CAISR

Center for Applied Intelligent System Research

Annual Report 2021

HALMSTAD UNIVERSITY

CAISR

Center for Applied
Intelligent Systems Research

Annual Report 2021

Knowledge Foundation

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CAISR

Director's statement

The covid-19 pandemic continued and dominated 2021, but the world mood was much better than in 2020. Vaccines were developed at a record pace, and everyone in Sweden who wanted got 2 to 3 vaccine shots in 2021. The vaccines did not protect us from getting covid; I suspect that the majority of the CAISR staff have now experienced covid, but the symptoms were often mild, and we got through it.

In 2021 our focus increased on education, and we have over the last two years had dramatic growth in AI education for professionals. Many positive facts deserve attention in the development of our education and our students' results over the last years, so we have chosen to emphasize education more in this annual report.

In early 2021, after our School had received feedback from the external panels on the suggested research strategy, we decided to develop a new AI-oriented Bachelor's program that would be open to students with more varying backgrounds; a program that emphasized the application of AI in different settings rather than the development and core of AI algorithms. The panel lauded this idea. The working name was "AI for Social Good", with inspiration from the "Data Science for Social Good" fellowship that one of our PhD students (Ece Calikus) did in 2019. In the end, the program name had changed to "Applied AI", which is considerably drier, although perhaps a more accurate description of the contents. It will start in the fall of 2022.

There was a clear drop in scientific production (publications) in 2021 compared to 2020 and 2019. This is probably not surprising given that our education volumes are increasing, especially the education for professionals. Even though we continue to recruit with a high tempo, we could not keep up with demand; we did not have time to finish as many papers in late 2020 and 2021 as in 2019 and early 2020.

The great results in CAISR are the results of all the great people here. In 2021 we reached more than 60 staff members, an increase of more than 20% compared to 2020, and an increase of more than 130% compared to ten years ago. The gender balance is also improving; the number of female staff grows four times faster than the male staff. In Halmstad University's job satisfaction polls, the School of Information Technology generally gets relatively high scores, and 2021 was no exception. This reflects the very positive attitudes we have here at CAISR.

Thorsteinn Rögnvaldsson

CAISR **Research Agenda**

The ability to create and transfer knowledge efficiently is a key competitive advantage for a company or an organization. It follows that being able to use computers to automatically, or autonomously, create transferable knowledge from product and customer data is a key competitive advantage. Autonomous knowledge creation is the common research vision for CAISR, and we refer to a system that can autonomously create knowledge as an *aware* system.

A good formalism for discussing how to create knowledge is the *Data, Information, Knowledge, and Wisdom* (DIKW) hierarchy[1] , often illustrated with a pyramid (see figure below); the higher a system reaches on the pyramid, the more aware it can be.

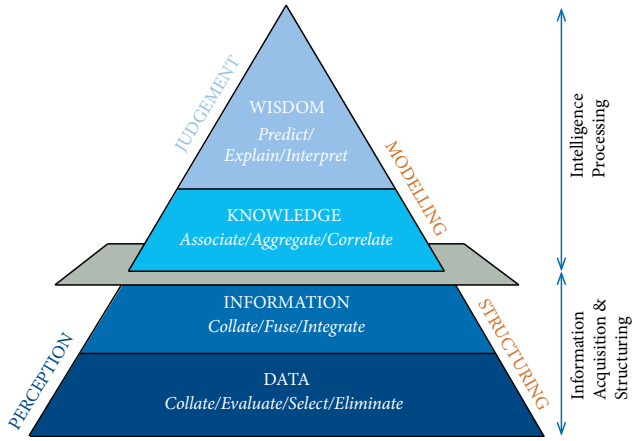


Figure 1. The knowledge pyramid, adapted from Ackoff (1989). "From Data to Wisdom". Journal of Applied Systems Analysis 16: 3–9

The bottom level in the pyramid, *data*, deals with collecting and representing data. A key research question here is how to autonomously select what data to collect. How can a system decide what data are (or will be) relevant, and can features/representations be learned? With endless streams of data, it is impossible to save all raw data; it is necessary to work with representations of the data.

The *information* level relates to questions that begin with "who, what, when, and how many", creating "events" from the data in the layer below. This deals with classification, rearranging/sorting, aggregating, performing calculations, and selection. Much machine learning research is devoted to this stage. Important open research questions here regard autonomous clustering and categorization of events.

The *knowledge* level is about creating "rules" from the information, which requires combining information from different sources. An obvious example is supervised learning, which matches "events" (input) with correct responses (target) provided by an expert. A relevant question deals with knowledge representations; can knowledge be represented so that it can be used better for reasoning and prediction, or easier to transfer from one scenario to another? A knowledge structure should evolve from experience, allowing for learning from data and human experts, and be capable of taking into account initial domain knowledge.

The top level, denoted the *wisdom* level, relates to the question "why" or "what will happen"? It is about the ability to project into the future and reason back into the past. An aware system must be capable of extrapolating information into the future, to evaluate the consequences of actions, and able to explain why something happened.

> *An aware system must be capable of extrapolating information into the future, to evaluate the consequences of actions, and able to explain why something happened.*

It is obvious that to do tasks on each of these levels autonomously would be a sought after ability, and even more attractive to merge them into an autonomous knowledge-creating, or even wisdom-creating, system. Hence, the CAISR scientific vision of aware systems. Two clear examples where these abilities can be demonstrated are predictive maintenance in machines and for people (healthcare). Here, the complexity of the problem(s) is so high that it is difficult for a human expert to grasp it all, but the amount of data is growing fast and the aim is to have AI systems uncover (surprising) knowledge for human experts and to illustrate relations that are not apparent to the experts. Information-driven healthcare represents a step up in awareness from data-driven healthcare (although we would call it "knowledge-driven" rather than "information-driven" to match with the DIKW hierarchy).

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

Smart forklift trucks

Toyota Material Handling and CAISR collaborate around smart forklifts. For the researchers in CAISR, it is a possibility to work with real-life data and develop algorithms for that. Toyota get access to the CAISR researchers' state-of-the-art knowledge in machine learning to further develop their products.

It is in Toyota Material Handling's factory in Mjölby with about 3,000 employees that the smart forklift trucks are tested. In total, about 80,000 electric indoor trucks are manufactured here per year. More specifically, the smartness means that the trucks are equipped with integrated telematics that can describe in detail what they do 24 hours a day. This is what Jonas Klang, Program Manager for Innovation, says, with the task of making the business more innovative.

- On our trucks we have a computer that controls and monitors things. Now, in collaboration with the university, we have developed an algorithm that automatically classifies what the truck does based on the streaming data in the CAN-bus system. The algorithm must figure out what the truck is doing through combinations of messages and data. The question is whether the same "approach" used for image recognition is useful for these high-resolution data streams, he says.

The hope is that it will lead to a more efficient use of the trucks, an improvement of the service and maintenance planning, and that accidents can be avoided with increased knowledge of how customers use their trucks.

- We connected our trucks already 15 years ago but are convinced that there is still a lot to learn about what we can do with the information. Halmstad University has knowledge in machine learning that allows us to develop an even better system for control and monitoring. At the same time, we can give the university a platform to demonstrate that their theories work in reality, says Jonas Klang.

Boris Ahnberg, Solution Architect at Toyota Material Handling, is one of the initiators of the collaboration with Halmstad University. He says that the knowledge that exists about algorithm-driven knowledge systems has been an engine in the collaboration since 2015.

- I think it is extremely valuable to collaborate with Halmstad University, and also with the Royal Institute of Technology (KTH), and Linköping University. Students and colleges can learn from our reality at the same time as we need access to their cutting-edge expertise. I would also like to see increased collaboration between us and the university's other partners, he says.

Thorsteinn Rögnvaldsson, professor of computer science and director of the Center for Research on Applied Intelligent Systems (CAISR) at Halmstad University, sees it as an important task to make Swedish industry more competitive with the help of AI and machine learning.

- Then of course we will get a lot of interesting research as well. The collaboration with the industry is exciting because it places great demands on problem solving. It is never a matter of just taking an algorithm and driving and everything works. Here researchers must take reality into account. I am convinced that the collaboration with our industrial partners will both sharpen our researchers and strengthen competitiveness at Swedish companies, he says.

The article is from The Knowledge Foundation's Annual report 2021. It's republished with their permission. Author: Carina Järvenhag.

Predictive maintenance

Predictive maintenance builds upon the idea that components or subsystems can be monitored such that it is possible to precisely estimate their health status and, by anticipating future degradation, estimate their remaining useful life. This enables optimization of maintenance processes and increased efficiency of operations. Predictive maintenance has challenges that fit the CAISR scientific agenda very well.

In our annual report for 2019, we described how the field of machine learning for predictive maintenance seems to be taking off, with the number of publications increasing by 30% annually. Multinational companies are investing in predictive maintenance and machine learning, and several startups have appeared. One such startup is Stratio Automotive (stratioautomotive.com) in Portugal. Stratio's vision for future vehicle maintenance is very much in line with CAISR's vision, and during 2021 we ran an EU-funded pilot project together with them.

Researchers in CAISR have been active in the predictive maintenance field for roughly 15 years, initially almost exclusively in the heavy-duty vehicle sector together with our partner AB Volvo. We performed an analysis of where CAISR is placed in a national perspective in the field of data-driven predictive maintenance. This was done by extracting all scientific papers from Swedish universities in Web of Science over the years 2017-2021, with the keywords "anomaly detection", "maintenance", "diagnosis", "prognostics", and "remaining useful life", and then reading all abstracts and selecting the papers that dealt with data-driven predictive maintenance. This resulted in a total of 156 papers, where the affiliation-fractionalized citations and number of papers were computed for each university. The figure shows the results of the analysis: Luleå University of Technology is, by a wide margin, most productive in this field, and the Royal Institute of Technology (KTH) and Linköping University come second. CAISR (Halmstad) comes in fifth place. Only three universities, Luleå, Linköping, and Halmstad, work on heavy-duty vehicles. Furthermore, only CAISR and Linköping work with trucks and buses – Luleå works more with mining equipment and railways. From the scientific perspective, based on the analysis of the departments where the research is taking place, Halmstad is the only of those with a focus on the development of Machine Learning methods, i.e., an AI-oriented center.

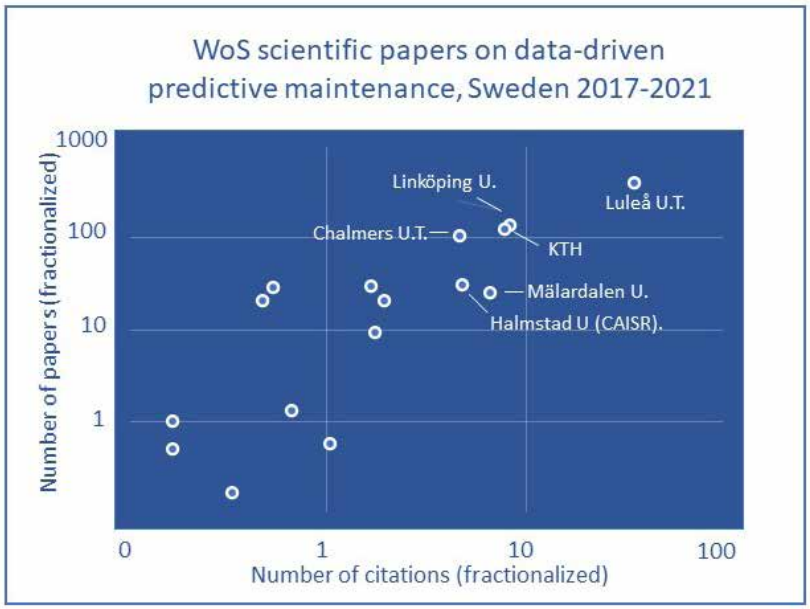


Figure 1: Positioning of Swedish universities in data-driven predictive maintenance. Note the logarithmic axes.

A somewhat surprising discovery was found in the acknowledgments for funding support; Chinese funding agencies are acknowledged equally often as Swedish funders (mentioned about 1/3 of the time). Thus, Chinese research funding is a significant contributor to predictive maintenance research done at or in collaboration with Swedish universities, mainly at Luleå, KTH, and Linköping. The Knowledge Foundation is the most often acknowledged Swedish funding organization, followed by Vinnova. All papers that acknowledge the Knowledge Foundation originate from either Mälardalen or Halmstad (CAISR).

Predictive Maintenance

Projects

The **CAISR+** project runs between 2020 and 2023 and is funded by the Knowledge Foundation, Halmstad University, and several industrial partners. The industrial partners are Volvo GTT, Volvo Truck Corporation, Volvo Bus Corporation, Volvo Group Connected Solutions, and Toyota Material Handling. The CAISR+ project includes the development of methods to describe the usage of machines, methods for predicting the remaining useful life of equipment, survivability modeling, and deployment issues.

In the **XPM** project, funded by the EU as part of the CHIST-ERA programme, we will (together with France, Poland and Portugal) develop predictive maintenance methods with built-in explanations. While machine learning models are typically black boxes, we will provide several different types of explanations (anything from visual analytics through prototypical examples to deductive argumentative systems) and demonstrate their usefulness in four selected case studies: electric vehicles, metro trains, steel plants and wind farms. In each case, we will show how the right explanations of AI decisions lead to improved results across several dimensions: identifying the component where the problem has occurred; understanding the severity and future consequences of detected deviations; choosing the optimal repair and maintenance plan based on different priorities; and understanding the reasons why the problem has occurred as a way to improve system design for the future. The project started in 2021 and will end in 2023.

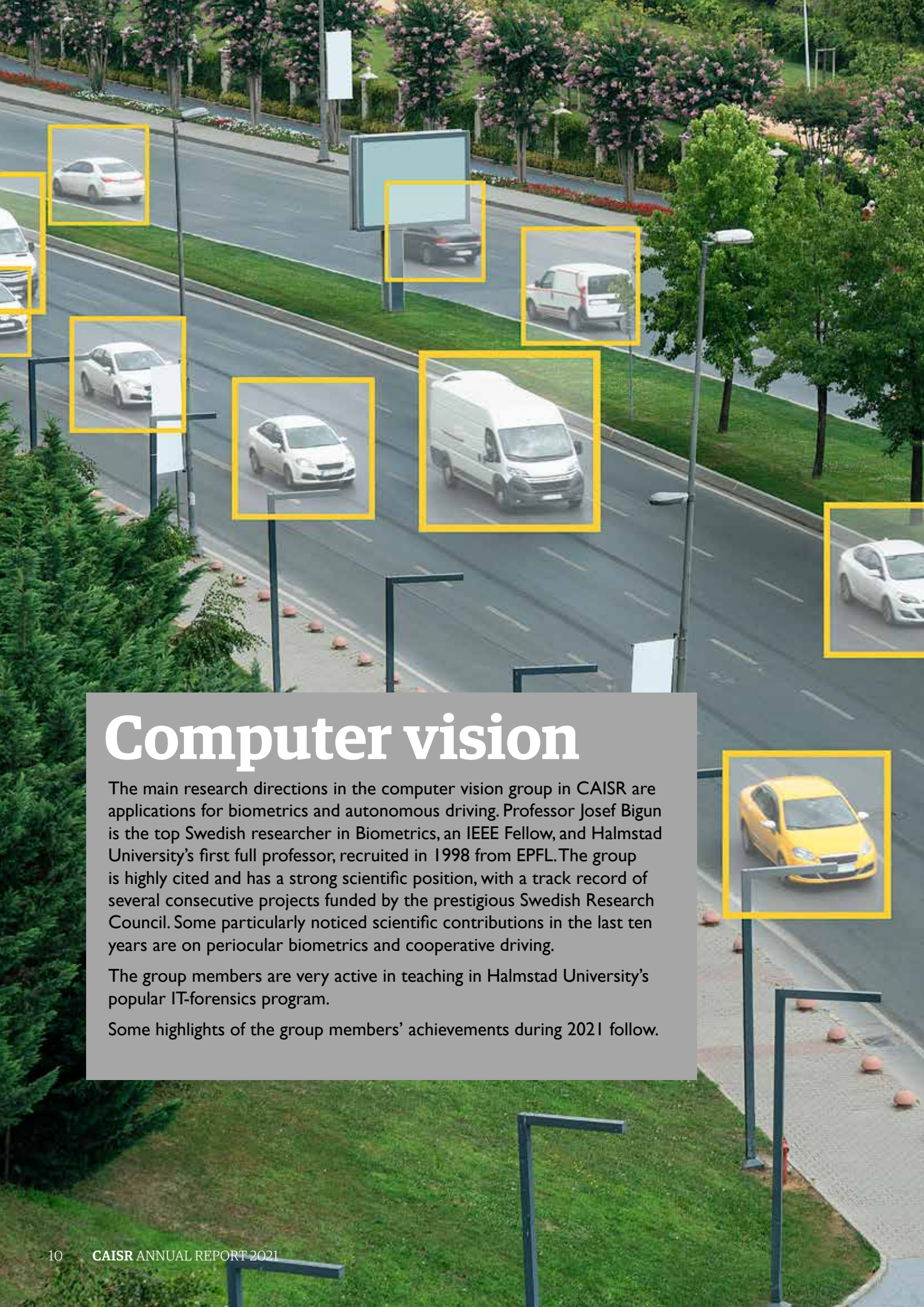
Battery Cortex was an EU-funded Eurostars project (in collaboration with Stratio Automotive from Portugal), running from November 2020 to December 2021, building an anomaly and fault detection platform for automated analysis of EV battery packs data, to identify battery condition and battery performance. This was done through predictive fault detection and early discovery of issues affecting the lifetime of battery packs and cells, as well as understanding the conditions affecting capacity and charging/discharging behaviour under different usages and environments. These new insights are invaluable for vehicle manufacturers, fleet operators & EV product/service providers.

We have several ongoing projects, and projects that recently ended in 2021, with different funders directed towards data-driven predictive maintenance.

The **EVE** project is a Vinnova funded project that runs 2019 to 2023 together with Volvo Bus Corporation. Electric vehicle (EV) batteries are expensive, and prolonging their life is crucial before electromobility becomes an economically viable alternative for diesel on a large scale. Homogeneous historical data on failures of electric driveline components are rare due to the fast changes in battery technology, and in EVE, transfer learning is used to build better models for battery health degradation. The resulting insight into the degradation of drive batteries has proved useful by several actors for optimizing the deployment, usage, and maintenance of these components.

In the **SeMI** project (running from 2016 to 2021) we developed a general framework and various methods to discover valuable knowledge autonomously, or with minimum supervision from human experts. The unique format with six industrial partners enabled the transfer of knowledge across domains and industries, which is a very valuable co-production output. The main objective of the project was the creation of group-based self-monitoring methods for industrial networks, heat pumps, and district heating domains. This was identified by our industrial partners as crucially important. The AI-based techniques based on analyzing available data were supplemented by taking into account expert feedback, through "joint human-machine learning".

We collaborate closely with **Alfa-Laval** through a strategic recruitment of a senior researcher, jointly funded by the Knowledge Foundation, Alfa-Laval, and Halmstad University. Alfa Laval's Industrial Internet of Things (IIoT) generates time series with several complexities, far from the capacity of state-of-the-art time series models. The IIoT series includes tens of contextual factors, such that a combination of these factors can affect the measurements. Current sophisticated models are unable to incorporate such hyper-contextuality. We work on methods to deal with these complexities, with a focus on interpretable and explainable models based on multi-linear (tensor) techniques. Tensor methods inherently can model multi-contextual data; however, adopting tensor methods for hyper-contextuality and other complexities is not trivial.



Computer vision

The main research directions in the computer vision group in CAISR are applications for biometrics and autonomous driving. Professor Josef Bigun is the top Swedish researcher in Biometrics, an IEEE Fellow, and Halmstad University's first full professor, recruited in 1998 from EPFL. The group is highly cited and has a strong scientific position, with a track record of several consecutive projects funded by the prestigious Swedish Research Council. Some particularly noticed scientific contributions in the last ten years are on periocular biometrics and cooperative driving.

The group members are very active in teaching in Halmstad University's popular IT-forensics program.

Some highlights of the group members' achievements during 2021 follow.

Best Master's Thesis Award 2021 of the Swedish AI Society. Fredrik Svanström, a former student at the Master's program in Embedded and Intelligent Systems, received the Best AI Master's Thesis Award from the Swedish AI Society, SAIS. The thesis is about the detection of unauthorized drones at for example airports. Fredrik Svanström designed and built an automatic drone detection system that utilizes machine learning and sensor fusion, which means that data from several different sources are combined. Besides the common video and audio sensors, the system also includes a thermal infrared camera and a receiver for aircraft transponder data. All collected data used to train and validate the system is published in an open database. Fredrik's supervisors during the thesis work were Cristofer Englund, Fernando Alonso-Fernandez, and Eren Erdal Aksoy.

Tiago Cortinhal received the "Best Student Paper Award" at the IJCAI 2021 AI4AD workshop on Artificial Intelligence for Autonomous Driving.

PhD student Tiago Cortinhal received the "Best Student Paper Award" at IJCAI 2021AI4AD on artificial intelligence for autonomous vehicles. "The award was really a happy surprise! It shows that my research is appreciated and the recognition gives me motivation to continue", says Tiago Cortinhal. The winning article "Semantics-aware Multi-modal Domain Translation: From LiDAR Point Clouds to Panoramic Color Images" is authored by Tiago Cortinhal, Eren Erdal Aksoy, and Fatih Kurnaz at Middle East Technical University. The article introduces a novel multi-modal domain translation framework, which can, for the first time, synthesize a panoramic color image from a given full 3D LiDAR point cloud by leveraging the underlying semantics of the perceived scene. More information is available here: https://www.youtube.com/watch?v=eV510t29TAc

Associate Professor Fernando Alonso-Fernandez invited expert in a research study on "Technology Foresight on Biometrics for the Future of Travel". The research study explores the impact of emerging biometric technologies on facilitating the border crossing at the EU external borders.

https://frontex.europa.eu/media-centre/news/news-release/new-research-study-technology-foresight-on-biometrics-for-the-future-of-travel-ugObkJ

Fernando Alonso-Fernandez

Professor Josef Bigun appointed distinguished lecturer of the IEEE biometrics council. The IEEE Biometrics Council has introduced the Distinguished Lecturers Program (DLP) to support education-related activities for the biometrics community. The purpose of DLP is to increase awareness about topics relevant to Biometrics by creating a pool of leading experts who are willing to speak in meetings hosted by IEEE Chapters and Sections. Prof. Bigun will join other world-recognized experts in the field such as Kevin Bowyer, Mark Nixon, Sharath Pankanti, and Venu Govindaraju.

Josef Bigun

Facial Analysis in the Era of Mobile Devices and Face Masks

The Swedish Research Council granted 3,6 million SEK over three years for a new research project "Facial Analysis in the Era of Mobile Devices and Face Masks". The project goal is to provide reliable methods for face recognition when wearing a mask by analyzing the facial area surrounding the eyes. During the Covid-19 pandemic, the use of face masks increased greatly. This complicates visual face recognition, for example via smartphones. Another goal in the research project is to estimate so-called soft biometric indicators using the ocular region of the face. Examples of soft biometric indicators are gender, age, and ethnicity. These indicators can be used in a range of different applications, for example, age-dependent access, location of specific individuals in video streams, or child pornography detection.

Summary

Occlusion may appear in unconstrained environments, but it is now an issue even in controlled setups due to mandatory masks. Solutions must be also capable to operate on devices with hardware restrictions, a necessity if they are to be employed on devices such as smartphones or assistive robots in home or healthcare environments.

One project goal is to provide reliable methods to detect the face. Impressive performance is shown by deep learning solutions, but they use heavy Convolutional Neural Networks (CNN) of hundreds of megabytes, infeasible in mobiles or robots. Also, most are trained to detect the entire face, and not specifically to cope with occlusion. The researchers will use complex symmetry filters as attention mechanism to facilitate detection, coupled with CNN's with complex coefficients, given the success of such filters as a stand-alone method to detect face landmarks in controlled conditions.

Another goal is the estimation of soft biometrics indicators (gender, age, ethnicity). These indicators are easier to extract in unconstrained scenarios and can complement a non-conclusive result of a hard modality (iris or face). They have other applications as well, such as customized advertising, enhanced HCI, age-dependent access, location of specific individuals in video streams, or child pornography detection. However, the use of ocular images for such task and with light CNNs are unexplored avenues.

Project period: 2022 to 2025

Financier: Swedish Research Council

Project team at Halmstad University:

- Fernando Alonso-Fernandez (project leader)
- Josef Bigun
- Kevin Hernandez-Diaz

Swedish Research Council

Industrial Research School EISIGS

PRIME – Predictive Intelligent Maintenance Enabler

The goal of this project is predicting failures in a fleet of sterilizers deployed in hospitals all over the world.

The characteristics of this problem are general to the field of predictive maintenance for different application fields. Companies are interested in predictive maintenance to reduce the down time of their machines. In general the list of critical components, whose unexpected breakdowns would result in stopping the machine, is long. Therefore, the scope of a predictive maintenance system should be predicting failures in a big number of different components.

For several years, systems such as cars, sterilizers or industrial equipment have been equipped with a significant amount of sensors. Which signals to record is in general not decided based on the predictive maintenance needs, but on the requirements of security or controllers among other reasons. The sensors mounted usually don't describe the particular behavior of the components of interest, but measure physical quantities that can be influenced by the different behavior of several components.

Predicting what component will fail when requires historic data about the operation of the machines, but also needs to be linked to the occurrence of failures, so that we can label the recorded data. In general, companies have access and store data coming from their machines, but don't necessary have access to the whole history of repairs. The owner of the machines can decide whether to perform maintenance and repairs with the official service or any other unofficial service. The main research goal of this project is to build a framework that allows predicting all type of failures that can happen in a machine.

Pablo del Moral is an industrial doctoral student within the Embedded and Intelligent Systems Industrial Graduate School (EISIGS) at Halmstad University. He's doing his research in close cooperation with Getinge AB.

Embedded and Intelligent Systems Industrial Graduate School (EISIGS)

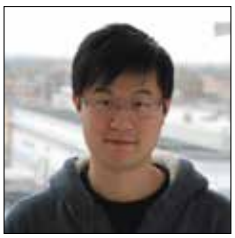
EISIGS is a graduate school with high industrial relevance focusing on cooperating embedded systems for intelligent applications, with a special touch of innovation aspects.

The goal of the industrial graduate school, named Embedded and Intelligent Systems Industrial Graduate School (EISIGS), is to provide the right environment for producing qualified, independent researchers (PhDs) that understand, advance, and champion embedded and intelligent systems research. EISIGS is funded by the Knowledge Foundation complemented by funding from industrial partners as well as from Halmstad University.

Former EISIGS-CAISR PhD students

Iulian Carpatorea
Industrial doctoral student at Volvo GTT. Licentiate exam 2017. Since 2018 Data Scientist at Volvo Group.

Hassan Nemati
Industrial doctoral student at Halmstad Energi och Miljö AB. PhD graduation 2019. Since 2020 Machine Learning Specialisr at Ortoma AB.



Yuantao Fan
Industrial doctoral student at Volvo Group Trucks Technology and Volvo Bus Corporation. PhD graduation 2020. Since 2020 Postdoctoral student at Halmstad University (CAISR).

Industrial Research School
Smart Industry Sweden

Smart Industry Sweden

Smart Industry Sweden is an industrial graduate school and an important initiative in meeting Swedish industry's needs for research excellence, as well as preparing their employees for tomorrow's specialist positions. It will create valuable networks for the participating companies – both with academia and between the companies. Working together, we can make ourselves ready to strengthen the competitiveness and innovativeness of Swedish industry. The Research school is funded by the Knowledge Foundation and is carried trough by

Halmstad University, Jönköping University, Mid Sweden University, University of Skövde and University West

Anonymization with deep learning

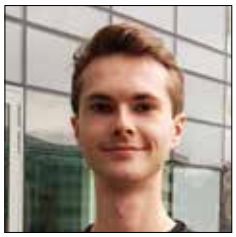
The research focuses on anonymization of data without destroying information and validation of these methods. By exploring the capabilities of recent advances for generative models for removing/replacing identity information while maintaining attribute information. The research has a strong focus on facial and traffic related data, in particular to be able to store large amount of data for training deep learning object or road user detection and driver monitoring systems.

Felix Rosberg

PhD Project in cooperation with Berge.

Explainable AI

The research aims at building knowledge around explainable and trustworthy AI. The project's hypothesis is that an increased explainability provides the foundation for greater trustworthiness of AI systems. Expainability, can be understood as both an ethical principal that explains certain technical requirements, such as accountability, and a technical feature itself. For an AI system to be explainable is for it to have the capability of displaying its decision-making processes. The research revolves around what information is needed from an AI system for users to understand its decisions and how can the system be built to provide for a balance between trustworthiness and trust from users.



Martin Torstensson

PhD Project in cooperation with RISE.

Explainable AI

Compared to today's vehicles, future heavy autonomous vehicles will need significantly improved functions to guarantee safe, economical, efficient, energy efficient and reliable operation. Such functions are deemed to need to be implemented mainly on board or in nodes near the vehicle (edge). Volvo will continue to be a leading provider of transport solutions in the future. This project aims to develop concepts, methods and technologies that meet future needs, which are based on AI / machine learning and with application primarily in operational reliability. The development will be conducted both with experiments on vehicles and through simulation, based on data that describe technical (physical, logical) operational parameters of a component or a subsystem, such as time series of pressure, temperature, rpm, voltage, etc. during operation. The initial stage focuses on techniques to detect anomalies in individual vehicle operation, specifically by using autoencoders, as well as in a fleet of vehicles, specifically based on federated learning.

Magnus Löwenadler

PhD Project in cooperation with Volvo GTT

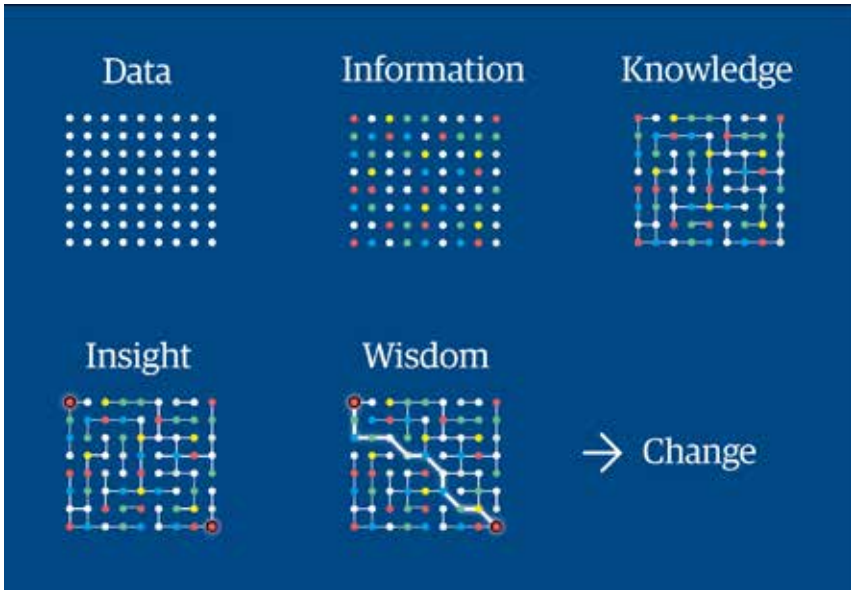
Information Driven Care

High quality healthcare for everyone is a central component in a modern society. Providing this is a matter of continuous improvement under increasing challenges. As living conditions improve, the population grows older, chronic and autoimmune diseases increase, and the expectations on the healthcare system increase. How can we meet the expectations and achieve our visions without drowning in the costs? A good use of the opportunities that follow from digitalization is one way, and Information Driven Care is about taking advantage of all the huge amounts of health-related data that are collected every day. This data can, with the help of AI methods, provide better insights about patient groups to predict the care and resources needed. There is an extensive research collaboration between CAISR and Region Halland within this area, a collaboration that also includes industrial partners.

Halmstad University and CAISR are investing considerable amounts into building up Information Driven Care as an excellent area for research, education, and collaboration. A new Knowledge Foundation funded profile, CAISR-Health, was started in 2021, corresponding to a research investment of well over SEK 100 million over 8 years if the partners' in-kind contributions are included. Several externally funded research projects are ongoing, with funding from the Swedish Research Council, from Vinnova (Sweden's Innovation Agency), and the Knowledge Foundation. The university healthcare innovation center, Leap for Life, also focuses on information driven care. A new vice chancellor supported research program is planned for 2022, meaning an additional Halmstad University strategic support of about SEK 100 million over 10 years. In 2021, the university started an ambitious data center together with Region Halland. Halmstad University. Taken together, these efforts really show how seriously the university and Region Halland are working toward being the competence hub for Information Driven Care.

"There are many initiatives in Sweden with the goal to develop healthcare by using artificial intelligence. What is notable in Halland is that we are working with real world data in sharp research projects where we collaborate across organisations and disciplines", says Markus Lingman, Medical Doctor and Strategist on the Halland Hospital board and Adjunct Professor of Medicine at Halmstad University.

"The collaboration between Region Halland and Halmstad University has broken new ground – we are already contributing to the necessary shift of our healthcare system to become more information-driven. It is time to move up the cognitive pyramid! Let the computers do what they are best at, and humans what we are best at", says Markus Lingman.



Data can become knowledge and lead to change.

Data from current patients can prevent future diseases

Information-driven care is a concept where artificial intelligence (AI), specifically machine learning, is applied to data that has been collected within healthcare organisations, and also used to achieve real improvements in healthcare. The data can be both clinical data and resource related data. Machine learning algorithms can find patterns and draw conclusions from large amounts of data and predict certain outcomes. This information can be used by clinicians to give their patients the best possible care and to enable early disease detection and prevention. The management of healthcare organisations can also use these prediction models to save resources without compromising the quality of care for the patients. To achieve real results, innovations, it is necessary to understand not only the challenges related to data and medicine, but also in organization and improvement processes. The Information Driven Care initiative therefore includes data scientists, economists, healthcare professionals and researchers specializing in improvement and implementation science in the healthcare sector.

Halmstad University and Region Halland have collaborated in research around data science and healthcare for the past decade. All research projects that handle health data are carried out within an approved legal framework.

Health Data Centre

The Health Data Center (HDC) was formed in the autumn of 2021. HDC is an industrial research center that connects AI and machine learning scientists with health data. The focus is to develop the area of information-driven care for improved healthcare delivery. HDC builds on a collaboration between Halmstad University, Region Halland and the healthcare technology company Hallandia V.

Halmstad University provides research competence (AI, data analytics, health innovation etc)

Region Halland provides health data upon agreement and clinical expertise

Hallandia V provides the data platform SHAARPEC and project & data management

The Health Data Centre:

- enables collaboration between experts across disciplines and organisations. Researchers – health organisations – companies.
- facilitates and provides a technical platform to retrieve, store and analyse health data in a safe environment.
- conducts research projects where AI is applied to health data for deeper insights to be used by healthcare organisations and companies.

Two particular directions in the collaboration during 2022 is to test and develop methods for generating synthetic data – data that can be shared more openly – and methods for privacy preserving federated learning. The latter would open up for nationwide analysis on large volumes and electronic health records.

Leap for Life

Leap for Life is Halland's innovation centre within information driven care. The centre is co-owned by Region Halland, Halmstad University and all municipalities in Halland. Leap for Life gathers the region, municipalities, academia and the business sector to support the development of a more information-driven and personalised healthcare and self-care.

Previously, Leap for Life was called the Centre for Health Technology Halland (HCH). On September 10, 2020, HCH changed its name and focus to Leap for Life

CAISR Health

CAISR Health is a cross disciplinary research profile at Halmstad University, funded by the Knowledge Foundation. The research profile started in July 2021 and focuses on information driven care and how this is implemented in healthcare in the best possible way. Within CAISR Health, researchers at the University collaborate with Region Halland, Brigham and Women's Hospital in Boston and the companies Cambio, Capio Sverige, Hallandia V, Mölnlycke, Novartis, InterSystems and Visiba Care.

Top-level research about how information driven care is best implemented

CAISR Health focuses on using the data that is generated through the entire healthcare process to enable qualified decision-making in healthcare.

"Data is generated every time a person comes into contact with healthcare, when they pick up medicine, or when they are in what we call 'intelligent environments'. Data can be refined into knowledge to, for example, better decide when a patient is ready to be discharged, what treatment an individual can most benefit from and make sure that the treatment is doing what it should", says Mattias Ohlsson, project manager for CAISR Health and Professor of Information Technology at Halmstad University and Lund University.

Mattias Ohlsson,

The access to health data is possible through Region Halland and is complemented by the Health Data Centre which the University and Region Halland have invested in. The goal is to establish a top-level research profile about how information driven care is best developed, implemented and used, about privacy preserving distributed data mining and machine learning for healthcare data.

Decision aid for heart failure and mental illness

Within the research profile CAISR Health, several different projects will be conducted – all with the aim of developing and implementing information driven care.

"In our research, we combine data from healthcare with data from, for example, smartwatches and sensors. Using information driven care, it is possible to act more proactive and health preventative.

One of our projects aims to predict which young adults risk being affected by mental illness in order to be able to offer these individuals support at an early stage. Another project focuses on wound care while a third project offers decision aid for doctors when they are discharging heart failure patients", says Kobra (Farzaneh) Etminani, deputy project manager of CAISR Health and Assistant Professor at Halmstad University.

Farzaneh Etminani

CAISR Health has three subject areas:

- Patient trajectories and XAI
- Healthcare transformation
- Information driven participatory care

More information:
www.hh.se/caisrhealth

National Research School in Health Innovation

A new research school in Health Innovation has been granted funds from the Knowledge Foundation. The graduate school is coordinated by Halmstad University and is a collaboration between seven Swedish universities, the business community, regions, and municipalities. The goal is to create a successful innovation ecosystem that can benefit from, and promote, digitalisation in healthcare.

The research school will play a central role in establishing an innovation ecosystem that brings together partners and concretizes ideas in the form of doctoral projects. It will be a collaborative project where all participating organizations will benefit from the experience, competence, and expertise that each partner provides. It will also lead to the partners together being able to develop innovation and new knowledge about societal challenges that should be handled in collaboration between several actors.

The research school is a collaborative project between Halmstad University, Blekinge Institute of Technology, Jönköping University, Mid Sweden University, Mälardalen University, Skövde University, University West and business, regions, and municipalities around Sweden. The graduate school will start in March 2022 and the doctoral students will be accepted in the autumn of the same year, with a second round of admissions planned for 2024.

The work of developing the network between the higher education institutions and other partners and producing the application for funding for the research school has been conducted under the leadership of Halmstad University's focus area Health Innovation.

New handbook from experts in information-driven care

The book A Handbook for Information-Driven Care - Insights from the Inside was recently released, with a collection of unique knowledge from some professionals in the field. The handbook tells about the work that is going on in information-driven care, what lessons have been learned and how it actually goes, through experiences from reality.

The book deals with everything from law to technical infrastructure and is based on experiences from several people in the field. The book is written to be used as a basis for work in information-driven care, with actual events that reflect reality as a basis, and to evoke thoughts about how care works with needs in relation to resources. The main author is Markus Lingman, chief physician and strategist at Halland Hospital Halmstad. He describes in the book what information-driven care really means.

"The approach in information-driven care is to see the world or at least the care world as it is and not as one wishes it to be. A cornerstone is therefore to take advantage of all the data that already exists in the healthcare system and which is generated in huge amounts every day. The difficulty is that they are often divided into different formats and in different storage locations in the care system and thus prevent a holistic view. "

The handbook provides an insight into the work with information-driven care and goes into depth in several of the chapters. The book describes, among other things, what information and data really are, how a database has been built up, the importance of planned healthcare finances and how the legal aspects play a role. Something that is also mentioned in the book is how AI can be used in health care. Mattias Ohlsson, professor of information technology, writes in the chapter Artificial Intelligence about the role AI can play.

Given the rapid development, many have seen opportunities to make use of AI in healthcare. The hope is that AI can help make future healthcare more efficient and secure and help meet the challenges of an aging population, increasingly limited resources and the difficulty of finding qualified staff. ”

Petra Svedberg, professor of nursing, and Jens Nygren, professor of health innovation, also write in the book about using AI in health care, and the importance of implementation due to the challenges that exist.

However, the implementation of a new technology is often a critical process between an organizational decision and the introduction of the technology and the professionals' willingness and ability to use the technology in their daily work. Barriers to implementation can arise at several levels of care, among patients among healthcare staff within the organization and at policy level. ”

Several co-authors

The Halland region has a major role in the development of information-driven care and several of the authors of the handbook have their affiliation with the region. Among others, Martin Engström, director of health and medical care at Region Halland, wrote the chapter Management perspective and Ola Lövenvald, Data scientist and data warehouse architect at Region Halland, wrote the chapter Data platform.

Magnus Clarin, Head of Academy at the Academy of Information Technology at Halmstad University, has written the chapter Triple Helix on the collaboration between the University, the Region, the Halland municipalities and the business community through Leap for Life.

Some of the authors: Markus Lingman, Chief physician, adj professor and part of the hospital management at Halland Hospital, appointed AI-Swede of the Year 2020, Mattias Ohlsson Professor in Information Technology and project manager of CAISR Health and Petra Svedberg, Professor in Nursing and deputy project manager of CAISR Health

Education

One of the goals we set up for CAISR in the start (now ten years ago) was to systematically grow the education volume, on Bachelor level, on Master level, and towards professionals. A good base of education on all levels up to PhD education is a prerequisite for a thriving and stable university research center; it is the fundament for recruiting staff, for connecting research with education, and a key argument for the university management to invest money into it.

We have worked with increasing both education volume and quality. The growth in volume has been very strong the last two years, especially in the form of an increased offering towards professionals with our Expert Competence program (MAISTR), and two specific covid-19 related efforts (DIGIBUS and RELIFE), all funded by the Knowledge Foundation. This is illustrated in the figure below, which shows the number of full time equivalent (FTEs) students in IT on advanced level in courses directed towards professionals. Many of them studied courses related to AI. The number grew from zero (in 2017 and 2018) to almost 45 in 2021. Since these are FTEs and a course is typically 1/12-1/8 of a full year's education, this corresponds to about 400 individuals.

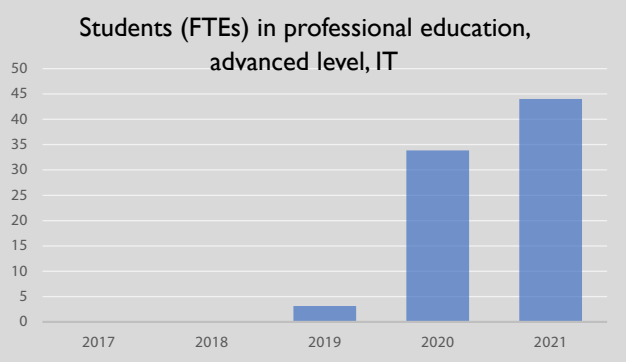


Figure 1: The increase in professionals following courses on advanced level in IT at Halmstad University.

Some indicators of quality in the education are the ratio of passed thesis projects to non-finished thesis projects and how many thesis projects that lead to scientific publications. Another indicator of quality is if theses are awarded for quality by external organizations, and this is described on the following pages. The figure below shows both the increase in number of Master theses supervised by CAISR staff and the ratio of theses that finish. The pass ratio is increasing, and this can possibly be attributed to that we now allocate more than one supervisor to each thesis project. Over the period 2017-2021 we have supervised 135 Master theses, of which 72 have finished. Of the 72 finished, at least 21 (29%) have led to a scientific publication. Three are still in review so the number will probably grow.

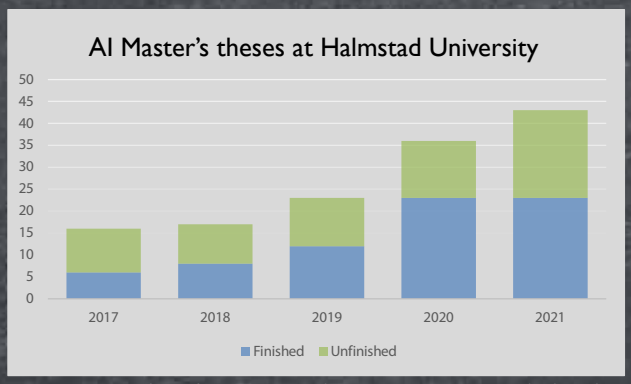


Figure 2: Number of AI Master's theses 2017-2021 Finished and unfinished

CAISR researchers/teachers are involved in several programs at Halmstad University:

Basic level (3 year):

- Bachelor of Science and Engineering – Computer Science and Engineering
- Bachelor in Digital Design and Innovation
- Bachelor of Science and Engineering – Electrical Engineering
- Bachelor in IT Forensics and Information Security
- Bachelor of Science and Engineering – Mechatronics Engineering
- Bachelor in Applied Artificial Intelligence (starts 2022)

Basic and advanced level (5 year):

- Master of Science and Engineering – Computer Science and Engineering
- Master of Science and Engineering – Intelligent Systems

Advanced level (2 year):

- Master's program in Embedded and Intelligent Systems
- Master's program in Information Technology
- Master's program in Digital Service Innovation
- Master's program in Network Forensics

In addition to these, we also give the Master program in AI and Service Design (MAISTR) for professionals with a large offering of shorter courses that are given online. The MAISTR program includes a total of 26 courses where each course is 3, 4 or 5 credits. The students can choose to study the entire program or individual courses. The program is flexible and can be followed by people with ongoing professional careers. MAISTR combines courses on AI, human-centered design and innovation management.

The MAISTR program is developed and offered in collaboration between Halmstad University, University of Skövde, Blekinge Institute of Technology (BTH) and the Swedish research institute RISE. The course offering and the course contents are developed in collaboration/dialogue with industry people.

A new Bachelor's degree: "Applied Artificial Intelligence (AAI)"

During 2021 we developed a new Bachelor's degree program for Halmstad University with *"Data Science"* as the main field of study. It will start in the fall of 2022, and with a degree from the *"Applied Artificial Intelligence"* program, students will have learned to develop and use data science tools to find solutions to societal challenges in, for example, business, healthcare, and energy supply. The program connects to the United Nations' goals for sustainable development (Agenda 2030) and teaches students to use AI ethically, safely, and sustainably. It also turns students into data scientists that combine skills and knowledge from different subject areas.

The program offers courses in data science, often focusing on ethical, human, and social aspects. It includes courses related to:

- Programming for Data Science.
- Data management and analysis (e.g., Introduction to Data Science, Databases, Principles and Techniques for Data Science)
- Design (e.g., Human-centered Design for AI, Communication for Data Science).
- Ethics and society (e.g., Ethics and Human Contexts, AI and Sustainable Development, AI and Society).
- Mathematics (e.g., Linear Algebra, Statistics, Mathematics for Machine Learning).
- Machine Learning (e.g., Applied Machine Learning, Neural Networks, Computer Vision with Deep Learning, Natural Language Processing).

In addition, to apply their acquired knowledge and skills, students are required to choose an area of specialization (among Healthcare, Energy engineering, or Business development) and take three domain-specifie courses within the selected area. The program is developed and offered in cooperation between all four schools at Halmstad University. The teachers in the program are active researchers involved in applied research in close collaborations with industry and the public sector, and many of them have international academic backgrounds. The program will mostly be given in English.

Mohamed-Rafik Bouguelia Program Director for the new Applied Artificial Inetelligence program, and Verónica Gaspes, one of the program's creators.

Awarded students

Our Bachelor and Master students often receive external recognition for their work. We list here results for the last five years, to illustrate our students' skills. As the lists show, we have many reasons to be proud of our students.

Sparbanksstiftelsen Kronan

The Sparbanksstiftelsen Kronan Foundation annually awards stipends to thesis students at the three universities Blekinge Institute of Technology, Linné University, and Halmstad University. The Foundation's criteria are that the thesis should show high academic level, originality, relevance, and business potential. Over the period 2017-2021, the Foundation awarded 41 stipends to Halmstad University student theses, of which ten (24%) were supervised by CAISR staff (see Table). This is a high fraction, given that approximately 800 thesis projects are finished at Halmstad University each year and CAISR staff supervise only 30-40 of these (4-5%).

Year	Student(s)	Thesis title	Edu. Program	Supervisor(s)	Stipend
2017	Oskar Svensson and Simon Thelin	Indirect Tire Monitoring System – Machine Learning Approach	Computer Science and Engineering (Bachelor)	Stefan Byttner & Yuantao Fan	50 000 SEK
	Viktor Austli and Elin Hemborg	Standardization of Bug Validation	IT-forensics and Information Security (Bachelor)	Eric Järpe	25 000 SEK
2018	Jacob Harsten and Dawid Ejdeholm	Detection of Common Environmental Interferences in Front of a Camera Lens	Computer Science and Engineering (Bachelor)	Josef Bigun	50 000 SEK
	Fredrik Nilsson	Automated Pulsation Rig with Surveillance and Logging of Measurement Data	Mechatronics (Bachelor)	Stefan Byttner	25 000 SEK
	Erik Karlsson	Automated Aeroponic Farming	Electrical Engineering (Bachelor)	Eren Erdal Aksoy & Cristofer Englund	25 000 SEK
2019	Olof Magnusson and Mats Hurtig	Post-Quantum Public Key Cryptography for the Internet of Things	Network Forensics (Master)	Eric Järpe	25 000 SEK
2020	Martin Asplund and Robin Landin	Steering of the Second Front Axle in Volvo Trucks	Mechatronics (Bachelor)	Pablo del Moral	50 000 SEK
	Dawid Ejdeholm and Jacob Harsten	Manipulation Action Recognition and Reconstruction using a Deep Scene Graph Network	Computer Science and Engineering (Master)	Eren Erdal Aksoy	25 000 SEK
2021	Felix Nilsson	Joint Human-Machine Exploration of Industrial Time Series Using the Matrix Profile	Computer Science and Engineering (Master)	Mohamed-Rafik Bouguelia & Thorsteinn Rögnvaldsson	25 000 SEK
	Karl-Johan Djervbrant and Andreas Häggström	Capacitated Multi Depot Green Vehicle Routing for Transporting End-of-Life Electrical Waste	Computer Science and Engineering (Master)	Jennifer David & Thorsteinn Rögnvaldsson	25 000 SEK

Table 1: Recipients among our students of Sparbanksstiftelsen Kronan stipends 2017-2021

The Swedish AI Society

Since 2000, the Swedish AI Society has an annual award for the best Master thesis oriented towards AI. Their criteria are novelty, thoroughness, readability, scientific value and relevance to AI, both with respect to research and to potential applications. During 2017-2021, Halmstad students have been awarded this twice (see table below).

Year	Student	Thesis title	Edu. Program	Supervisor(s)
2017	Thomas Rosenstatter	Modelling the Level of Trust in a Cooperative Automated Vehicle Control System	Master Embedded and Intelligens Systems	Cristofer Englund
2020	Fredrik Svanström	Drone Detection and Classification using Machine Learning and Sensor Fusion	Computer Science and Engineering (Master)	Cristofer Englund Fernando Alonso-Fernandez Eren Erdal Aksoy

Table 2: Recipients among our students of the Swedish AI Society's award for best AI Master thesis.

The Wiman prize

Since 2000, the Swedish Association of Graduate Engineers (Sveriges ingenjörer), awards the national Wiman prize; a prestigious annual award for the best Swedish thesis project for Bachelor of Science in Engineering. The criteria for the award are engineering skills, scientific level, creativity, knowledge integration, usability, and disposition. One of our students, Erik Karlsson who is mentioned in the list over Kronan stipend awards, was awarded the Wiman prize in 2019. This was the first time a student from Halmstad University received the Wiman prize.

Various competitions

Fortunately, and very positively, our students often say yes to the challenge to participate in different international competitions. The table below shows some competitions where our students have done well in the past five years.

Year	Student(s)	Competition	Program(s)	CAISR support
2017	Sowmya Narasimman and Daniel Westerlund	International Robot Art Competition (6th place)	Master Embedded and Intelligent Systems	Martin Cooney
2017	Camilla Vaske	Best session talk, 2017 3rd Int'l Conference on Frontiers of Signal Processing (ICFSP), IEEE (paper based on B.Sc. thesis)	IT-forensics and Information Security	Eric Järpe
2018	Patrick Karlsson, Emil Johansson, Marcus Rodén, Jacob Carlsén, Anders Bogga, and Emil Andersson	The 2018 Cyber-Physical Systems Challenge (2nd place)	Computer Systems Engineering (Bachelor), Electrical Engineering (Bachelor), Mechatronics Engineering (Bachelor)	Jennifer David
2019	Moa Almarsson and Matilda Sander	Halmstad Municipality award for best B.Sc. thesis directed towards disabilities.	Digital Design & Innovation (Bachelor)	Susanne Lindberg
2021	Vivek Uddagiri	IJCAI 2021 Human Application Challenge (HAC): Robot Magic and Music Competition (2nd place)	Master Embedded and Intelligent Systems	Martin Cooney

Table 3: International competitions where our students have done well 2017-2021

Emil Andersson, Emil Johansson, Marcus Rodén, Jakob Carlsén, Patrick Karlsson and Anders Bogga attended the 2018 Cyber-Physical Systems Challenge in Arizona.

Complementary competencies

As a part of their degree project, six students from Halmstad University participated in an international competition with an advanced self-flying drone. The Swedish team was the only one outside the US that managed to qualify for the final in Arizona, where they took an honorable second place. The students' complementary competencies were required to create the drone. The data guys were responsible for the drone being able to search, find and land by analyzing images from the drone's camera. The mechatronics students were responsible for the design and construction of the drone and its grip claw, while sensors and navigation have been developed by the two electrical engineers.

Universities must get ready for new types of teaching

From traditional teaching to lifelong learning – everyone knows that we need to make the shift. But how?

Pontus Wärnestål often grapples with that question.

– All universities are designed for young people spending four years in academia, then going out into the world. But this doesn't match the needs of society anymore. We must find the best ways to continue educating people parallel to their work.

Wärnestål is an associate professor in informatics, researching people-centered AI and digital service innovation. He is a design director at the company inUse and author of the book *Design of AI-powered services.* At Halmstad University he works with the programs *AI.m, MAISTR* and *Digital design and innovation*, and he was a project manager at the founding of DLC, the University's Digital Laboratory Center, where digital technologies for teaching and research are developed and tested.

In 2019, Wärnestål created a university course in the shape of twelve podcast episodes, *Human-Centered Machine Learning.*

– Lots of people use podcasts to learn things while commuting or exercising. I realized that this is a great opportunity for lifelong learning.

On podcast platforms the specialty programs are seldom quality-assured, and the podcasts issued by academia are almost all produced by the communication departments. Wärnestål figured there was room for something new; a real university course. With financing from Vinnova he and his colleagues set about creating such a course.

– We did much better than I had dared to expect and got over 6000 listeners! Compared to a regular MOOC, that is a lot.

He sees an untapped potential in podcasts and pre-recorded lectures.

– The classical monologue lecture in a classroom is a waste of resources, I'd say. It forces students to become passive recipients, instead of active learners. At basic level, every teacher says almost literally the same thing as fifty others. It would be better with basic online courses for everyone, then branching out on site.

Automation only half the point

Wärnestål has always enjoyed teaching and has received the Excellent Teacher Pedagogical Merit at Halmstad University. He believes that many more people need to be educated on AI and design. A common misconception, he says, is that AI primarily is useful for automating existing workflows.

– Anyone who believes that, misses at least half the point. You risk trying to automatize people out of the equation. This simply passivates the employees, they lose skills and knowledge, and quality goes down. We must see AI as a tool to strengthen people's abilities, not a way to replace them.

He exemplifies with an AI-enhanced camera developed by a tech company, which hired Wärnestål and some colleagues to analyze a possible implementation. The camera was meant to visualize basic health data in the emergency room, saving time for the nurses. Instead, the analysis showed that the basic idea was wrong. The simple fact that a nurse put a hand on the patient's shoulder provided important information which the camera could not detect. It also comforted the patient. Rather, he medical staff and the camera needed to work together, measuring different things and increasing the nurses' skills and competence.

Pontus Wärnestål

Adjusting to the need for life-long learning

There used to be a dystopic vision of super-intelligent AI taking over the world. This is not something that concerns Wärnestål. If anything, he believes "stupid" AI might pose a risk.

– Machine learning is always based on historical data, biased data, and machine learning reinforces bias. If we are to recruit a new manager and enter CVs from previous managers, the model will not tell us whether an applicant is a good manager. It will only say if an applicant is *similar* to previous managers. People are not very aware of this today.

Wärnestål wants to continue exploring how higher education can adapt, to help with life-long learning.

– People change career and we must be ready to support that. We need to develop new pedagogical approaches, platforms and methods. Maybe completely re-shape our model – not reside only on campus but instead work part-time as researchers, part-time as learning coaches in workplaces. But today, we are still very conventional.

Unique design perspective in Halmstad's AI education

Stefan Byttner got his first computer already before he started school. It had a tiny light that flashed red when the computer processed something, and he heard the adults saying "look, the computer is thinking".

– That fascinated me. Can a machine think? What does that really mean?

He did not get an answer to his question at the time, but the curiosity remained. When as a master's student he began to understand some of the mathematics behind AI, he felt that this was a field he really wanted to explore.

Byttner has been instrumental in starting the research area related to machine learning for remote diagnostics in vehicles and has worked with applying such concepts to heat pumps and district heating substations. More recently he has been part of a project developing algorithms to analyze PET scans, as a decision support for doctors diagnosing dementia.

Byttner is also head of the Department for intelligent systems and digital design at the School of Information technology at Halmstad University, project manager of the *MAISTR* program, and one of the managers in the *AI.m* program.

– When a job is a little difficult – that's when I find it fun and rewarding. Whether it's research or teaching matters less, as long as it feels new, and I believe I can make a positive change.

Tech, service and business design perspective

MAISTR is a so-called expert competence program, a concept initiated and financed by the Knowledge Foundation to support academia in developing new methods for lifelong learning.

– Universities are normally good at creating education for young people, who need to be on campus to be sort of fostered into the environment. Active professionals lack that need for physical presence, and instead want a more flexible education format. But so far, universities have not been very good at offering this opportunity.

MAISTR – a collaboration with the University of Skövde, RISE and Blekinge Institute of Technology – offers independent courses at advanced level, focusing on AI and service innovation. Right now, a complete program is being developed, after a two-year pilot project which received very positive reviews. Among other things, the industrial partner Volvo view MAISTR as "unique in Sweden".

Stefan Byttner

– If you want to provide a good, holistic perspective on AI, you need three things: the technology, the service design and the business perspective. Many offer the first and third, but we are the only university in Sweden with a broad and deep offering of courses in service design based on AI, Byttner says.

He is not sure why that is, but assumes that one reason is that technologists often think first of technical solutions, secondly of business – but lack even basic knowledge of design.

– Had I been head of a computer science department at another university, I might very well not have had any designers at all on my staff. Here in Halmstad I am the manager of AI people as well as design people. We have, for example, a professor of design ethnography in my department – very humanistic, indeed.

Interdisciplinary thinking permeates the work around Byttner, even more so after the introduction of programs such as MAISTR and AI.m, which have increased collaboration across subject boundaries.

AI.m benefits researchers as well as companies

In AI.m, Byttner was one of the initiators. He was convinced that Halmstad University ought to collaborate more with the region's innovation arenas and science parks. While some types of companies found it natural to connect with the University, there were others who did not even know that Halmstad has a strong research environment in AI. Byttner contacted the incubator High Five, and together with them and the colleague Pontus Wärnestål founded AI.m with funding from the European Regional Development Fund. Each semester, the program accepts five companies into the incubator, giving them a chance to work together with researchers as well as business and service developers.

– We start out looking specifically at their business model and their data, to see what new opportunities could be created for them using machine learning.

This is followed by a workshop in service design and development of a prototype for the company. AI.m also offers help with competence development, and support if the company wants to apply for public funding to move along with the idea.

– This is a process benefitting both companies and researchers. For our doctoral students, it paves a way into the companies and creates a relationship with them. That has been very valuable, not least for our international staff.

AI could help making education better in the future

Martin Cooney was born in Canada, to an Austrian mother and a father working as a diplomat. This meant a fair bit of moving around. As a child, Cooney liked fantasy novels, and programming with his older brother on an Apple IIGS signed by Wozniak.

At university he wanted to study robotics but there was no robotics program at the nearest university, so he chose computer science with a focus on AI. Robots remained a pastime for years, until he decided to pursue a master's degree in Japan, followed by a PhD working in a well-known lab which developed androids.

– I had seen on their website that the leading researcher of this lab had written cartoons. I liked that. I had tried it myself, and knew that it requires imagination, hard work and a desire to understand people.

Today, Cooney does research on social robots for wellbeing. He manages Halmstad University's Master's Programmes in Information Technology and in Embedded and Intelligent Systems, and one thing he finds interesting is how to measure if education is successful.

Martin Cooney

Hoping for more data-driven evaluations

Course surveys are common practice, and he used to believe that a high score indicated a good course. But he has changed his mind.

– Few students take the surveys sometimes, and their rating depends on a lot of things. Did they like the topic? Was it easy? Did they get good grades, and did they agree with the result? A course can get a very high grade one year, a very low one the next.

Nor is the rate of students passing enough to know, he says. A teacher with low demands or who doesn't want to deal with re-exams could pass many students, while a more stringent one could reject more students. The result might be that the second teacher seems less skilled than the first, which might not be true.

– But even if today's metrics are imperfect, they are not useless. I think that the education at Halmstad University is good, we have good teachers, good research and plenty of time for each student. But that doesn't mean that we cannot get better – at everything.

Cooney is convinced that in the future, evaluations of education will be much more data-driven than today and build more on continuous analysis.

– Intelligent Agents and Recommender Systems, "Explainable AI", will be able to monitor and provide feedback in ways that people understand. Imagine being able to assess the students' attitude and knowledge when they start, how and when this changes – and why.

He compares with the use of AI in future healthcare. Today many see their doctor only once a year, risking that a disease goes unnoticed for months. In the future, we may instead have sensors that register various parameters in our bodies and announce when it is time to schedule an appointment. In the same way, AI systems could detect early on which students have problems, increasing the likelihood that teachers will be able to help.

Supportive courses for industry a positive experience

When the pandemic broke out, Cooney helped create the program *Relife*, funded by the Knowledge Foundation and targeted to people whose work was affected by the pandemic.

– All summer we had big meetings to plan the courses. I really felt like the whole school came together around this program.

Based on a survey filled out by industry partners, Cooney and colleagues charted what courses seemed most interesting for people working in industry, and what format and pace would be suitable for them. A handful of courses were chosen, mainly within AI and computer science, programming, and security. The courses were broken down into smaller modules and presented in the form of Zoom classes and recorded lectures.

– Our communication department handled the external information, the administrative department helped students get into the system, and many of our best teachers volunteered. The result was great.

Almost 500 people took the courses and about half of them achieved academic credits.

– Credits are useful if you want to move on to a master's degree or a PhD. But some just wanted to learn. Surveys showed that the students came from all sorts of companies, often a few from each. It was not their managers telling an entire department that they should take a course, but instead people had seen our ads and applied due to their own true interest. It felt very positive.

Shaping AI education for practical use in society

In the fall of 2022, Halmstad University will present a new bachelor's program named *Applied AI*. It is tailored for people who do not primarily have an interest in the engineering sciences, but who will be using AI in, for example, healthcare or energy innovation. One of the program's creators is Verónica Gaspes, associate professor of computer science at Halmstad University.

– There is a need for educating people with a broad background, who want to understand how AI can contribute to their fields. We decided from the beginning that technical courses should be presented in parallel with the courses on ethics, communication and so on – so that the students are not at any point overwhelmed by either the technical or non-technical content.

Instead of opening with basic tech or mathematics, the new program starts out with courses oriented towards applications. Students will right away start to practice working with data, reflecting on what questions can be asked using large data amounts, and learning what bias can arise in machine learning. Traditional AI skills like statistics, mathematics and computer science will be combined with ethics, law and sustainability.

A focus on practical problems

– A substantial part of the program will be integrated with the student's field of interest. That is unique, I think. The goal is that at least some of these students will become connectors between AI and their own domain, such as healthcare or business economics.

The three tracks offered initially are sustainable energy engineering, business, and healthcare innovation and the courses will to a large extent focus on practical problems that students may encounter when working with AI in the community.

The team behind the program created a slogan for it; "AI for social good". The overarching idea is to use AI techniques in a responsible manner, to address sustainable development goals.

– We want to give the students generic skills, but also go deeper and really ask domain specific questions: What do people who work in a hospital need? What data can we collect, and what questions can these data answer? You must be able to identify the problems, the questions, and also to determine which data is relevant, and if data quality is good.

AI more prominent in tomorrow's education

Gaspes grew up in Argentina where she began her education, but she has lived in Sweden since the 1990s when she came here to study and defend her dissertation. Since 1999, she has taught computer science at Halmstad University. In 2011 she received the University's pedagogical prize.

– Here in Halmstad I have gotten the chance to work together with colleagues in many different fields, and that is something I find very rewarding. All the expertise we need for the three tracks in the new program, we have here on site. In the future we would like to have an education track as well, so that the teacher education at Halmstad University also links to this. But we want to start out safe, offering just a few options, to see how the program is received.

In the future, Gaspes believes that many of the traditional educational programs, such as sociology or economics, will include courses on AI, simply because professions are changing. In the same way that Excel is taught now, AI tools will be taught tomorrow, she thinks.

Verónica Gaspes

Personally, she is interested in AI both as a teacher and as a citizen. She reflects that technology has a great influence on our social interactions today, and although most people know that a lot of systems collect data about us, we seldom know how it is used.

– I think this has consequences both for how we behave towards other people, and for democracy. If so, we need to be educated about what AI is, so we can make good decisions about which systems we should use and in what way. We do not all need to become experts in AI and computer science, but we must understand how AI works in our immediate environment – in our workplace, as well as in our private lives.

Licentiate exam Alexander Galozy

Data-driven personalized healthcare: Towards personalized interventions via reinforcement learning for Mobile Health

Abstract

Medical and technological advancement in the last century has led to the unprecedented increase of the populace's quality of life and lifespan. As a result, an ever-increasing number of people live with chronic health conditions that require long-term treatment, resulting in increased healthcare costs and managerial burden to the healthcare provider. This increase in complexity can lead to ineffective decision-making and reduce care quality for the individual while increasing costs. One promising direction to tackle these issues is the active involvement of the patient in managing their care. Particularly for chronic diseases, where ongoing support is often required, patients must understand their illness and be empowered to manage their care. With the advent of smart devices such as smartphones, it is easier than ever to provide personalized digital interventions to patients, help them manage their treatment in their daily lives, and raise awareness about their illness. If such new approaches are to succeed, scalability is necessary, and solutions are needed that can act autonomously without costly human intervention. Furthermore, solutions should exhibit adaptability to the changing circumstances of an individual patient's health, needs and goals. Through the ongoing digitisation of healthcare, we are presented with the unique opportunity to develop cost-effective and scalable solutions through Artificial Intelligence (AI).

This thesis presents work that we conducted as part of the project improving Medication Adherence through Person-Centered Care and Adaptive Interventions (iMedA) that aims to provide personalised adaptive interventions to hypertensive patients, supporting them in managing their medication regiment. The focus lies on inadequate medication adherence (MA), a pervasive issue where patients do not take their medication as instructed by their physician. The selection of individuals for intervention through secondary database analysis on Electronic Health Records (EHRs) was a key challenge and is addressed through in-depth analysis of common adherence measures, development of prediction models for MA and discussions on limitations of such approaches for analysing MA. Furthermore, providing personalised adaptive interventions is framed in the contextual bandit setting and addresses the challenge of delivering relevant interventions in environments where contextual information is significantly corrupted.

The contributions of the thesis can be summarised as follows: (1) Highlighting the issues encountered in measuring MA through secondary database analysis and providing recommendations to address these issues, (2) Investigating machine learning models developed using EHRs for MA prediction and extraction of common refilling patterns through EHRs and (3) formal problem definition for a novel contextual bandit setting with context uncertainty commonly encountered in Mobile Health and development of an algorithm designed for such environments.

Licentiate exam
Title: Data-driven personalized healthcare: Towards personalized interventions via reinforcement learning for Mobile Health
Author: Alexander Galozy
Supervisors at Halmstad University: Sławomir Nowaczyk, Professor, Mattias Ohlsson, Professor
Opponent: Fredrik Johansson, Chalmers University of Technology, Gothenburg.
Examiner: Josef Bigun, Professor, Halmstad University

AI important for the individualized care of the future

An aging population and limited resources pose major challenges. Doctoral student Alexander Galozy believes that artificial intelligence (AI) will play a significant role in the future in managing long-term illness, both for caregivers and patients. The use of AI could reduce the workload and costs of healthcare and increase the independence of patients.

- It is therefore of great value, both for healthcare but also for society at large, to understand how and when these AI technologies are used most effectively, says Alexander Galozy, doctoral student at the Academy of Information Technology at Halmstad University.

Alexander is part of the research group at the University which, together with Region Halland, runs the project iMedA (Improving Medication Adherence through Person Centered Care and Adaptive Intervention). The researchers believe that there is a need to develop individualized digital solutions to support patients with high blood pressure, so-called hypertension, to follow prescribed treatment. Patients with high blood pressure are good at taking prescribed medication. However, it is not necessarily the same as actually taking your medication. Therefore, the researchers hope that AI and individual digital aids can be a way to support the patient group.

Mobile application as support

The project is developing a mobile application that will take into account the patients' different behaviors and needs, as the reasons for not following their treatment plan differ within the group. The first step in this has been to identify various reasons why patients with high blood pressure do not follow prescribed treatment. The researchers have done this by analyzing large amounts of patient data. As part of the iMedA project, Alexander Galozy in his licentiate thesis has analyzed the problem of using large amounts of patient data to measure patients' compliance with prescribed drug treatment. He has also investigated how machine learning models can be used on patient data to predict patients' behavior around following their treatment.

- Measuring how the patient group follows their prescribed treatment plans using patient data is not easy. There is a lot that can complicate the work, for example through duplicates and the lack of data. This makes the analyzes incorrect. However, we have begun to find solutions on how we can fix the problems, says Alexander Galozy.

Machine learning needs correct data

Another obstacle to predicting the behaviors of the patient group is the data generated by patients who frequently visit their doctors. It can be interpreted that these patients are more likely to renew their prescriptions, but it is not certain that patients actually pick up their medicines or follow their treatments. - It complicates the work of developing machine learning models when we can not fully trust the data we use. Methods to address the problem of skewed data are still lacking but are under development, says Alexander Galozy.

Tailor-made reminders

The researchers in the iMedA project want to bring about lasting behavioral changes in patients with high blood pressure. Through techniques in so-called enhanced learning, patients should be able to receive tailored reminders and personalized information through a mobile application. Many solutions today depend on patients generating useful and accurate information and often take a long time before they function optimally. This can lead to the user, ie the patient, losing interest in using the tool. As another part of his licentiate thesis, Alexander has developed a setting and algorithm that can be used to propose tailored efforts.

- In my research, I have combined strategies to be able to personalize the solutions in the digital aid. Although enhanced learning looks promising, there is still a long way to go before methods become a natural part of our technical solutions, says Alexander Galozy.

Alexander will continue in the academy and his career as a researcher in AI.

- Licentiate is just a small step in that direction and there are still many interesting questions that I want to answer!

Outreach

Book on AI powered services

In August 2021, Pontus Wärnestål released his book "Design of AI powered Services", published by Studentlitteratur. It is a book about how to design AI powered services with a focus on user experience and usefulness, it expands the toolbox for digital designers. Or in Pontus Wärnestål's own words: "Designing useful services and great user experiences is not trivial; all too often, we have seen technology-driven approaches go wrong and end up with services and systems that do not live up to the expectations. Sometimes with unintended negative consequences. Human-centred design is a collection of methods that can help in this regard".

Smart Energy summer school and workshop

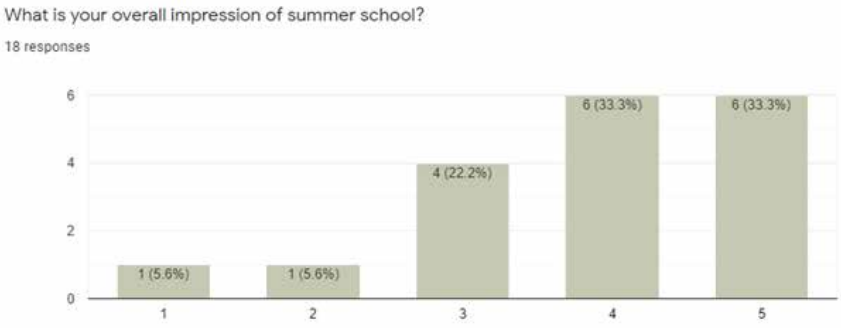
August 22-27, 2021, Slawomir Nowaczyk and Kobra Etminani co-organized the 9th DHC+ Summer School 2021 in district heating and cooling with NetPort Science Park in Karlshamn and NODA Intelligent Systems held by Euroheat & Power in Belgium. The summer school took place in Karlshamn.

Top machine learning podcast

In 2021 Welp Magazine listed our podcast on Human-Centered Machine Learning among the "20 Best Machine Learning Podcasts of 2021". The podcast (https://dap.hh.se/) is funded by Vinnova and co-developed by CAISR members Pontus Wärnestål, Stefan Byttner, and Cristofer Englund.

Summer School on Machine Learning on Predictive Maintenance

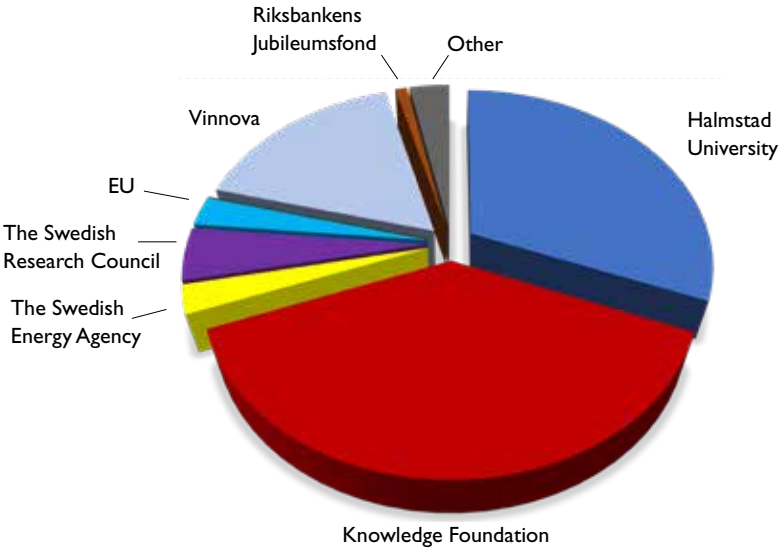
In September-October 2021, CAISR researchers co-organized a Summer School on Machine Learning for Predictive Maintenance. It was organized by the partners in the European XPM project (described earlier) and covered the basics and the recent state-of-the-art in the field. It was a very appreciated summer school, as the evaluation afterward showed (see picture).



Funding

The research turnover 2021 in CAISR was 26.4 MSEK (million Swedish kronor) on the university side (not including in-kind efforts by our partners). We could still see some pandemic effects on the projects, e.g. industrial reorganizations done during 2020 were still affecting the projects. However, the feeling towards the end of 2021 was that projects were moving at expected speeds. The external funding ratio remained high (69% in 2021). The different sources of research funds to CAISR (on the Halmstad University side) are illustrated in the pie diagram. The Knowledge Foundation was the largest contributor, with more than 50% of the external funding to CAISR in 2021. The second largest external funder was Vinnova (Sweden's Innovation Agency). Both the Knowledge Foundation and Vinnova focus on projects done in close collaboration between academics and industry (or public sector).

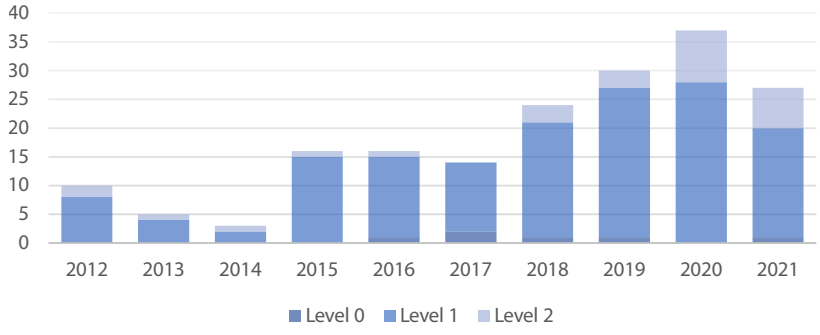
Funding on the University side 2021



Scientific publications and impact

The scientific publication output dropped significantly in 2021, compared to 2020 and 2019 (see the figure). This is not surprising given the covid-19 problems with projects in 2020 and our increased education efforts in 2020 and 2021 (see the earlier section on Education). Our rate of publications in more prestigious journals (Norwegian level 2) remains high. Our scientific production in relation to research expenses is also good, with more than one Journal publication per million Swedish kronor.

CAISR Journal Publications (Norwegian levels)



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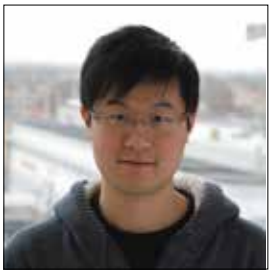

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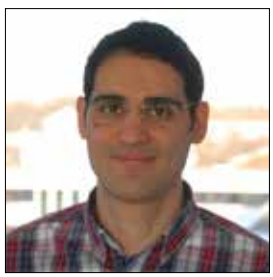

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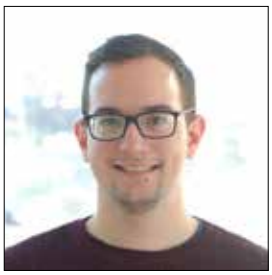

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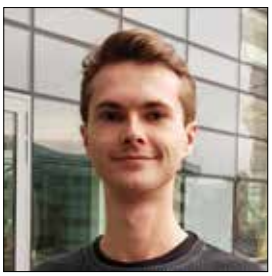

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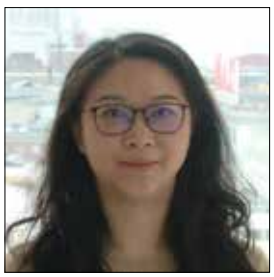

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CAISR Publications 2012–2021

JOURNAL PAPERS

2021

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Farouq, S., Byttner, S., Bouguelia, M.-R., & Gadd, H. (2021). Mondrian conformal anomaly detection for fault sequence identification in heterogeneous fleets. Neurocomputing, 462, 591–606.

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

The Knowledge Foundation has the following objectives:

- to support the exchange of knowledge and skills between the business sector on one hand, and universities, higher education institutions (HEIs), and research institutes on the other.
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- to promote information technology.

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

VINNOVA
Sweden's Innovation Agency

Vinnova is Sweden's innovation agency. Vinnova is a government agency under the Ministry of Trade and Industry and the national liaison authority for the EU Framework Program for Research and Innovation.

Vinnova's task is to promote sustainable growth by financing needs-motivated research and the development of effective innovation systems. "Innovation systems" refer to networks of public and private actors where innovations and new knowledge are developed, disseminated, and used. In order to achieve sustainable growth and strengthen Sweden's competitiveness, the authority must, from a challenge-driven perspective, work for the utilization of research and the promotion of innovation.

Every year, Vinnova invests approximately SEK 3 billion in research and innovation. This is done in many forms, typically co-operative projects between partners with complementing competencies. For CAISR one particularly important funding program is FFI, the Vehicle Strategic Research and Innovation program, which is a collaboration between the government (Vinnova, the Swedish Transport Administration and the Swedish Energy Agency) and the Swedish automotive industry (Scania CV AB, AB Volvo, Volvo Car Group and FKG - Vehicle Component Group).

Thanks to
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CAISR

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

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

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

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Halmstad University, School of Information Technology, June 2022