2024-09-09
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LINK-SIC

Linköping Center for Sensor Informatics and Control

A Vinnova Competence Center
2017-2023

VERKET FÖR INNOVATIONSSYSTEM - SWEDISH GOVERNMENTAL AGENCY FOR INNOVATION SYSTEMS

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Competence Centre – LINK-SIC final report

1. Introduction

This document constitutes the final report for the Competence Centre LINK-SIC (Linköping Center for Sensor Informatics and Control). LINK-SIC has been supported by Vinnova (project no 2016-05152), and it has been in operation from fall 2017 to fall 2023. The development of the center, in terms of center partners, has been as follows. The center started in November 2017 with Linköping University as host, represented by the divisions of Automatic control and Vehicular systems respectively, and with the industrial partners

- ABB Corporate Research
- ABB Marine & Ports
- ABB Robotics
- Actia Nordic AB
- Alelion Energy Systems AB
- Intuitive Aerial AB
- Saab AB
- Scania CV AB
- Senion AB
- UMS Skeldar Sweden AB

In 2019, Atlas Copco Industrial Technique AB joined LINK-SIC, and during 2019 Intuitive Aerial AB changed its name to Newton Nordic AB. During fall of 2021, Newton Nordic AB got new owners with new ambitions, and the company left LINK-SIC at the end of 2021. In 2021 Senion AB was acquired by the telecom operator Verizon. Verizon (Senion AB) and Alelion Energy Systems AB decided to not take part in LINK-SIC during the sixth and final year. A presentation of LINK-SIC is found via the website https://liu.se/en/research/link-sic.

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2. Vision, Mission, and Goals

The vision of LINK-SIC has been:

To be the leading research environment for the Swedish system building industry in sensor informatics and control

and the work towards this vision is summarized in the mission

To contribute to a sustainable society and the competitiveness of Swedish industrial ecosystems by developing cutting edge knowledge and competitive solutions in sensor informatics and control.

Based on the vision and the mission, the strategy of LINK-SIC is summarized in the following four items, where each item is detailed with some key tools identified to achieve the strategy:

- To contribute to new products and processes via the development and knowledge transfer of high-quality research results and highly qualified educated people on PhD and MSc level.
    - Regular tools as MSc and PhD projects.
    - A role model in industry collaboration based on e.g. industry PhD-projects as well as contributing to more structured approaches for career-long boundary spanners.
    - Shaping of a wider eco-system where SMEs and larger companies are integrated by respecting the different timeframes of such actors.
- To impact the relevance of the engineering education at Linköping University with up-to-date course content based on recent research updates and industrial and societal needs.
    - Active contributions to education through CDIO- projects
    - Summer projects and MSc-projects
    - Developing courses and course books
    - Center leaders very active in the development of education
- To have a positive influence on the gender balance within the education and research connected to the center.
    - Introduce role models, organizing seminars
    - Issue discussed at every management and board meeting
- To ensure an international perspective through collaboration with international partners.

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- Selecting key partners complementing and strengthening LINK-SICs ability to perform its mission

The contribution to a sustainable society is illustrated by the connection of the mission statements to UN's goals for sustainable development. The first strategy statement has a clear connection to goal 9 about *Industry, innovation, and infrastructure*, the second and third statement connect to goal 4 about *Quality education* as well as goal 5 about *Gender equality*, and the fourth statement has a clear connection to goal 17 *Partnership for the goals*. Perhaps more indirectly, the contributions of the center have had the potential to contribute to several other of the sustainability goals, including for instance sustainable cities and communities, responsible consumption and production, and decent work and economic growth.

In the following sections, it is described how the various activities in the center have contributed to the fulfillment of the vision, mission, and goals. The presentation starts with an overview of the educational activities, with direct connection to the scope of LINK-SIC, which was carried out during the time frame of the report. In the subsequent sections the activities and results within the Application areas are presented.

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3. Center Projects

The Research program of the center is summarized in Figure 1 below, where the Application areas have been closely connected to the participating partners. The boundaries between Application areas are relatively fluid, and some of the partners can be connected to more than one Application area.

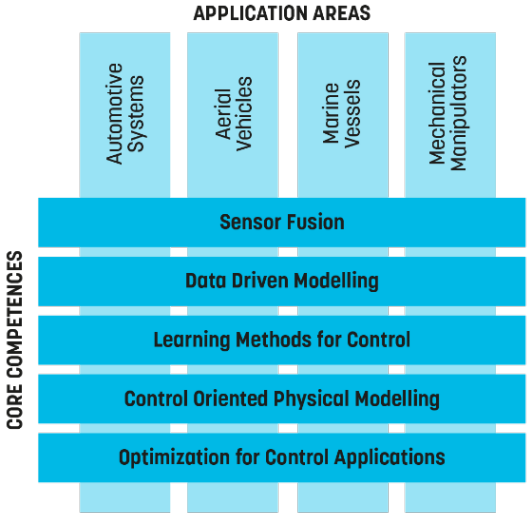

Figure 1: Research program

The activities within each of the Application areas are described briefly here. A more thorough description of the activities is given in Section 4.

The Application area Automotive systems is closest related to Scania CV AB, Atlas Copco Industrial Technique AB, Alelion Energy Systems AB, and Actia Nordic AB. The activities have resulted in five PhD degrees and several Master's theses. Summer projects have been carried out in collaboration with Alelion Energy Systems AB and Actia Nordic AB. Erik Höckerdal, Scania CV AB, has been Adjunct Associate Professor within LINK-SIC.

The key companies connected to Aerial vehicles are Saab AB, UMS Skeldar Sweden AB, and Senion AB. The research has resulted in three PhD degrees, two Licentiate degrees, and several Master's theses. Summer projects have been carried out together with UMS Skeldar Sweden AB and Senion AB. Zoran Sjanic, Saab

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AB, has been industrial postdoc and later Adjunct Associate Professor within LINK-SIC.

The key partner within Marine vessels has been ABB Corporate Research and via them ABB Marine. The activities have resulted in one PhD degree, one Licentiate degree, and several Master's theses.

The Application area Mechanical manipulators has had close connection with ABB Robotics, ABB Marine & Ports, Atlas Copco Industrial Technique AB, and Newton Nordic AB. The activities have resulted in three Licentiate degrees and several Master's theses. Summer projects have been performed in collaboration with Newton Nordic AB. Mikael Norrlöf, ABB Robotics has been Adjunct Professor within LINK-SIC.

4. Goal Completion

4.1 Education

The research groups of the academic partner in the center, i.e. the Divisions of Automatic control and Vehicular systems, have a strong involvement and commitment in the engineering education at Linköping University, including long-term development of pedagogical approaches such as challenge-based learning and initiatives related to the educational framework CDIO that is focused on the next generation of engineers.

4.1.1 Master's level courses

The following Master's level courses with strong relevance for scope of the center have been given on a regular basis:

- Digital signal processing. Students primarily from the Applied physics and electrical engineering program (4th year).
- Optimal control. Students primarily from the Mechanical engineering program and the Applied physics and electrical engineering program (5th year).
- Automatic control, advanced course. Students from the Mechanical engineering program (4th year)
- Control theory. Students from the Applied physics and electrical engineering program (4th year)

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- Industrial control systems. Students from the Mechanical engineering program and the Applied physics and electrical engineering program (4th year)
- Sensor fusion. Students from the Applied physics and electrical engineering program, Mechanical Engineering, and Computer science and engineering (4th year)
- Automatic Control - Project course. Final CDIO project course with students from the Applied physics and electrical engineering program, and the Mechanical engineering program (5th year).
- Modelling and Learning for Dynamical Systems. Students primarily from the Applied physics and electrical engineering program, and the Mechanical engineering program (4th or 5th year).
- Autonomous vehicles -- planning, control, and learning systems. Students from the Applied physics and electrical engineering program, the Mechanical engineering program, and the Computer Science program (4th or 5th year).
- Modelling and control of engines and drivelines. Students from the Mechanical engineering program and the Applied physics and electrical engineering program (4th year).
- Vehicle dynamics and control. Students from the Mechanical engineering program and the Applied physics and electrical engineering program (4th year).
- Diagnosis and supervision. Students from the Applied physics and electrical engineering program, and the Mechanical engineering program (4th year).
- Vehicle propulsion systems. Students from the Applied physics and electrical engineering program, and the Mechanical engineering program (4th year).

4.1.2 PhD level courses

PhD level courses represent a key component in the PhD student education, and the participating divisions in LINK-SIC offer a large set of courses on PhD level, where several of the courses are given on a regular basis. The list below contains a subset of the courses that have been given during the period LINK-SIC has been running.

- Linear systems
- System identification
- Robust multivariable control
- Target tracking

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- Robot modeling and control
- Convex optimization
- Nonlinear control systems
- Optimal filtering
- Statistical Inference
- Simulation of ordinary and differential-algebraic equations
- Optimal Vehicle Maneuvers
- Non-linear observers

4.1.3 Academic leadership

Several members of the Management team have deep involvement in education development through important academic leadership positions concerning the engineering education at Linköping University.

- Martin Enqvist is vice chairman of the Program board for education programs within Electrical engineering, physics, and mathematics. He is also responsible for the Master's specialization Control and information system within the Applied physics and electrical engineering program.
- Lars Eriksson is a member of the Program board for education programs within Mechanical engineering and design. He is also responsible for the Master's specialization Mechatronics within the Mechanical engineering program.
- Johan Löfberg is Director of Studies for the area Control systems, encompassing the Divisions of Automatic Control and Vehicular Systems.
- Svante Gunnarsson is CDIO coordinator within the Faculty of Science and engineering and involved in various international networks for new international educational structures and pedagogics, such as the CDIO Initiative and ECIU (European Consortium of Innovative Universities).

4.2 Automotive systems

The Automotive Systems area has the general theme of modeling, control, and supervision of functions in vehicle powertrains. The aim is to develop control systems that can obtain optimal performance, safety, energy utilization, and environmental stability for all kinds of powertrains. It is especially important, as we advance to adapt the project portfolio to cope with the strive towards electrification and the green hydrogen society. This has mainly been executed in the form of 3

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PhD projects, boosted with associated senior and PhD projects, and a guest researcher period for a 3 month on site visit of the TNO & TU/e affiliated professor Frank Willems on the topic Control Oriented Modeling of Internal Combustion Engines and Aftertreatment Systems during 2019.

The first project resulted in the PhD Kristoffer Ekberg who defended his thesis in June 2021 and left for Wolfram MathCore. Kristoffer mainly studied the effects of introducing electrically assisted turbo chargers on heavy duty diesel engines and produced the open source LiU-Diesel 2.0 model. Thereafter, Max Johansson joined in 2022 studying fuel cell hybrid electrical vehicles. Together with Robin Holmbom, he designed a hydrogen optimal benchmark problem for the IFAC World Congress 2023. The benchmark task is to develop a hydrogen optimal energy controller for a fuel cell hybrid electrical vehicle that minimizes the wear/aging of the fuel cell membrane and batteries. During the autumn 2022, Max spent 3 months at the Imperial College of London to study and collect measurement data from a fuel cell.

The second project ensured finalization of PhD student Xavier Llamas finishing in March 2018 and went back to Spain. Xavier developed a compressor model parametrization tool that is available as a free Matlab GUI. In 2019, Robin Holmbom joined as a PhD student. Robin worked with crank angle resolved mass flow models for engines with variable valve trains and has previously worked in a project together with Volvo Cars. He finalized his PhD by using the developed models for MPC of throttle and cam phasers in Januari 2022 and started as a lecturer at Vehicular Systems, LiU.

The third project started in 2019 when Atlas Copco Industrial Technique AB joined the center with the PhD student Nils Dressler. Nils studied tightening technics for handheld electric torque and angle wrenches where friction modeling was one research topic.

Beside the three center funded projects, the following associated projects have benefited from the activities within the LINK-SIC center research environment.

- An FFI project – Customer-Oriented Operations Research for Electrification (Condor), Scania, LiU.
- An FFI project – Dynamically Configurable Battery Control (CoCo), Scania, LiU, KTH.
- A MISTRA project – Modular Multilevel Converter (MMC) Concept Battery, LiU, Scania, SEM, Chalmers.
- An SEC (Swedish Electromobility Center) project – Diagnostics and Supervision of Dynamically Configurable Battery, LiU, Scania.

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- An SEC project – ECCV, Electro-Chemical Commercial Vehicle, LiU, LTH, Volvo, ABB.
- A Vinnova project – E-Charge: Systemdemonstration av elektrifierade långväga lastbilstransporter, Lindholmen Science Park AB, et al.
- An Energimyndigheten/Battery fund project – Pulse4life: Prolonged battery life through pulsed charging, LiU, Scania.
- An SEC project – ECOTS: Evaluation and Control of Thermal Management Systems.
- An FMW project – LOLO: Fuel cell propelled submarine, KTH, LiU, Scania.

4.3 Aerial vehicles

The focus in the aerial vehicles application area is on efficient use of sensor data for various aeronautical applications, e.g., system identification of aircraft, target tracking, navigation, and simultaneous localization and mapping. The main results in this application area are three PhD theses and one Licentiate's thesis. The research has also been strengthened by significant in-kind contributions from a senior Saab researcher with a PhD in the field from 2013.

The first PhD thesis was defended in 2018 and concerns tracking of both animals and other objects like icebergs using cameras and presents a newly developed approach to constrain tracked targets to a particular region and a method for incorporation of observations sampled at uncertain time instants. Two of the applications studied are tracking of dolphins in a basin and tracking of birds in a cage. In both these applications, it is not possible to calibrate the cameras using standard techniques and a new approach is proposed as an alternative.

The second PhD thesis was defended in 2019 by an industrial PhD student from Saab AB. This thesis covers both methods for identification of unstable nonlinear systems operating under closed-loop conditions, like the Gripen aircraft produced by Saab, and methods for online modeling. In particular, the challenges posed by process disturbances such as atmospheric turbulence have been investigated and a relatively simple approach for nonlinear system identification has been proposed. Furthermore, a sequential system identification method for online modeling has also been developed further to give improved performance when a complete aircraft model with six degrees of freedom is estimated from flight test data where the excitation levels vary over time. Furthermore, unique flight test data from a model jet aircraft has been collected and analyzed using this method.

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The third PhD thesis concerns decentralized target tracking and was defended in 2023 by another industrial PhD student from Saab AB. The main results in this thesis are a general framework for optimal conservative fusion of estimates with unknown correlations and several dimension-reduction algorithms that can be used to reduce the communication load in a sensor network. Optimality is guaranteed for some of these algorithms and an optimization strategy to compute dimension-reduced estimates while maintaining data association properties is also proposed.

In addition, a Licentiate's thesis about modeling and diagnosis of UAVs was defended in 2018. The main topics in this thesis are closed-loop and sensor-to-sensor system identification of quadcopters for the purpose of model-based diagnosis of mass changes, increased drag and sensor and actuator failures. This thesis also describes a particular equivalence property in sensor-to-sensor system identification. The PhD student in this subproject left the university in January 2022 before finishing his PhD thesis to take a job in industry but has continued working on his thesis in his spare time and has written two additional papers on the theoretical and practical aspects of sensor-to-sensor modeling and diagnosis. The current plan is that he will defend his PhD thesis during the winter 2024-2025.

4.4 Marine vessels

Support systems for marine automation was the main topic in the marine vessels application area. More specifically, various aspects of sensor data processing were investigated with the common goal of extracting useful information from the sensors, including ship properties that cannot be measured during normal operation. Having accurate estimates of these properties and hence, being able to predict a ship's behavior, is essential to maneuver the ship in a safe manner and to increase energy efficiency. One natural approach to obtain these estimates is to apply methods from system identification and sensor fusion.

The main achievement in this area was the successful completion and defense of a PhD thesis about identification of nonlinear marine systems in 2022. The main results in this thesis and the related papers are a novel approach to data-driven ship modeling for second-order modulus models, a dictionary-based approach for design of ship experiments and the formulation of a motion-planning problem which makes it possible to obtain a complete experiment in the form of spatially feasible trajectories based on a previously optimized set of informative sub-experiments. Furthermore, the thesis contains new results on wind and water current disturbance

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estimation and the results from experimental work using data from real ships as well as scale models of ships. The PhD graduate from this project left the university in December 2022 to start working at the industrial partner ABB.

4.5 Mechanical manipulators

Over the past years, research in the application area of mechanical manipulators has made substantial progress, focusing on a range of topics including modeling, control, sensor fusion, planning, diagnosis, and optimization. The work, conducted in close collaboration with primarily ABB Robotics and ABB Marine & Ports, has involved four PhD students, supported by five senior scientists and a team of senior specialists and engineers from ABB. This collaboration has yielded significant advancements in industrial applications, culminating in several international publications, licentiate thesis and successful transitions of PhD students into industry roles.

Following a long tradition of research activities in earlier LINK-SIC constellations, the identification and modelling of flexible industrial robots has been the topic of one PhD student, in collaboration with ABB Robotics. The research led to a Licentiate thesis in 2023 and is still on-going with several publications also in 2024. The student is now employed part-time by ABB Robotics while still pursuing their PhD studies. A second project running in collaboration with ABB Robotics touched on various aspects of control, modelling and estimation in robotic systems, with both practical and more academic perspectives, and culminated in a licentiate thesis in 2020. The PhD student who was involved in this project has also demonstrated the successful movement of people over the industrial-academic border in LINK-SIC, as significant time was spent at ABB Robotics to learn more about the industrial applications, needs and limitations.

A second leg in the research has been optimal control in mechanical systems. One project in this direction, in collaboration with ABB Robotics, has been trajectory optimization in applications where multiple robots collaborate to solve tasks, considering critical aspects of load distribution and internal forces when manipulating objects jointly. This research resulted in a licentiate thesis in 2021 and subsequent journal publications. Another PhD student has also worked on the application of optimal control, but in collaboration with ABB Marine & Ports. In this project, time-optimal control was investigated to develop efficient loading and unloading strategies of ship-to-shore (STS) containers, leading to novel theoretical results on how to combat some intrinsically hard problems that arise in these optimization problems. The student spent a large part of 2023 at ABB Marine & Ports part-time employed as an intern, once again illustrating the successful transfer

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of skills and people between academia and industry within the center. The research is still on-going and is currently pursuing ideas on how to incorporate uncertainty in models when solving optimal control problems.

4.6 Key performance indicators

The operation of the center has been monitored using a set of Key Performance Indicators (KPIs), and details concerning the KPIs are given in the annual reports. From an academic viewpoint the number of degrees and publications are the KPIs of biggest interest, and they can be summarized as follows.

- Nine PhD theses
- Six Licentiate theses
- 58 Master's theses
- 42 journal papers
- 57 conference papers.
- Two new or revised textbooks
- Handouts for the Thematic workshop about Reinforcement learning.

A list of these theses and papers is given in Section 5, and they can be accessed via the publication database DiVA.

4.7 SME Activities

4.7.1 Student summer projects

For the companies that have participated in LINK-SIC on a lower financial level, of which some are categorized as SMEs, the center has arranged summer projects for students. The companies have proposed tasks suitable for six weeks of work for one or two students, and thereafter the summer projects have been announced and suitable candidates have been selected and hired by LINK-SIC. The students have worked on the projects during summer, with, if needed, supervision from LINK-SIC, and the outcomes of the projects have been presented during the poster session at the annual workshop. The list of summer projects that have been carried out and the participating companies is given below. In some cases, the summer project has led to further collaboration in terms of Master's theses. The posters presenting the summer projects can be accessed via the site https://liu.se/en/article/link-sic-events.

2018:

- Alelion Energy Systems AB - Thermal Model of Lithium-Ion Battery Cell
- UMS Skeldar Sweden AB- An Experimental Project of Inertial Navigation and Relative Positioning Performance

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- Actia Nordic AB/Senion AB - ACTIA–Senion Summer Project

2019:
- Alelion Energy Systems AB - Log Data Digestion and Analysis
- UMS Skeldar Sweden AB - Test and Evaluation of Navigational Receivers
- Senion AB - Summer project: Updating an Android app
- Intuitive Aerial AB (Newton Nordic AB) - Developing a Figure of Merit for Image Stability

2020:
- Senion AB - Business Intelligence Web Portal
- Alelion Energy Systems AB - IoT Industrial Battery Surveillance
- Newton Nordic AB - Model estimation of a camera stabilizing system

2021:
- Newton Nordic AB - Modeling of a Motorized Gimbal System
- UMS Skeldar Sweden AB - Modeling of waves and ship motion
- Senion AB - Business Intelligence Web Portal

2023:
- UMS Skeldar Sweden AB– System Identification of a Skeldar Helicopter

4.7.2 SME funding from Vinnova

In addition to the main funding from Vinnova, the companies that according to Vinnova´s definition are categorized as SMEs, have had the opportunity to apply for separate SME funding. This possibility was used by Senion AB twice, and the company received funding for two development projects.

4.8 Annual workshops

The annual workshops of LINK-SIC have been organized in November each year, often including study visits at the participating companies. It can be noted that the organization of the 2020 and 2021 workshops were affected by the Covid-19 pandemic, which required flexibility in terms of means of participating. The workshops were arranged as follows:

2017: LiU

2018: Saab AB

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2019: ABB

2020: Distance mode

2021: Hybrid (LiU)

2022: Atlas Copco Industrial Technique AB & Scania CV AB

2023: LiU

Information about the programs of the workshops, the presentations and posters can be found via the website https://liu.se/en/article/link-sic-events.

4.9 Core competence and thematic workshops

LINK-SIC has also arranged workshops around Core competences and thematic workshops around topics of common interest. These workshops include workshops about

- Learning methods in control
- Numerical optimization
- Batteries
- Reinforcement learning (arranged in distance mode)
- Friction
- Modeling and control of after-treatment systems

4.10 Visits and visitors

Several researchers have visited LINK-SIC for both longer and shorter stays. The possibilities for visits were affected by the pandemic, which prevented travels and visits for almost two years. Concerning visits there has been an emphasis on collaborations with Brazil, since this is a prioritized country for both Sweden, Linköping University, and Vinnova. In addition, Sweden has a strong industrial presence in Brazil since many years. The list of visitors includes Marcelo Costa from UFMG in Belo Horizonte who visited LINK-SIC in 2018 and 2022 and worked on diagnostics for industrial robots. Antonio Braga, also from UFMG, gave a talk at the opening workshop of LINK-SIC in 2017. Enabling visiting PhD students to the center has proven to be excellent in that it creates new contacts, and LINK-SIC was visited by Aline Kraemer, ITA, in 2018 and Aldo Diaz, UniCamp in 2019. Neusa Maria Franca de Oliveira, ITA, visited LiU and LINK-SIC as guest researcher during 2023 and parts of 2024. In addition, Svante Gunnarsson, Center Director of LINK-SIC, visited UFMG in 2018 and 2020. Frank Willems from TNO

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in the Netherlands visited LINK-SIC during the fall of 2019 for collaboration with Lars Eriksson and researchers in his team.

4.11 Networking and dissemination

In addition to the regular activities in the center, LINK-SIC researchers have been involved in networking and dissemination activities, and these include:

- A series of discussion sessions (Think tanks) around the Core competences of LINK-SIC were arranged between December 2020 and February 2021.
- On October 7, 2021, Lars Eriksson and Svante Gunnarsson represented LINK-SIC at the Scania Innovation Day.
- On July 4 – 7, 2022, the 25th International Conference on Information Fusion was arranged in Linköping with Fredrik Gustafsson and Gustaf Hendeby as key organizers.
- The LINK-SIC team has developed a simulation platform for fuel cell electric vehicles where control designs can be developed and tested. Based on the platform a control benchmark with 14 inputs and 14 outputs was formulated as a competition for the IFAC World Congress held in Yokohama, Japan in July 2023. Approximately 30 teams downloaded the platform and six teams (two from USA and one from each of Korea, Austria, Italy, and The Netherlands) contributed with solutions for the problem, highlighting the benefits of bringing teams together, working in an international effort.
- For networking as well as sharing experiences and best practices, contact was established with the TECoSA competence center and activities have included two center director presentations, given by Svante Gunnarsson at TECoSA's quarterly meeting in September 2021, and Martin Törngren, center director for TECoSA at the LINK-SIC workshop in November 2021.

4.12 Awards

The research within LINK-SIC has resulted in several awards, with focus on the research around Lars Eriksson:

- In 2018 Lars Eriksson, together with Kræn Vodder Busk, MAN Energy Solutions, Denmark; Mogens Blanke, Technical University of Denmark; and Morten Vejlgaard-Laursen, Maersk, Denmark, received the Rudolf Kalman Best Paper Award for the article *Control-Oriented Model of Molar Scavenge Oxygen Fraction for Exhaust Recirculation in Large Diesel Engines*.

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- At the IFAC World Congress in Berlin in 2020, Lars Eriksson was awarded the Control Engineering Practice Best Paper Award for the paper Nielsen, Blanke, Eriksson, and Vejlgaard-Laursen, *Adaptive Feedforward Control of Exhaust Recirculation in Large Diesel Engines*.
- In 2023, Lars Eriksson was awarded the Håkan Frisinger Scholarship for his outstanding scientific achievements and substantial contributions to the transportation industry. The prize included an individual award of 300 KSEK and a period as a visiting researcher at a university in Sweden, along with a grant of 500 KSEK to the university hosting the visiting researcher through Volvo's Research and Education Foundation's guest researcher program.

4.13 Diversity and gender balance

Diversity and gender balance are important aspects to consider in all processes, and Linköping University is working extensively on all levels with these questions. Likewise, LINK-SIC has also been working actively to promote and ensure equal opportunities and rights, e.g. by always having diversity as a standing item on the agenda for the board meetings. Another concrete measure has been to promote and maintain gender balance in the Center Board as well as in the International Scientific Advisory Board.

4.13.1 Inspiration lectures

In collaboration with the strategic research area ELLIIT (Excellence Center at Linköping-Lund in Information Technology) and the student organizations for female students Yvette, Donna, and Emma at the Faculty of Science and Engineering, LINK-SIC has arranged a series of inspiration lectures given annually. The topic of the talks for these lectures has been "*Vägen hit"-The path that led me here"* where the invited speakers have been given full freedom to present how their careers have developed, highlighting factors that have influenced decisions along the way. In most cases the speakers have been alumni from Linköping University now working at LINK-SIC companies. The talks were highly appreciated by the audience and led to many interesting questions and discussions related to the future career as an engineer. The participating speakers have been:

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- Charlotte Jalkebo, Scania CV AB
- Mia Knutfelt, Saab AB
- Julia Nielsen, ABB
- Johanna Rost, Scania CV AB
- Johanna Wallén Axehill, Saab AB
- Elina Vartiainen, ABB
- Karin Hermansson, ABB
- Marianne Klang, Saab AB
- Emma Nyström, Volvo Cars

4.13.2 Talks at the annual workshops

To provide additional attention to the importance of diversity and gender aspects presentations around these topics have been arranged in conjunction to the annual workshops of the center. In 2018, Max Parknäs, Vinnova, gave a talk about Vinnova's view on diversity within the Competence Center program, and at the workshop in 2022 Johan Aaro, Atlas Copco Industrial Technique, presented Atlas Copco´s work around diversity and inclusion. The slides from the talk by Max Parknäs can be accessed via https://liu.se/en/article/link-sic-workshop-2018.

4.13.3 Summer challenges

During the summer of 2022, LINK-SIC arranged two summer challenges in collaboration with the student organizations Yvette, Emma, and Donna. Two groups of students were recruited to work for two weeks during the summer on a topic of their own choice. The topics that were chosen were *Software testing* and *Treatment of Diabetes type 1* respectively. Considering the limited time frame for these summer challenges, the resulting work was of very good quality. The results were presented via posters at the annual workshop 2022 and these can be accessed on the LINK-SIC website https://liu.se/en/article/link-sic-workshop-2022.

5. Publications

5.1 PhD theses

Clas Veibäck, *Tracking the Wanders of Nature,* Linköping Studies in Science and Technology. Dissertations. No. 1958, 2018.

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