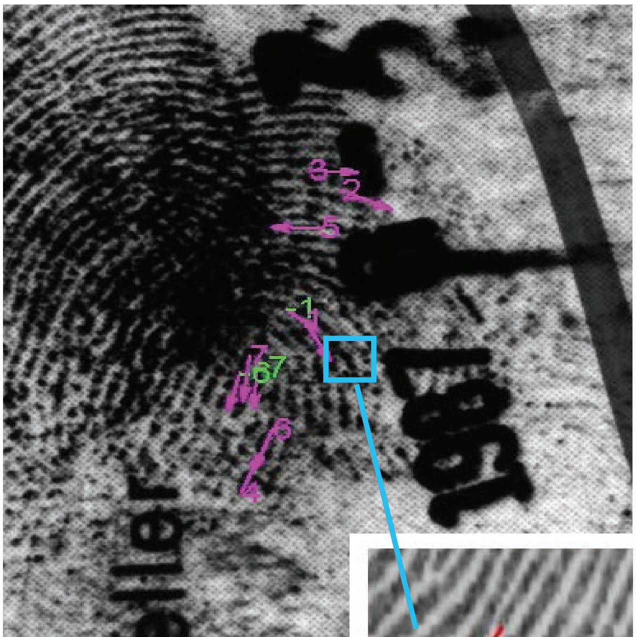
One can find stories about people being convicted and later found to be innocent due to bad fingerprint matching or a human factor. One of the reasons is how little information you can extract from bad quality fingerprint images. Examiners may sit hours or days trying to extract fine details from images, which they later input into a matching algorithm. If the examiner misses something - something that can make a difference between two prints - the result might be unfavorable. The only decision the examiner can make is yes or no.

In forensic fingerprinting nowadays only fine details extracted by the expert are used. The rest is thrown away - similar to throwing garbage in the past, when people did not know that you can recycle the paper, metal or glass. In fingerprints it is similar. The examiner looks at the image and extracts 5 to maybe 20 fine details, depending on the quality of the image. The rest... is discarded. Even though there may be more information in the image.

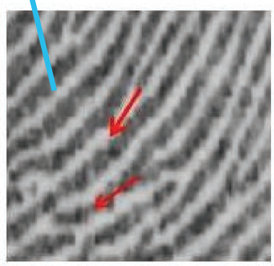
Noisy images is not a specific forensic problem, it is a challenge of image analysis in general. We address it by joining different sources of information, yielding dense frequency and orientation maps in an iterative scheme comprising smoothing of the original. This is done along (but never across) the ridges. Ridge distance, for example, is influenced by frequency as well as orientation and vice versa. Accordingly, reliable estimation of these dense maps is important.

Normally, the collection of irrefutable tiny details, e.g. bifurcation of ridges, called minutiae, in the enhanced image is used to tie the pattern of such points to the identity behind the finger producing the pattern. The image information between the points is thrown away. In our study we have demonstrated that there is information that is valuable for identity establishment in the discarded material. We collect and compress the image information in the neighborhoods of the fine details to vectors, one per minutia, and use the vectors to ”color” the minutiae. When matching two patterns (of minutia) even the color of the minutia must match to conclude that they come from the same identity. In a way, we made the matching more colorful because we paint the points. We have introduced recycling because we use information that used to be discarded as garbage.

Searching a forensic database for a matching pair is accurate only when both images have around 15 (or more) fine details in common. This number varies from country to country and depends on the uniqueness of available features and the expert opinion of the examiner. We are trying to prove that fewer points (for example 5) can be as powerful as 15 if all available information is utilized properly.



Ending or bifurcation of ridge line - a minutia

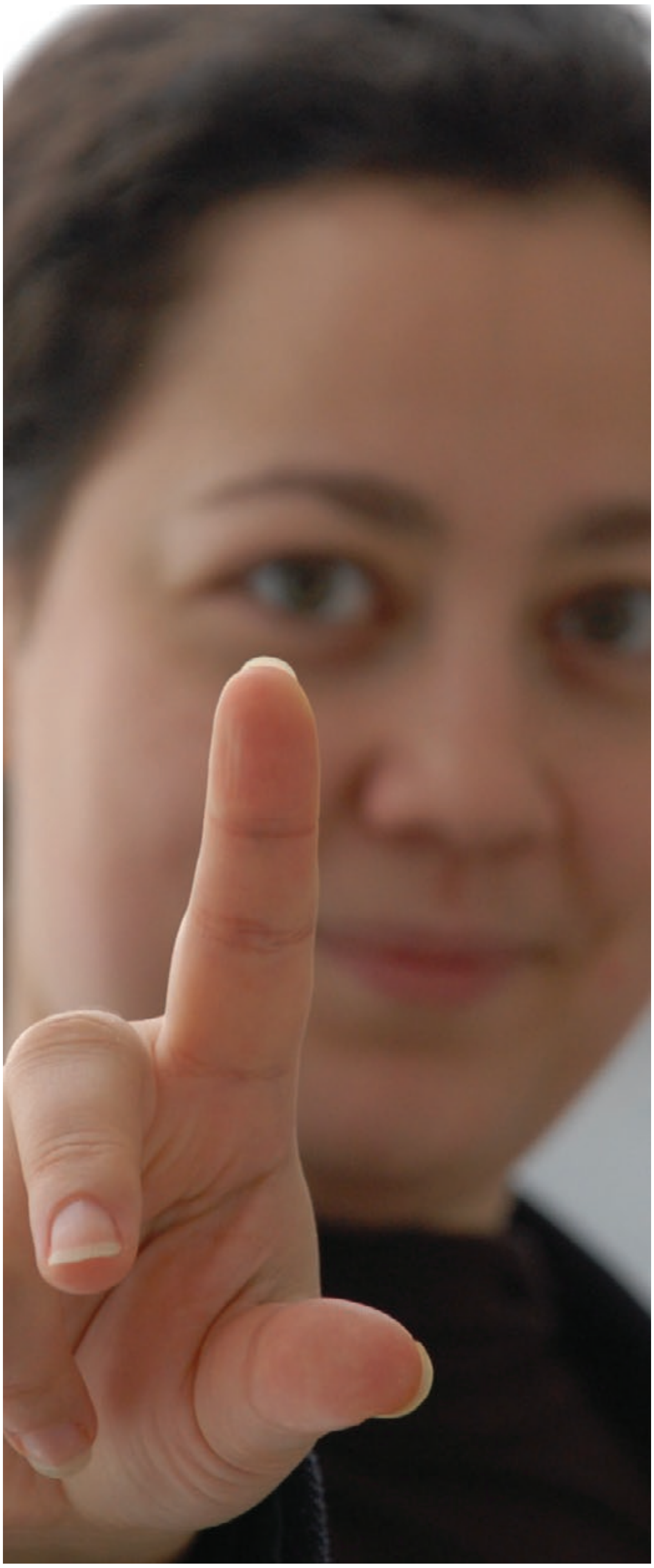


Fingerprints

The average human finger has 75 to 150 ridge characteristics (except forensic cases), which are ridge endings or splittings. These are called minutiae or Galton characteristics, according to a police officer that developed them 200 years ago. If we count what is the chance of finding two persons with the same characteristics in the same position - it is one in a million. What are those characteristics that define us uniquely? First, on a global level we have core or/and delta patterns, which are mostly used either for classification or for an alignment (if the image is rotated). Second, we have the aforementioned fine features, ridge characteristics, that are used for identification. Third, we have even finer features - sweat pores, which are also very unique. Unfortunately, the resolution of forensic fingerprints does not always allow noting third level features. Fingerprint identification as forensic discipline have served governments world- wide for more than 100 years and no two people have been found to have the same the fingerprint patterns, even identical twins.

Project

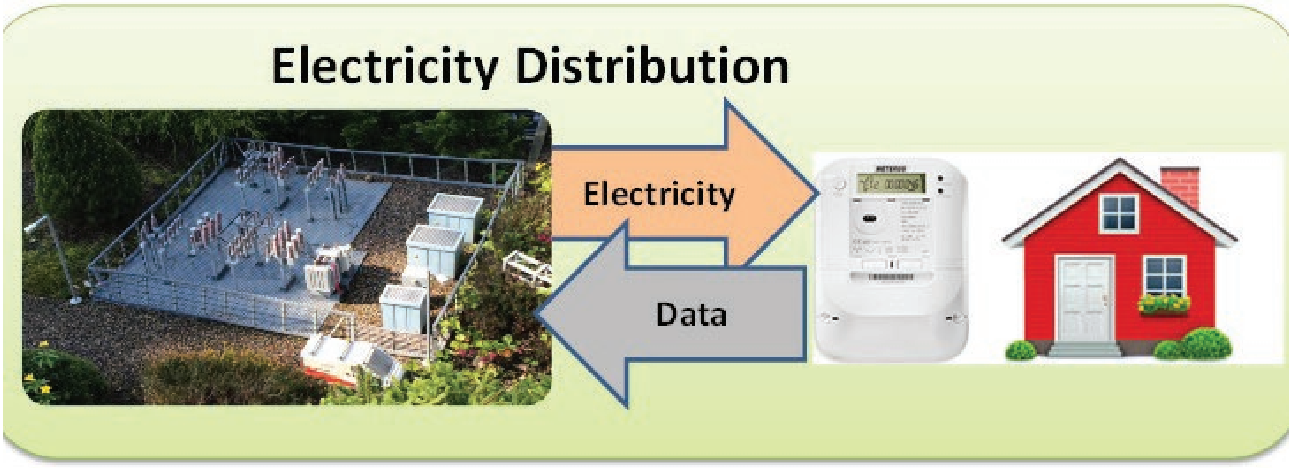
Marie Curie action is a research fellowship grant provided for young researchers by the European Commission and set to provide a network of universities, research institutes and companies. In 2009 Halmstad University became a partner in the Bayesian Biometrics for forensics (BBfor2) project, which joined young researchers of different countries, which specialized in interpreting evidence from biometrics traces. Universities of Spain, Italy, England, Netherlands, Belgium and Sweden, research institutes IDIAP (CH), NFI (NL), NBI (FI) joined together to provide a network for young researchers such as doctoral students and postdocs. Within the project it was required to do at least two research visits or internships. This was used by many of us to benefit from different work environments and research topics.



Data mining for smart grids

Smart grids are advanced power networks that aim to provide clean, safe, secure, reliable, efficient and sustainable energy by using modern hardware and software technologies. They are the next generation of power grids, employing multiple energy sources including renewables, to ensure minimized environmental footprint. Such systems depend on real time, two-way communication that enables high degree of automation within the network.

Modern intelligent sensors, including so called "smart meters," distributed throughout the grid, allow for continuous collection of valuable data. In addition, large amounts of information related to historical faults, repairs, reported alarms, and so on, are recorded in different ways. This information can be used for many purposes, including fault detection, failure prediction and load forecasting.



However, most power electricity companies do not utilize this data fully and they often do not realize the full benefits of doing so. For example, smart meters are usually only used to measure power consumption for billing purposes. However, they have a variety of additional features such as monitoring voltage, current, and frequency.

This research project, a collaboration between CAISR and HEM Nät, is about bringing all of this information together and using data mining techniques to analyze it in a holistic manner. The main goal is to improve the reliability and efficiency of the electricity distribution network in Halmstad.

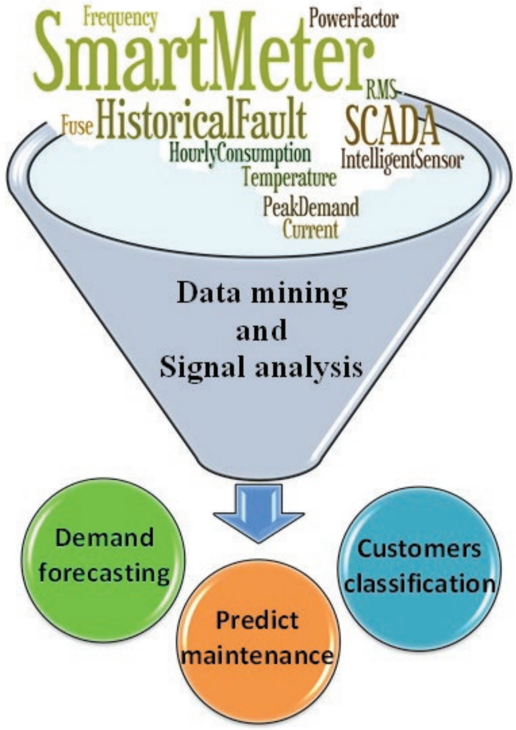
We are employing a number of machine learning and data analysis algorithms to extract relevant information from available data. We investigate three aspects: predictive maintenance, i.e., discovering and anticipating faults before they become serious problems, load forecasting, i.e., estimating future energy consumption, and customer clustering, i.e., finding similarities between energy consumption patterns of different users.

The main focus of the project is predictive maintenance, and we are currently pursuing several directions of data analysis. They are all interesting and important for the goals of the company, but differ in their focus.

First direction is fault analysis, which consists of investigating different types of failures, finding out causes of their occurrences, as well as evaluating their importance and defining which data is required for predicting them. We look at questions such as: "which types of faults are most significant," and "on which methods should we focus to predict them." For example, if a fuse in a substation or underground cable fails, it is important to investigate the cause of the failure, its effects on the grid as a whole, the number of disconnected customers, and the possible methods to prevent similar problems in the future.

The second direction is history-based maintenance, which is based on analyzing the historical information of the network as a whole, or of parts of the network characterized by similar components, usage and external conditions. The goal is to determine the expected lifetime of various assets, often using probabilistic models. This can be used for planning replacement or maintenance operations, in order to prevent faults. This type of analysis can also be called preventive maintenance. For example, we can use historical data of fuses or cable faults in a particular location to recommend replacements after 8 years, even though information from the manufacturer suggests an expected lifetime of 10 years.

The third direction is symptom-based maintenance, which is based on analyzing sensor readings measuring the operation of individual grid components. Signal analysis techniques allow us to use available data, collected from smart meters and other sensors distributed on the grid, to distinguish between assets that are in good condition from those that are starting to reveal fault symptoms. This allows us to base maintenance and replacement operations not only on historical predictions, but also on the current status of the network. For example, by monitoring the energy loss in a fuse or a cable, we may discover fault symptoms building up, before the asset stops working.



Smart Meters

Smart meters are a new generation of energy meters that can collect a variety of information about power consumption, voltage, current, frequency and power factor. These advanced meters are able to regularly send the information back to the control system, allowing users to better monitor their electricity consumption. From companies' perspective, this information can be used for many purposes such as fault detection, failure prediction, and load forecasting.

In Sweden, hourly meter reading for all large scale customers became mandatory since July 2006. And since 2009, monthly meter reading is mandatory for all customers. The new legislation aims to provide customers with regular feedback on their electricity consumption to increase awareness and promote energy efficiency.

The Partner

This project is a collaborative work with Halmstad Energi och Miljö AB (HEM), the energy company operating in and around Halmstad. HEM was formed in 2006, by the merge of Renhållningsbolaget Company and Energiverken. Today, HEM serves over 45,000 customers with various services in waste management and energy, including electricity and district heating. In 2007, HEM deployed 38,000 advanced electricity meters to manage and reduce energy consumption by providing feedback to the customers. At the moment, the average power outage in HEM's network is about 20 minutes per customer per year. The goal for the company is to reduce this to 10 minutes or less.

Distribution grids

Electricity distribution grids are one of the critical infrastructures in any country. Hospitals, airports, factories, banks, and companies are very much dependent on electricity. For these users, the financial and human risks related to power outages are very high. Even for small consumers, such as households, regular or long outages can become a very serious problem. Swedish law imposes a major penalty scheme for distribution companies for each outage longer than 12 hours, as means of customer compensation. Furthermore, no interruptions above 24 hours are allowed.

Presentation of PhD students

Iulian Carpatorea

I have received my Master's Degree at Halmstad University in 2012. The following period I spent my time as a research engineer in a collaboration involving Halmstad University and Volvo Groups Trucks Technology regarding fuel consumption and driver behavior for truck drivers. After 18 months the project turned into a PhD position partly funded by VTT under the supervision of Prof. Rögnvaldsson and Assistant Prof. Novaczyk. My research focus is to use data mining in order to be able to provide answers to questions like "How much should the fuel consumption be?" given a set of parameters as well "Which actions performed by the driver influence fuel consumption?". We aim at answering those questions both in an online environment in order to improve driver performance as well as in an offline environment to assist fleet operators in their daily activities.

Jennifer David

I am Jennifer David and here, at Halmstad University, I am pursuing my PhD in Intelligent Vehicles and joined CAISR in 2014 under the supervision of Assistant Prof. Roland Phlippsen and Prof. Thorsteinn Rögnvaldsson. I am funded by the EU FP-7 project Cargo-ANTS (Cargo Handling by Automated Next Generation Transportation Systems for Ports and Terminals). Apart from Halmstad, the other partners of this project are TNO and ICT from Netherlands, CSIC from Spain and AB Volvo from Sweden. My contribution to this project is mainly focused on the planning and control of multiple vehicles. (This includes assignment of task for each vehicle, planning an obstacle free path to planning the trajectory suitable for the input to the vehicle controller.) The objective is to increase the safety as well as the throughput of containers in a container terminal area. My main interests include "mobile robots", "motion planning" and "multiple robots". Prior to this, I was a Mechatronics Engineer graduate completed by MS from IIT Madras, India.

Stefan Ericson

I received my M.Sc. in Electrical Engineering from University of Skövde in 1999. After my studies I worked at Omnisys Instruments AB where I designed electronics for the space industry. I stayed there for three years before I went back to Skövde and since then I have worked as a lecturer at University of Skövde. In recent years I have been studying part time towards a PhD degree. My studies are in collaboration with CAISR at Halmstad University, under the supervision of Associate Prof. Åstrand and Prof. Rögnvaldsson. My research interest is visual navigation of mobile robots in agricultural environment. I have mainly been on parental leave for the two last years, but in 2015 I will be back full time and the plan is to finish my thesis during this year. However, during the last two years I participated in the summer school on image processing (SSIP2013) where I received the price for the second best project. I have also been able to upgrade my experimental platform and perform some new field experiments during the summer 2014.

Klas Hedenberg

In 1995, I graduated from University of Skövde with a degree in Electrical Engineering and worked three years as a system engineer at Saab Military Aircraft in Linköping conducting tests for hardware and software. I did an M.Sc. in Electrical Engineering at the University of Skövde and graduated there in 1999. Following this, I continued to work as a lecturer in Electrical engineering at the University of Skövde. I have been the program director for engineering programs and have taught in many engineering courses. My research interest is driverless trucks in industrial environments and how computer vision systems can be used for obstacle avoidance. I am currently working on how thin objects can be detected. I presented my licentiate thesis, "Obstacle detection for driverless trucks in industrial environments", in 2014. I am supervised by Prof. Rögnvaldsson and Associate Prof. Åstrand

Peter Mühlfellner

I obtained my Masters degree from Halmstad University, Sweden, and my Diploma Degree from the Salzburg University of Applied Sciences, Austria, in 2011/2012 respectively. Currently, I am an industrial PhD-Student with Halmstad University and Volkswagen Group Research. My research interests include both robotics and computer vision, with a focus on Lifelong Visual Localization and Mapping for automated vehicles. In order to deal with changes in visual appearance, we construct visual maps that are updated as new information becomes available. This allows us to build geometrically consistent maps over time-spans of a year. These maps provide the basis for the pose estimation used for automated navigation. We have proposed a framework for summary strategies that allow selecting the most useful information from these ever-growing maps. My thesis work is supervised by Prof. Rögnvaldsson and Associate Prof. Philippsen. I plan to defend my PhD thesis during 2015.

Siddhartha Khandelwal

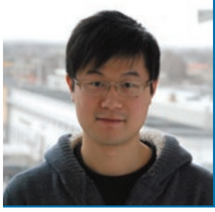
After finishing my Masters in Robotics from WUT, Poland and ECN, France, I joined CAISR to pursue my PhD in Human Motion Analysis using wearable sensors. I am associated with the HMC2 project: Human Motion Characterization and Categorization with focus on Gait Analysis using accelerometers. My research involves investigating human gait in order to develop robust tools for clinical analysis of neuro-physiological diseases and related movement disorders. My goal is to find robust and cheaper ways to carry out the analysis outdoors, in their daily lives, to have long-term and continuous monitoring of their gait movements. Not only would this elevate the understanding of the complex human neuro-locomotory system but also help further investigation and develop tools that are early indicators of such pathologies. Since outdoor gait analysis is closely knitted with many other healthcare applications and products, I also work with health activity monitors that can provide more useful, accurate and richer information about our daily activities.

Anna Mikaelyan

My background is in mathematics and I previously worked with applying it to problems in finance. During my PhD studies the research focus has been changed to Signal and Image Processing in Biometrics and Forensics. I started my studies within the European Marie-Curie project BBfor2 - Bayesian Biometrics for Forensics, which was created to stimulate collaboration between European Universities and research centers. Within the project I have spent my time in TU, Netherlands and Forensic Laboratories of Netherlands and Finland - NFI and NBI. The main direction of my research has been automatic feature extraction from forensic fingerprints, images with high noise level. During this time, I was trying to answer the question whether it is possible to use low quality fingerprint images to identify a person with higher certainty. Along the way, I had a chance to work with forensic shoeprint images, trying to determine the brand of the shoe print of low quality. I plan to present and defend my PhD thesis during 2015.

Rune Prytz Andersson

I studied Electrical Engineering at Lund University in Sweden. My studies was concentrated towards automatic control and real time systems Following that I started working at Volvo Technology Cooperation in 2004. In 2009 I as an Industrial PhD student in cooperation with Volvo and Halmstad University. My interests are within fleet based predictive maintenance using both unsupervised and supervised approaches. I have mainly been working in the research project ReDi2Service and now I continue in the In4uptime project. I presented my Licentiate thesis in September 2014.



Yuantao Fan

I received my B.Eng. in Electrical and Information Engineering from Shanghai University of Engineering Science in 2011. The focus of my bachelor thesis was on developing algorithm for an electronic Sphygmomanometer. I then attended the M.Sc. program in Embedded and Intelligent Systems at Halmstad University. I graduated by defending my thesis on "Exploration and Mapping of Warehouse Using Quadrotor Helicopters". After that I worked as a research engineer on the AIMS project within CAISR at Halmstad University. The work was to develop a driver package of a sensory system for AGVs (Auto Guided Vehicles). In February 2014, I started my PhD studies in data mining related to vehicle diagnostics at Halmstad University, under the supervision of Prof. Rögnvaldsson and Assistant Prof. Nowaczyk. My current research is concentrated on using machine learning to predict component failure by utilizing on-board vehicle data streams and developing a data-driven predictive maintenance method for heavy vehicles.

Hassan Nemati

I received my B.Sc. in Power Electrical Engineering from Azad University, Iran in 2007, and M.Sc. in Embedded and Intelligent Systems from Halmstad University, Sweden in 2010. In 2014, I joined CAISR at Halmstad University as a PhD student. My research area is about data mining for smart grids.

The project is a collaborative work with Halmstad Energi och Miljö AB (HEM), one of the Swedish energy companies.

The aim of the project is to improve the reliability of HEM's electricity distribution network. I will investigate and implement data mining techniques for extracting relevant information from data collected using smart meters and other sensors, in order to detect faults, prevent black-outs, and optimize maintenance.

Gaurav Gunjan

Having done my Bachelors in Electrical Engineering from NIT Durgapur, India, I worked for a couple of years as a quality assurance engineer at the construction site of a thermal power plant. After that I pursued my Masters at École Centrale de Nantes, France in the ASP program with specialization in Robotics. Here I worked on Dense-SLAM using stereo-camera. Following that, I joined CAISR in February'2014 to pursue my PhD. under Prof. Rögnvaldsson and Assistant Prof. Philippsen. The project I am associated with is VASCO which deals with mapping and semantic labeling of outdoor work-yard type environments like harbor, shipyard, construction site etc. The objective is to create detailed maps for shared human-robot autonomy in a dynamic outdoor environment.

Magnus Svensson

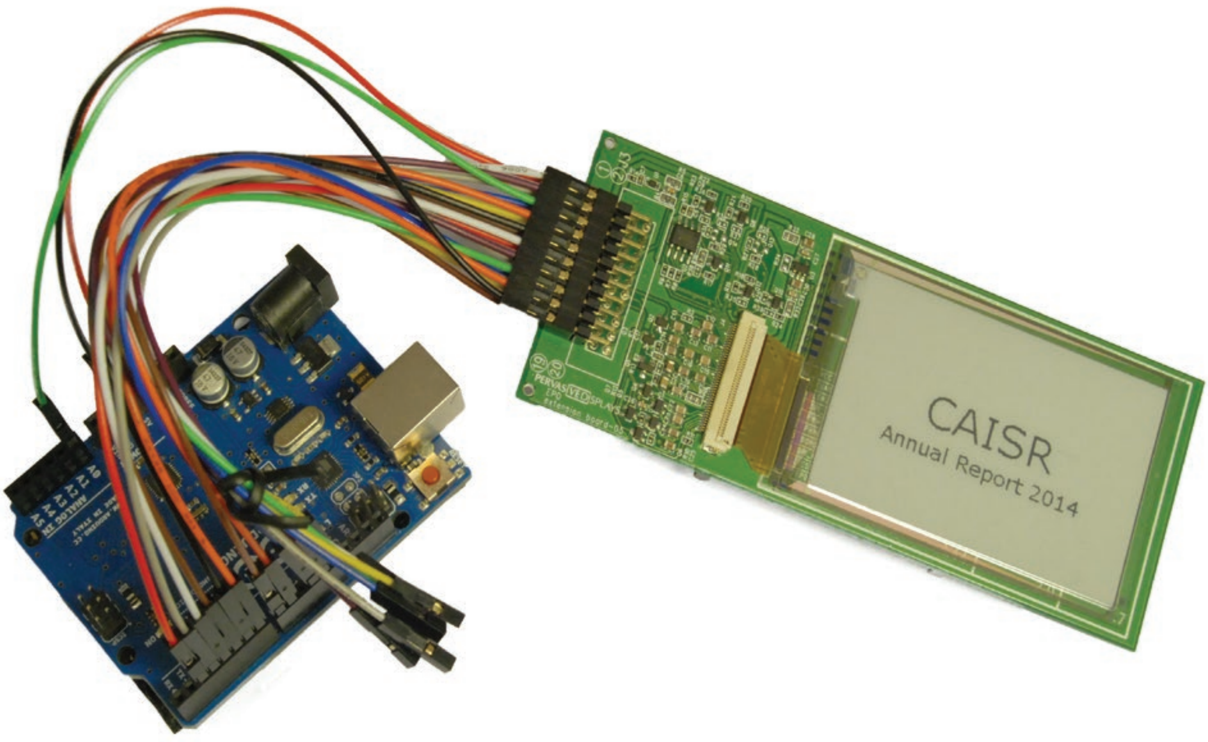
I have a MSc in Electrical Engineering from the Royal Institute of Technology in Sweden 2007. I am an industrial PhD student employed at Volvo, where I am also Uptime Specialist, Advanced Technology and Research. I have worked at Volvo for more than 10 years. My research topic is deviation detection of on-vehicle systems based on self-organized search for signal relationships. I presented my Licentiate thesis, "Vehicle Monitoring with Anomaly Detection by Embedded Agents", in 2010. At Volvo I have previously developed embedded control software for various applications in the automotive field, not least on climate control where I developed the first fully automated climate controller in the heavy duty segment. I have also worked with developing and improving the innovation process at Volvo Technology.

Petras Ražanskas

I earned BSc and M.Sc. degrees in applied mathematics at Kaunas University of Technology (KTU). The studies heavily emphasized statistical methods of analysis, as well as techniques of digital data manipulation and data mining. In particular, I focused my attention on various methods of pattern recognition based on artificial intelligence approach, such as fuzzy logic systems or neural networks. These interests, as well as the knowledge of statistical analysis, were perfectly matched when I was offered an opportunity to participate in a CAISR project about an intelligent system for fatigue detection and evaluation during cycling as a part of joint PhD studies in KTU and Halmstad University under the supervision of Prof. Antanas Verikas. My research at the moment is concentrated in the HMC2 project, around the analysis of spectral and temporal features of electromyographic signals, collected during a cycling exercise, with the goal of accurately predicting the fatigue levels of the test subjects.

Saeed Shahbandi Gholami

I studied Electrical Engineering at University of Mazandaran in Iran. Accomplished my BSc studies in "electronics" and "digital design" by "implementation of a convolutional decoder on FPGA". Following my education I attended a robotic master program (ASP) in Ecole Central de Nantes in France. Participating in Cart-O-Matic robotic group in University of Angers (ISTIA). I joined CAISR at Halmstad University in 2012, working in the AIMS project under supervision of Prof. Verikas and Associate Prof. Åstrand. My contribution to the project is mainly focused on map analysis and semantic annotation (e.g. structural labels as corridors or local label such as pillars and pallet cells). The objective is to increase the support for awareness of lift-trucks (AutomatedGuided Vehicles; AGVs) by providing them with an understanding and knowledge on their surrounding environment. My main interests lie in robotics, computer vision and machine learning.



CAISR

PhD Graduation Jens Lundström

Situation Awareness in Colour Printing and Beyond

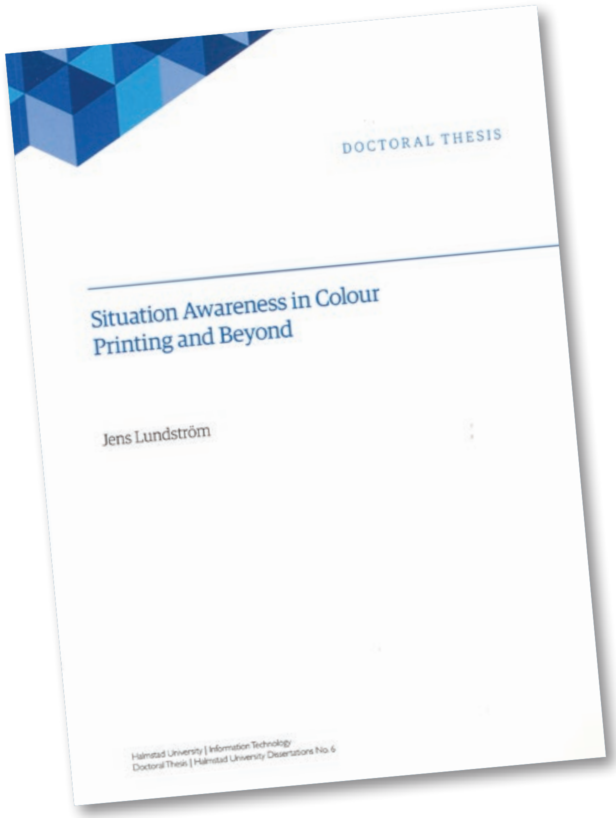
PhD thesis, Halmstad University
Main supervisor: Prof. Antanas Verikas, Halmstad University
Co-supervisor: Professor Ivan Kalaykov, Örebro University
Dr Magnus Hållander, Halmstad University
Opponent: Prof. Juan A Botía, Universidad de Murcia, Spain
Grading Committee: Prof. Lars Niklasson, Jönköping University, Sweden
Assistant prof. Ulf Johansson, University of Borås, Sweden
Associate professor Amy Loutfi, Örebro university, Sweden

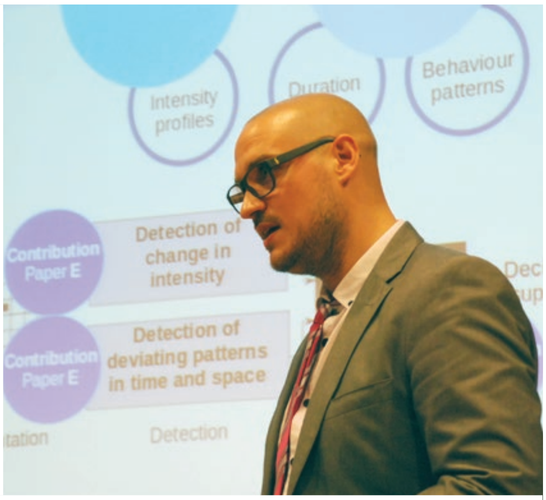
Machine learning methods are increasingly being used to solve real-world problems in society. Often, the complexity of the methods are well hidden for users. However, integrating machine learning methods in real-world applications is not a straightforward process and requires knowledge both about the methods and domain knowledge of the problem. Two such domains are colour print quality assessment and anomaly detection in smart homes, which are currently driven by manual monitoring of complex situations. The goal of the presented work is to develop methods, algorithms and tools to facilitate monitoring and understanding of the complex situations that arise in colour print quality assessment and anomaly detection for smart homes. The proposed approach builds on the use and adaption of supervised and unsupervised machine learning methods.

Novel algorithms for computing objective measures of print quality in production are proposed in this work. Objective measures are also modelled to study how paper and press parameters influence print quality. Moreover, a study on how print quality is perceived by humans is presented and experiments aiming to understand how subjective assessments of print quality relate to objective measurements are explained. The obtained results show that the objective measures reflect important aspects of print quality. These measures are also modelled with reasonable accuracy using paper and press parameters. The models of objective measures are shown to reveal relationships consistent to known print quality phenomena.

In the second part of this thesis the application area of anomaly detection in smart homes is explored. A method for modelling human behaviour patterns is proposed. The model is used in order to detect deviating behaviour patterns using contextual information from both time and space. The proposed behaviour pattern model is tested using simulated data and is shown to be suitable given four types of scenarios.

The thesis shows that parts of offset lithographic printing, which traditionally is a human-centered process, can be automated by the introduction of image processing and machine learning methods. Moreover, it is concluded that in order to facilitate robust and accurate anomaly detection in smart homes, a holistic approach that makes use of several contextual aspects is required.




Intensity profiles
Duration
Behaviour patterns
Contribution Paper E
Detection of change in intensity
Contribution Paper E
Detection of deviating patterns in time and space
Detection

Licentiate thesis Klas Hedenberg

Obstacle Detection for Driverless Trucks in Industrial Environments

Licentiate thesis, Halmstad University
Main supervisor: Prof. Thorsteinn Rögnvaldsson, Halmstad University
Co-supervisor: Associate Prof. Björn Åstrand, Halmstad University
Discussion leader: Roger V Bostelman, NIST National Institute of Standards and Technology, USA
Examiner: Prof. Josef Bigun, Halmstad University, Sweden

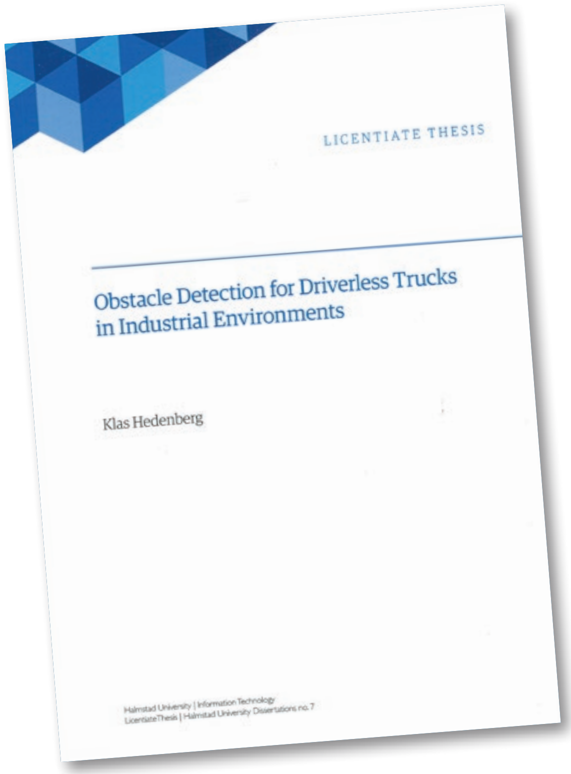
With an increased demand on productivity and safety in industry, new issues in terms of automated material handling arise. This results in industries not having a homogenous fleet of trucks and driven and driverless trucks are mixed in a dynamic environment. Driven trucks are more flexible than driverless trucks, but are also involved in more accidents. A transition from driven to driverless trucks can increase safety, but also productivity in terms of fewer accidents and more accurate delivery. Hence, reliable and standardized solutions that avoid accidents are important to achieve high productivity and safety.

There are two different safety standards for driverless trucks for Europe (EN1525) and U.S. (B56.5–2012) and they have developed differently. In terms of obstacles, they both consider contact with humans. However, a machinery-shaped object has recently been added to the U.S. standard (B56.5–2012). The U.S. standard also considers different materials for different sensors and non-contact sensors.

For obstacle detection, the historical contact-sensitive mechanical bumpers as well as the traditional laser scanner used today both have limitations – they do not detect hanging objects. In this work we have identified several thin objects that are of interest in an industrial environment. A test apparatus with a thin structure is introduced for a more uniform way to evaluate sensors.

To detect thin obstacles, we used a standard setup of a stereo system and developed this further to a trinocular system (a system with three cameras). We also propose a method to evaluate 3D sensors based on the information from a 2D range sensor. The 3D model is created by measuring the position of a reflector with known position to an object with a known size. The trinocular system, a 3D TOF camera and a Kinect sensor are evaluated with this method. The results showed that the method can be used to evaluate sensors. It also showed that 3D sensor systems have potential to be used on driverless trucks to detect obstacles, initially as a complement to existing safety classed sensors.

To improve safety and productivity, there is a need for harmonization of the European and the U.S. safety standards. Furthermore, parallel development of sensor systems and standards is needed to make use of state-of-the-art technology for sensors.



Rune Prytz

Licentiate thesis

Machine Learning Methods for Vehicle Predictive Maintenance Using Off-board and On-board Data

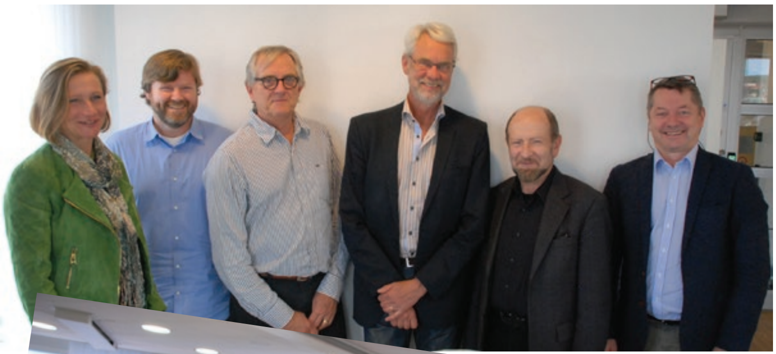
Licentiate thesis, Halmstad University
Main supervisor: Prof. Thorsteinn Rögnvaldsson, Halmstad University
Co-supervisor: Assistant Prof. Slawomir Nowaczyk, Halmstad University
Discussion leader: Prof. Paul Davidsson, Malmö University, Sweden
Examiner: Prof. Antanas Verikas, Halmstad University, Sweden

Vehicle uptime is getting increasingly important as the transport solutions become more complex and the transport industry seeks new ways of being competitive. Traditional Fleet Management Systems are gradually extended with new features to improve reliability, such as better maintenance planning. Typical diagnostic and predictive maintenance methods require extensive experimentation and modelling during development. This is unfeasible if the complete vehicle is addressed as it would require too much engineering resources.

This thesis investigates unsupervised and supervised methods for predicting vehicle maintenance. The methods are data driven and use extensive amounts of data, either streamed, on-board data or historic and aggregated data from off-board databases. The methods rely on a telematics gateway that enables vehicles to communicate with a back-office system. Data representations, either aggregations or models, are sent wirelessly to an off-board system that analyses the data for deviations. These are later associated to the repair history and form a knowledge base that can be used to predict upcoming failures on other vehicles that show the same deviations. The thesis further investigates different ways of doing data representations and deviation detection. The first one presented, COSMO, is an unsupervised and self-organized approach demonstrated on a fleet of city buses. It automatically comes up with the most interesting on-board data representations and uses a consensus based approach to isolate the deviating vehicle. The second approach outlined is a supervised classification based on earlier collected and aggregated vehicle statistics in which the repair history is used to label the usage statistics. A classifier is trained to learn patterns in the usage data that precede specific repairs and thus can be used to predict vehicle maintenance. This method is demonstrated for failures of the vehicle air compressor and based on AB Volvo's database of vehicle usage statistics.

Some Highlights

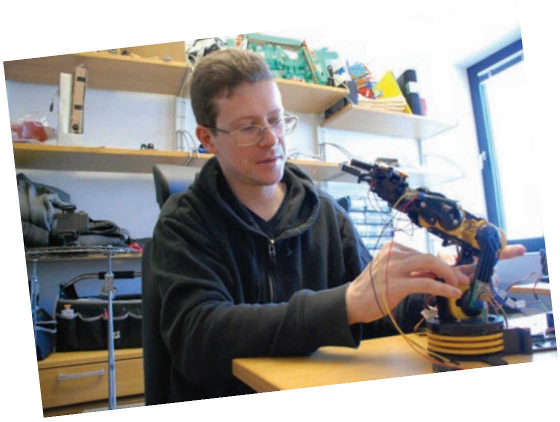
People



CAISR Reference Group met twice during 2014, this meeting was held in September, one of the two meeting days was together with the Industrial Advisory Board.

Meeting with the reference group and industrial advisory board in February. Sławomir Nowaczyk, Christer Fernström and Anita Sant'Anna in the foreground.

Robert Evans, new member in the CAISR Reference Group. Currently Software Engineer at Google. Working on PACO, an experiential sampling-based experimentation platform for health and wellness applications using mobile (Android) and cloud (AppEngine) technologies.



New Post doc #1
Martin Cooney attaches angle sensors to a toy robot arm in this photo, for generating some enjoyable interactive behavior. After graduating from a PhD degree at Prof. Ishiguro's android lab in Japan, he has been working on developing a smart environment with robots intended to support people's health and well-being.

New Post doc #2
Rafael Valencia is a Postdoctoral Researcher from January 2015. Previously, he was a Postdoctoral Researcher at Örebro University. In April 2013, Rafael received his PhD from the Technical University of Catalonia (UPC), at Barcelona, Spain. His research has focused on different aspects of autonomous mobile robot navigation, from perception (SLAM, Mapping, Localization) to action selection problems (path planning, exploration).

Docent lectures held on Oct 1:
Nicholas Wickström - Computer Systems Engineering for Health
Roland Philippsen - Motion Planning and Control for Robots and Vehicles

Rune Prytz defended his licentiate thesis "Machine Learning Methods for Vehicle Predictive Maintenance Using Off-board and On-board Data. September 26.

Klas Hedenberg defended his licentiate thesis "Obstacle Detection for Driverless Trucks in Industrial Environments". September 10.

Jens Lundström defended his Ph.D. thesis "Situation Awareness in Color Printing and Beyond". June 13.

Health Tech Workshop

Approximately 120 people attended the September 23 CAISR Health Technology Workshop. Besides many internal participants, several researchers from Lund University, Sahlgrenska Academy (University of Gothenburg), and Örebro University, as well as many participants from industry, attended the workshop. The main purpose of the workshop was twofold: to present CAISR Health Technology to a wide audience; and to establish new collaborations and new partners.

Invited speakers

"Model-based approaches to behavioral informatics in support future healthcare"
Dr. Misha Pavel

"Internet of sports - combining sports and computer science to cool services"
Christer Norström

"An introduction to person-centered care"
Dr. Axel Wolf

"Paco: an open D-I-Y platform for behavior experimentation for researchers and individuals"
Robert Evans

"Promoting self-management with wearable technologies"
Dr. Christopher Nugent and Dr. Huiru Zheng

Christer Norström

Axel Wolf

Health Innovation is an overall research theme at Halmstad University. The theme includes researchers from several different research environments. CAISR has since the start had Health Technology as one application area and will play an important role in the multidisciplinary Health Innovation research.

Demonstrators at the workshop

- Motion estimation by optical flow
- Breathing rate detection using ultra-wideband radar
- Bike Around
- SA³L – Situation Awareness for Ambient Assisted Living
- Usefulness of robots in healthcare for the elderly
- Toward self-powering robots with energy harvesting
- Database-centric architecture to support ambient intelligence

Martin Cooney describing a concept for a teleoperated robot intended to care for the elderly: visitors tried controlling the robot's base and arm manually and walking with the robot in automatic following mode

Wagner de Morais presented the "Smart Home in a Raspberry Pi" demonstrator and described how affordable and commercial available sensors (e.g. motion, contact and temperature sensors) and actuators (e.g. power outlet switches) can interoperate to offer new or advanced functionalities.

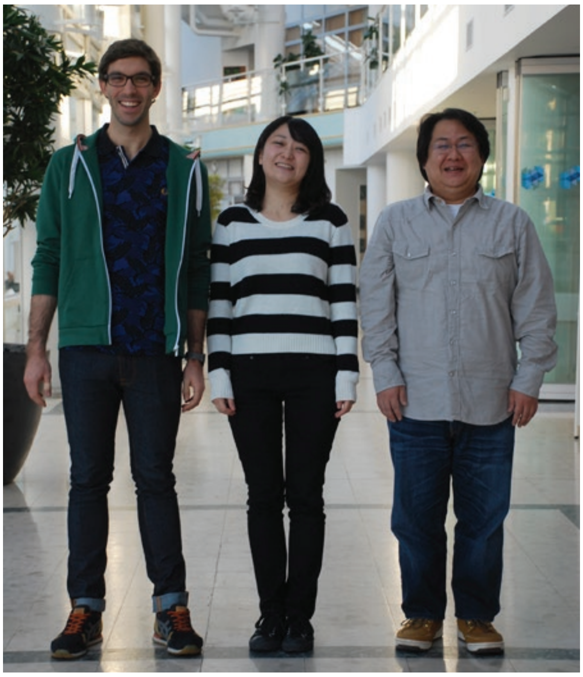
Per-Arne Wiberg and Chris Nugent (CAISR guest professor from Jan. 1, 2015) discussing a radar used for breathing rate detection.

- This is a great opportunity for us to communicate what we do to companies, governmental organizations, and other researchers. Events like this put the university in the spotlight and generate networking opportunities, where we can initiate new collaborations and projects. We are trying to foster not only multidisciplinary collaborations but also triple helix collaborations. This workshop will greatly contribute to profiling CAISR in the area of health technology and health innovation.

Anita Sant'Anna, Health Technology track coordinator

International Guests

I am Pascal from ETH, Zurich and I accomplish my semester project here at CAISR and Halmstad University. In my three month stay I worked on trajectory planning and optimization for multiple mobile robots. With a 2D implementation of a novel trajectory optimization technique called CHOMP I performed further researches in robot - obstacle and robot - robot behavior. The friendly atmosphere at the lab was a wonderful experience.



Pascal Bosshard, Akane Ishida and Takafumi Asao.

My name is Takafumi Asao. I am an assistant professor in Kansai University, Japan. I am a visiting researcher at CAISR from September 2014 to September 2015 and my research fields are human factors engineering and ergonomics. I collaborate with Viktoria Swedish ICT related to traffic safety by analyzing cyclists behavior while distracted by use of a mobile phone.

My name is Akane Ishida, I'm a master's course student at Kagawa University in Japan. My major is optics and I am developing a non-invasive blood sugar sensor. I am researching estimation of glucose level using machine learning at Halmstad University. I visited CAISR between September 2014 and January 2015.

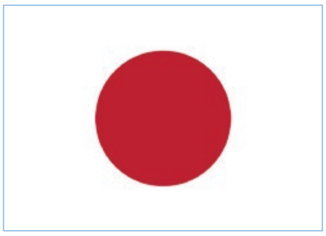
Science without Borders

Halmstad University has through the Brazilian scholarship program Science without Borders received two Brazilian graduate students. Maria Luiza Recena Menezes will during the coming years study at CAISR. Antanas Verikas will be her main supervisor, Anita Sant'Anna her co-supervisor and Wagner Ourique de Morais will be her mentor. Only a few Swedish universities have been fully funded scholarships for graduate students through the program.

Matthias Mayr is a student in electrical engineering and information technology at Karlsruhe Institute of Technology, Germany, He visited CAISR on an internship and worked on the enhancement of the home assisted living architecture of Wagner De Morais with the services of a mobile robot. One goal was to enable the robot to find a person in an apartment and ask for the well being if the a assisted living system assumes that there's something wrong.

Seminar with Roger V. Bostelman, from NIST, National Institute of Standards and Technology, Intelligent Systems Division, USA. He gave a seminar talk on September 10 entitled: "NIST technologies and AGV safety and performance measurement research"

Japan day was arranged on the 3rd of September to inspire Swedish students to study in Japan. Fifteen students from Kagawa University in Japan presented their research work, Japanese culture and scholarship opportunities to Swedish students. Afterwards, the Japanese students visited CAISR for presentations of our research.



Halmstad Colloquium

The Halmstad Colloquium is a distinguished speaker series. The prominent speakers are invited from universities and companies around the world. Two of the guests during 2014 were in the area of intelligent systems.

"Big Data Analytics for Connected Cars"

Professor Hillol Kargupta, Agnik and Department of Computer Science and Electrical Engineering, University of Maryland, Baltimore, USA

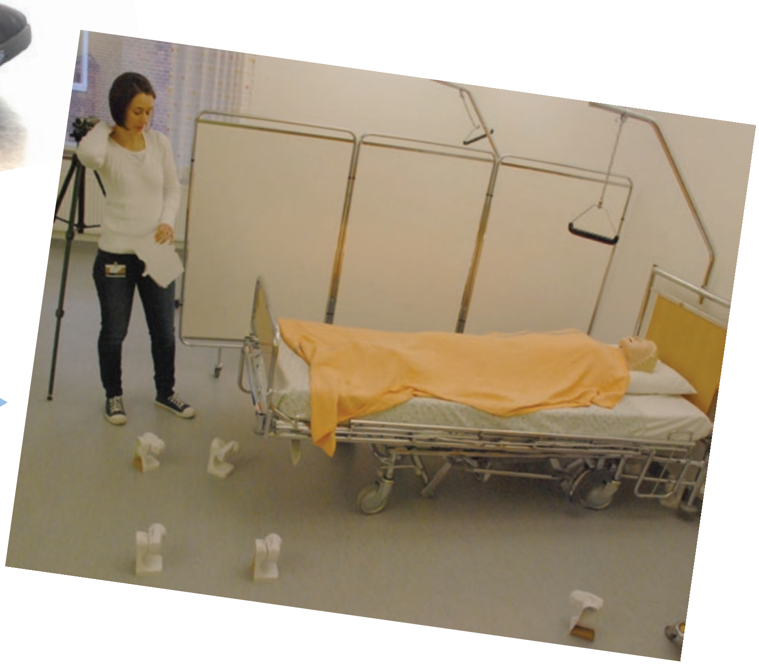
"Self-management of health and wellbeing: The role of Smart Environments"

Chris Nugent, professor of biomedical engineering at University of Ulster, Northern Ireland

Data Collection

A research and technology demonstrator for the SA3L project was developed during autumn 2014. Using the flexible and portable technology-equipped environment, the research was showcased by live-demos at the Health Technology Workshop (Halmstad September 23rd) and at the fair "Båstads digitala välfärdsdag" (November 4th). Moreover, an IEEE conference paper on testing capabilities of the demonstrator was submitted during early December 2014.

Shoe instrumented with force sensors to evaluate the performance of gait event detection algorithm using accelerometers for outdoor walking and running. This would be useful for gait related long-term and continuous monitoring applications. Here used in the HMC² project.



People falling, not at least in the hospitals are a big challenge. Here Anita Sant'Anna is preparing a test on optimal placing of sensors to detect when a person is leaving the bed. The project is done in cooperation with Region Halland.

Data collection on the slippery road track at Kristinehedsbanan in Halmstad. The data collection was performed as part of a master thesis project related to detecting slip with the purpose of storing and communicating this information to nearby vehicles. The project was completed by ERASMUS exchange students from KU Leuven; Robin Vanden Ecker and Ghijs Schauwears under the supervision of Stefan Byttner and Tony Larsson.

Outreach activities

Roland Philippsen with the humanoid Nao informing students on a Secondary School about the new education "Civilingenjör", that started up at Halmstad University in September.

Staff at CAISR informing students taking the course "Perspectives on Computer Science and Engineering" about current research at the center. The course is a part of the education programs in Computer Science and Engineering, and Computer Engineer.

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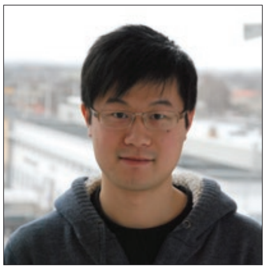

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CAISR, the Center for Applied Intelligent Systems Research, is a long-term research program on intelligent systems established by Halmstad University. The program is funded by the University and the Knowledge Foundation with support from Swedish Industry.

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Halmstad University, Communications Department, March 2015.