Activity Report 2018

Automatic Control

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Content

Introduction

A short summary of the main activities at the Department of Automatic Control, Lund University during the period January 1 to December 31, 2018

PROFESSOR INAUGURATION 2018 - FIRST FEMALE PROFESSOR AT THE DEPARTMENT OF AUTOMATIC CONTROL - CHARLOTTA JOHNSSON

Charlotta Johnsson is working at the Faculty of Engineering (LTH), Lund University, Sweden. She is the Vice Dean for Collaboration and Innovation at LTH and since February 2018 she holds a position as a Professor at the Department of Automatic Control.

The role as Vice Dean at LTH for Collaborations and Innovation includes building and strengthening the innovative culture at LTH, as well as initiating and supporting collaboration activities with the surrounding society and industries. The vice dean is part of LTH's management team, and is also the link to Lund University collaboration and innovation activities.

Her research interest is divided into four major areas; Automation, Innovation, Leadership and Pedagogy.

Charlotta is the Chair for ISO/TC184/SC5. ISO is a well-recognized international standardization body. TC184 (industrial automation and integration) and SC5 (Interoperabilty, integration and architectures for enterprise systems and automation applications) constitute important committees for work related to Smart Manufacturing.

Charlotta received her Master degree in Electrical Engineering at Lund University, Sweden in 1993. She did her PhD, focusing on graphical languages for batch control, at the Department of Automatic Control, LTH, Lund University and got her Ph.D. diploma in March 1999. In 2011 she got the Reader degree (Sw: docent) and the ETP (Excellent Teaching Practitioner) diploma, and in 2018 she became Professor.

Charlotta has been awarded the Carlo Guido Stella Award in Manufacturing Automation in 2012, and was selected to the Process Automation Hall of Fame in 2016.

Before joining the department, Charlotta worked four years in industry as a Product Manager with Siemens, Italy (2000-2004). Charlotta has been an adjunct professor at Control Science and Engineering at Zhejiang University, Hangzhou, China (2012) and she has been a visiting scholar at Center for Entrepreneurship and Technology, UC Berkeley, CA, USA (2013-2014).

Charlotta is married to Hans Nilsson, they live in Lund and have three children.

AUTOMATIC CONTROL 2018 - HIGHLIGHTS

Another year has passed, and at the Department of Automatic Control we can summarise the year in numbers as below:

The economy showed a turnover for 2018 of 55 MSEK, an increase from last year of around 4 MSEK. We are now 45 persons working at the department (guests not included). More about financial figures is found in the chapter *Economy.*

Today (2018) the department has 7 full time professors, 1 senior professor, 2 professors emeriti, 1 adjunct professor, 4 associate professors, 1 assistant professor, 4 research engineers, 4 administrators, 1 post-doc, 3 researchers, 20 PhD students and 2 industrial PhD students. Some of these numbers include part-time positions. During the year, 3 new PhD students were admitted to the department. We also have our first female professor as from February 2018—Charlotta Johnsson (biography to the left). More will follow in the chapter *Staff.*

Two PhD theses by Gabriel Turesson and Jacob Bergstedt were completed during 2018. The total number of PhDs graduated from the department is now up to 121. This year there were no licentiate theses presented.

During 2018 the department gave 17 different courses to 1093 students at LTH, and 30 students presented their master's theses at the department. For the second year we held the basic course at Beihang University, China, for both Swedish and Chinese students. Teachers and PhD students from our department were responsable for lectures and laboratory exercises.

There is increased attention in the interconnection of control, artificial intelligence and machine learning. This takes several forms: in basic education, master's theses, company contacts, PhD courses and research proposals. The control department has together with colleagues worked with a proposal for new International Master's program, *Machine Learning, Systems and Control*, now planned to start in the autumn of 2020.

We also arranged several PhD courses. More about this in the chapter *Education.*

In April our TA group was visiting IPA Frauenhofer and the University in Stuttgart—this is an opportunity to exchange work related issues and ideas between universities.

Every second year the various control departments at our national universities meet for discussions, meetings and poster exhibition. This year the Automatic Control Meeting (*Reglermöte*) took place in June at KTH, Stockholm.

Our 10-year project LCCC had it's last focus period in October 8 to November 9, on Learning and Adaptation for Sensorimotor Control. The purpose was to gather outstanding researchers with complementing competences in learning, control, robotics and neuroscience to stimulate exchange of ideas and inspire new research directions. During 2019 we will prepare for final reporting of this project.

The department's involvement in WASP, the Wallenberg AI, Autonomous Systems and Software Program, has increased further during the year. The total number of WASP-funded PhD students at the department is now 8, including two industrial PhD students. Two WASP expedition project proposals involving the department have also been approved. In total 3 new postdoc positions are currently under appointment. Read more about our research in the chapter *Research.*

euRobotics week is now well established and took place during three days at the end of November. This event is well visited by Lund surrounding schools and attract about 500 visitors.

As every year we have welcomed new colleagues and interesting guests. New projects have been contributing to the department, which opens up for new challenges in the years to come.

Anton Cervin and Monika Rasmusson

Education

Education on undergraduate and graduate level, dissertations during 2018

UNDERGRADUATE STUDIES

The engineering education at LTH follows the central European systems with five-year programs leading up to the university degree *civilingenjör*, with the international title MSc.

Automatic Control courses are tought as part of the engineering curriculum in Engineering Physics (F), Electrical Engineering (E), Computer Engineering (D), Mechanical Engineering (M), Information and Communication Engineering (C), Environmental Engineering (W), Engineering Mathematics (Pi), Industrial Management and Engineering (I), Biotechnology (B), Engineering Nanoscience (N), Chemical Engineering (K) and Biomedical Engineering (BME). Our advanced courses are included in more than fifteen of the master-level specializations in the various programs. During 2018, the first planning steps towards establishing an international master's program in Machine Learning, Systems and Control were taken, together with the Centre for Mathematical Sciences.

The department has been involved in LTH's China Profile for several years and has taught Automatic Control, Basic Course, at Zhejiang University and, more recently, at Beihang University in Beijing. This year, 17 Swedish and 20 Chinese students took the basic control course. A total of six staff from the department spent some time at Beihang University during the fall.

This year, in total 1080 students were registrered out of which 962 passed our courses. The number of registered students corresponds to 129 full-year equivalents during the year. In the table on the next page, our undergraduate courses are listed, along with the number of students who passed each course.

Our courses continue to receive very good evaluations from the students. During the study year 2017–2018, we had the highest average CEQ score among all the nineteen departments at LTH regarding overall course satisfaction. An top of this, professor Bo Bernhardsson was elected Teacher of the Year by the Engineering Physics students.

30 students completed their master's thesis projects, and a total of 24 theses were presented during 2018. More than half of the theses were performed in cooperation with industry. A number of exchange students from other universities also perform their master's theses at the department every year. A list of the master's theses is given in the *Publications and Seminars* chapter.

TOTAL NUMBER OF STUDENTS WHO PASSED OUR COURSES 2018

Automatic Control, Basic Course
(FRTF05 Reglerteknik AK) 554 (594)
Systems Engineering
(FRTF10 Systemteknik) 39 (39)
Control Theory
(FRTF15 Reglerteori) 14 (15)
Physiological Models and Computations
(FRTF01 Fysiologiska modeller och beräkningar) 33 (33)
Real-Time Systems
(FRTN01 Realtidssystem) 59 (67)
Nonlinear Control and Servo Systems
(FRTN05 Olinjär reglering och servosystem) 45 (55)
Multivariable Control
(FRTN10 Flervariabel reglering) 41 (45)
Predictive Control
(FRTN15 Prediktiv reglering) 16 (22)
Automatic Process Control
(FRTN25 Processreglering) 19 (20)
Network Dynamics
(FRTN30 Nätverksdynamik) 39 (56)
System Identication
(FRTN35 Systemidentifiering) 14 (21)
Project in Automatic Control
(FRTN40 Projekt i reglerteknik) 30 (31)
Mathematical Modeling, Advanced Course
(FRTN45 Matematisk modellering, fortsättningskurs) 28 (29)
Engineering Training Course
(FRTF97 Ingenjörsinriktad yrkesträning) 1 (1)
Degree Project in Automatic Control
(FRTM01 Examensarbete i reglerteknik) 30 (52)

*the numbers in parentheses show how many students were registered on our courses 2018

GRADUATE STUDIES

The PhD education consists of four years of studies, but since most students have 20% of department duties, the nominal time for the PhD education is 5 years. In the Swedish system there is also a possibility to do a half-time thesis called a "licentiate".

Last year, the department adopted a new general syllabus for PhD studies in Automatic Control. The course requirement for a PhD degree was lowered from 120 to 90 credits, while the thesis scope was increased from 120 to 150 credits. The new syllabus specifies that 30 out of the 90 course credits should be PhD courses in Automatic Control. The course component should also include at least 7.5 credits of general research studies courses. Similar changes were also adopted for licentiate thesis requirements.

In 2018 two doctoral theses were defended during the year, by Gabriel Turesson and Jacob Bergstedt. We have admitted Claudio Mandrioli, Albin Heimerson and Nils Vreman as new PhD students.

The following PhD Courses were given in 2018:

- *Optimal Control*; Kaoru Yamamoto, Yury Orlov
- *Robust Control*; Richard Pates, Bo Bernhardsson
- *Universal laws of architectures in complex networked systems*; John Doyle, Caltech, USA

Some of the PhD courses were organised within the WASP program, available for both WASP and affiliated students:

- *Autonomous Systems I*
- *Autonomous Systems II*

A number of our PhD students also attended the following course given at the Centre of Mathematical Sciences:

- *Functional Analysis in System Theory*; Andrey Ghulchak

DOCTORAL DISSERTATIONS

This year we had two PhD students defending their theses. The abstracts of the theses are presented below.


Gabriel Turesson


Jacob Bergstedt

MODEL-BASED OPTIMIZATION OF COMBUSTION-ENGINE CONTROL
Turesson, Gabriel

The work presented in this thesis is motivated by the need to reliably operate a compression-ignition engine in a partially premixed combustion (PPC) mode. Partially premixed combustion is a low temperature combustion concept, where the ignition delay is prolonged to enhance fuel-air mixing in the combustion chamber before the start of combustion. A premixed combustion process, in combination with high levels of exhaust-gas recirculation (EGR), gives low combustion temperatures, which decrease NOx and soot formation. Lowered combustion temperatures also reduce heat-transfer losses which increase the thermodynamic engine efficiency. The ignition delay is, however, determined by chemical reactions rates, which are sensitive to temperature, gas-mixture composition, fuel properties and fuel-injection timing. This sensitivity makes PPC more challenging to operate compared to conventional diesel combustion. Challenges related to PPC include an increased sensitivity to operating conditions, decreased combustion-timing controllability, high pressure-rise rates, and low combustion efficiency at low engine loads. These challenges put high demands on the engine control system that needs to be able to adjust fuel-injection timings and durations to compensate for the combustion sensitivity.

Therefore, this thesis investigates closed-loop combustion control for reliable PPC operation. The feedback loop from pressure-sensor measurement to fuel-injection actuation is studied in particular. A common theme for the controllers presented is the use of models in the controller design. Either to evaluate controller performance in simulation, or to optimize engine performance online. The principle of model predictive control is used for its ability to incorporate modeled system behavior in the controller design, and to control multi-variable systems with input and output constraints.

The problem of tuning robust and noise insensitive combustion-timing controllers, and its dependence on fuel reactivity is studied in simulation. Simulation results reveal a nonlinear relation between start of injection and combustion timing that depends on both load and fuel reactivity. Optimization is used to find robust and noise-insensitive controller gains. Guidelines for combustion-timing controller tuning are also presented.

Low-order autoignition models are evaluated and compared for the purpose of model-based controller design. The comparison shows that a simple autoignition model is sufficient for control of the ignition delay when the cylinder-charge properties are varied. This model is then used by a model predictive controller to simultaneously control ignition delay and combustion timing in transient engine operation, using both gas-exchange and fuel-injection actuation.

The effects of pilot injection on the combustion processes are characterized experimentally. Experimental results show that a pilot injection can decrease the main-injection ignition delay and maintain the pressure-rise rate at an acceptable level. This is utilized by a presented fuel-injection controller that manages to control both combustion timing and pressure-rise rate.

Strategies for improving the low-load performance of PPC are studied experimentally, where results show that the selection of injection timings and the use of a pilot injection are important when maximizing the combustion efficiency. The suggested low-load controller demonstrated a 9 % efficiency increase during transient engine operation.

This thesis also investigates the design of a controller that utilizes the degrees of freedom enabled by multiple injections to efficiently fulfill constraints on cylinder pressure, NOx emissions and exhaust temperature. A simulation study shows a potential 2 - 4 % indicated efficiency increase when two injections are used instead of one. These findings motivated the design of a hybrid multiple-injection controller that changes the number of injections depending on operating conditions. The controller designed was capable of reproducing the found efficiency increase experimentally with respect to constraints on pressure and NOx emissions.

A model-predictive pressure controller is also introduced. The controller predicts how the cylinder pressure varies with fuel injection by taking advantage of the estimated heat-release rate and a cylinder-pressure model. This feature was used to adjust fuel-injection timings, durations, and number of injections, for efficient constraint fulfillment in transient engine operation. Experimental results demonstrate that the pressure controller can also be used for tracking of cycle-resolved in-cylinder pressure trajectories, as well as finding the most efficient combustion timing.

Heat-release analysis is an essential component in the pressure-sensor feedback loop. Methods for calibrating heat-release model parameters with the use of engine data, and methods for detecting combustion timings are therefore discussed in the thesis.

The experimental results presented were conducted on a heavy-duty Scania D13 engine with a modified gas-exchange system. The fuel used was a mixture (by volume) of 80% gasoline and 20% n-heptane, to elevate the fuel octane number and allow for longer ignition delays.

STATISTICAL MODELING AND LEARNING OF THE ENVIRONMENTAL AND GENETIC DRIVERS OF VARIATION IN HUMAN IMMUNITY

Bergstedt, Jacob

During the last decade the variation in the human genome has been mapped in fine detail. Next generation sequencing has made it possible to cheaply and rapidly aquire vast amounts of biomolecular information on large cohorts of people. This have enabled large-scale epidemiological studies to investigate the relationships between environmental and genetic factors and human biomolecular traits. It is now possible to map variation in the genomic blueprint for human biology to variation in levels of epigenomic marks, gene expression levels and protein expression levels. This development has opened up the possibility of a "phenomic science": the data-driven study of the interactions between all levels of the relationship between the genotype, the environment, and the phenotype.

The Milieu Intérieur study of Institut Pasteur, Paris, aims at bringing the techno-logical develop-

ments of modern biology to bear on the study of the human immune system in homeostasis. Deep phenotyping has been performed on 1,000 healthy, un-related people of Western European ancestry. The cohort is evenly stratified across sex, and across five decades of life, between 20 and 70 years of age.

In this thesis, we combine the standardised flow cytometry of 173 parameters of innate and adaptive immune cells, genome-wide DNA genotyping, detailed information on life-style and environmental factors and MethylationEPIC array data of the Milieu Intérieur cohort, to identify the genetic and environmental drivers of variation in the human immune system. The increasing complexity of biological data requires the development of new statistical tools. In this work, we aim to integrate developments in machine learning, convex optimization, causal inference, and statistical methodology, to build robust and reliable tools for analysing the high-dimensional and highly complex biomolecular data of the Milieu Intérieur study. We construct a pipeline to perform genome-wide association studies on phenotypes with heterogenous distributions, while controlling for arbitrarily many environmental factors. The pipeline is applied to study the genetics of human immune system variation in homeostasis and the genetics of the function of the human thymus. Our pipeline identifies 15 loci that influence immunophenotypes. We show that these loci are enriched in disease-associated variants. We also report a commongenetic variant, situated within the T cell receptor locus, that increases the production of naive T cells within the human thymus. In addition, we find four key non-genetic factors that drive variation in the healthy human immune system: age, sex, latent cytomegalovirus infection and smoking. Age, sex, and smoking have a broad impact on the innate and the adaptive immune subsystems, while cytomegalovirus infection primarily seems to skew the T cell compartment of the adaptive immune subsystem towards inflammatory subsets. We also show that age and sex influence the function of the human thymus. Immunophenotypes are intimately connected to epigenetic markers in whole-blood. We leverage the >850,000 methylation sites probed in the MethylationEPIC array to build high-dimensional predictive models of 70 immune cell subsets and other traits such as age and smoking status. We employ elastic net regression and stability selection to build sparse, regularized models, and show that they are capable of estimating blood cell composition more accurately and cost-effectively than previous methods. The properties of elastic net regression and stability selection also enable us to investigate the relationship between DNA methylation and immune blood cell composition. This thesis develops methods for, and performs, the analysis of parts of the rich and multifaceted data of the Milieu Intérieur study. With the construction and analysis of this rich observational data we contribute to the young fields of population immunology and human phenomic science. We discover novel associations that will help in understanding the differences between people in vaccination efficacy and susceptibility to common autoimmune and infectious diseases. Finally, we present predictive models that will facilitate the application of immunological markers in the clinics.

Research

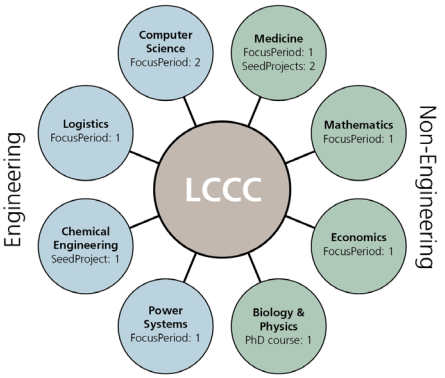
This chapter describes our three main research areas and their ongoing projects

EXCELLENCE CENTERS

LCCC – Lund Center for Control of Complex Engineering Systems
eLLIIT – The Linköping–Lund Initiative on IT and mobile communication
WASP – Wallenberg AI, Autonomous Systems and Software Program
HI2OT – Nordic University Hub on Industrial Internet of Things

The Linnaeus environment Lund Center for Control of Complex Engineering Systems (LCCC) ended in 2018 after 10 years of funding from the Swedish Research Council. It has been a very exciting and successful decade for the department, characterized by a large number of new research directions and results. The Linneaus funding has allowed us to increase the collaborations across borders, connecting subjects, departments and nations. Important instruments for LCCC have been the international workshops and focus periods organized in Lund, where young and more established scientists have met, presented their results, discussed and created new bonds.

Many of the projects presented in this annual report have been initiated under the umbrella of LCCC. They will now continue with funding from other sources, most notably the Wallenberg AI, Autonomous Systems and Software Program. The spirit of LCCC will still be present, as will the personal contacts and cross-disciplinary collaborations, for many years to come.



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Jakob Stoustrup, Aalborg University, Denmark

LCCC has been a very successful research environment where numerous exciting, often interdisciplinary, research results have been obtained. This has become possible through collaborations across borders, connecting subjects, departments and nations.

We closed with a focus period and workshop on Learning and Adaptation for Sensorimotor Control. The purpose of this five week focus period (October 8 to November 9) was to gather outstanding researchers with complementing competences in learning, control, robotics and neuroscience to stimulate exchange of ideas and inspire new research directions. The focus period included a workshop with more than 20 distinguished speakers, held in Lund, October 24-26, 2018.

Two courses were given during the focus period:

- Deep learning smorgasbord (Professor Kalle Åström, Lund University)
- Universal laws and architecture in complex networked systems (Professor John Doyle, Caltech

Workshop speakers

Thomas Wills, UCL, UK
Marie Csete, Caltech, USA
Ondrej Chum, Czech Technical University, Czech Republic
Mathew Diamond, International School for Advanced Studies, Italy
John Doyle, Caltech, USA
Auke Ijspeert, EPFL, Switzerland
Henrik Jörntell, Lund University, Sweden
Hedvig Kjellström, KTH, Sweden
Per Petersson, Lund University, Sweden
Ben Recht, UC Berkeley, USA
Angela Schoellig, University of Toronto, Canada
Terrence Sejnowski, Salk Institute for Biological Studies, USA
Patrick van der Smagt, Technical University of Munich and Volkswagen Group, Germany
Rodolphe Sepulchre, University of Cambridge, UK
Csaba Szepesvari, University of Alberta, Canada and DeepMind, London, GB
Paul Verschure, University Pompeu Fabra, Spain
René Vidal, Johns Hopkins University, USA

C I de Zeeuw, Netherlands Institute for Neuroscience, The Netherlands
Thomas Schön, Uppsala University, Sweden
Jean-Jacques Slotine, MIT, USA
Il Hong Suh, Hanyang University, Korea
Karl Johan Åström, Lund University, Sweden

Visiting scholars
Roshan Shariff, University of Alberta, Canada
Joel Sjöbom, Lund University, Sweden
Maximilian Karl, Technical University of Munich, Germany
Anahita Jamshidnejad, ETH Zürich, Switzerland
Miriam Zacksenhouse, Technion, Israel
Farnaz Adib Yaghmaie, Linköping University, Sweden
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Felix Kong, Sydney University, Australia
Eike Petersen, Lubeck University, Germany
Natalia M. López, National university of San Juan, Argentina
Yorie Nakahira, Caltech, USA

Experiences from the LCCC environment

– Right after my licenciate defense at KTH, I could join the focus period at Lund, which gave me the opportunity to receive constructive feedback on my own research from renowned researchers in the field, get to know different aspects and approaches as well as establish both personal and professional contacts. It was a warm and welcoming environment where students could not only collaborate with the other participants but also enjoy their time together in and around nice Lund.

Arda Aytekin, KTH (visiting scholar 2017)

– I believe that the value of the Linnaeus Lund Center for Control of Complex Engineering Systems to the academic community has been immense. I truly hope that an analogous structure will succeed LCCC at Lund soon, and that it will continue along similar lines in the future.

Tryphon Georgiou, University of California, USA (invited speaker 2014 and 2017)

– The highlight of the focus period was a 3-day workshop with an impressive participation of world-leading researchers. It was an unforgettable experience and a great opportunity to get together with other students and researchers from all over the world. The hosts in Lund did a wonderful job in creating a welcoming and open environment, which made it easy to establish new links and friendships, many of which last until today.

Johannes Schiffer, Brandenburg University of Technology, Germany (visiting scholar 2014)

– The LCCC workshop was an excellent platform to discuss the latest trends in automation. The format of the workshop was very fruitful. I found the discussion rounds, expertly facilitated by Charlotta Johnson, incredibly useful. I am incredibly impressed with the number of control engineers at LCCC which I believe are the centre's greatest assets.

Margret Bauer, University of Pretoria, South Africa (invited speaker 2016)

ELLIIT – THE LINKÖPING–LUND INITIATIVE ON IT AND MOBILE COMMUNICATION

Funding: Government-funded Strategic Research Area

eLLIIT is a large network that brings together complementary research skills from Linköping and Lund universities, as well as from selected research groups at Halmstad University and Blekinge Institute of Technology. The network has been put together in order to meet future challenges within IT and communications in a coordinated and broad manner. Three long-term research topics have been defined and six areas of application have been selected that cover a wide spectrum of future problems in industry and society:

- Mobile broadband
- Industrial automation
- Automotive and aeronautical engineering
- Intelligent buildings
- Healthcare
- Networking in society

eLLIIT stands out by the quality and visibility of its publications, and its ability to attract and retain top talented researchers, and aims at being recognized as a top international research organization.

eLLIIT achieves its goals by a judicious choice of funded focus projects, a structured process for international recruitment, a balanced way of stimulating cooperation between research areas and between the sites involved (LiU, LU, BTH, HH), and a proactive approach towards fostering and maintaining cooperation with Swedish industry.

The Department of Automatic Control participates in eLLIIT in the following ways: Karl-Erik Årzén is a board member of eLLIIT, and Bo Bernhardsson is an eLLIIT professor. The department also participates in the following eLLIIT research projects:

- Co-design of robust and secure networked embedded control systems
- Collaborative robotic systems
- Local positioning systems
- Scalable optimization for control systems
- Online optimization and control towards autonomous vehicle maneuvering

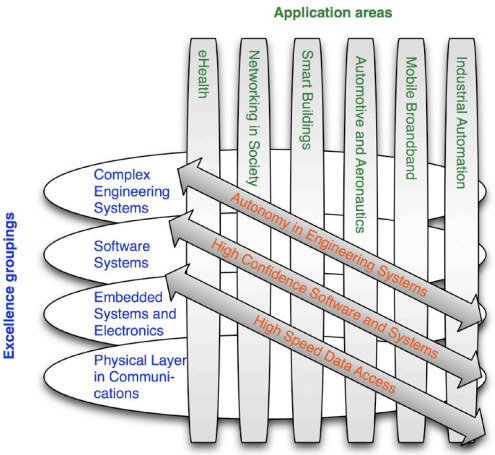


Illustration of the interaction between the themes, the application areas and the groupings (http://www.liu.se/eLLIIT)

Funding: Knut and Alice Wallenberg Foundation (KAW)

WASP—the Wallenberg AI, Autonomous Systems and Software Program funded by the Knut and Alice Wallenberg Foundation (KAW)—is Sweden's largest individual research program ever with a total budget exceeding 3.5 Billion SEK; a major national initiative for strategically motivated basic research, graduate education and faculty recruitment. The program addresses research on artificial intelligence, machine learning and autonomous systems acting in collaboration with humans, adapting to their environment through sensors, information and knowledge, and forming intelligent systems of systems. Software is the main enabler in these systems, and is an integrated research theme of the program.

A vision of WASP is still collaborating vehicles, robots and other complex software-intensive systems with the intelligence to achieve autonomy in interactions with humans. AI, together with software, is an important technology for achieving this. Autonomous systems and AI are scientifically challenging disruptive technologies that will fundamentally change society and industry.

The basis for WASP is the combined competence in electrical engineering, computer engineering, and computer science at Sweden's four major ICT universities: Chalmers University of Technology, Royal Institute of Technology (KTH), Linköping University (LiU), and Lund University (LU), together with Umeå University (UmU). In the AI part of WASP, called WASP-AI, also researchers from selected parts of Uppsala University (UU) and Örebro University (ORU) also participate.

Organizationally WASP consists of two parts: WASP-AS and WASP-AI. WASP-AS stands for WASP Autonomous Systems and Software and WASP-AI contains the AI and machine learning parts of WASP. Each of these parts have their own track in the WASP graduate school. The WASP-AS track contains two courses on autonomous systems, a course on Software Engineering and Cloud Technology, and a project course. The WASP-AI track contains courses on:

- Deep Learning and GANs
- Graphical Models, Bayesian Learning, and Statistical Relational Learning
- Learning Theory and Reinforcement Learning
- Large Scale Machine Learning
- Ethical, Legal, Societal and Economical Aspects of AI
- Topological Data Analysis
- Learning Feature Representations
- Deep Learning for Natural Language Processing

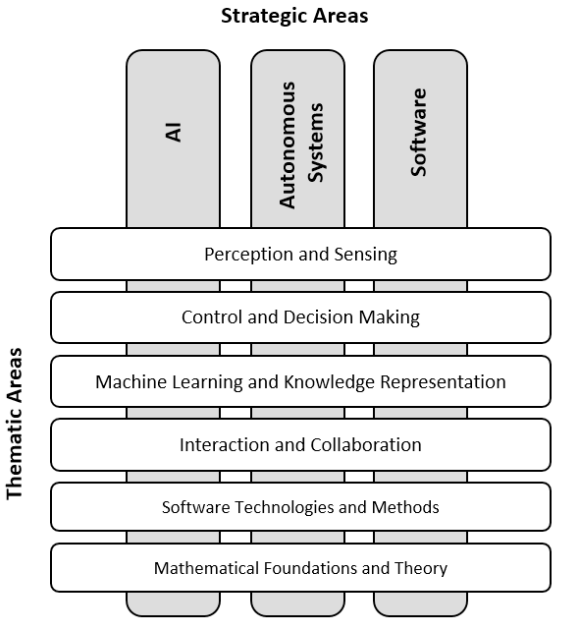
and a project course.

At the end of 2018, WASP was funding more than 150 PhD students out of which 58 were industrial PhD students. There were also 32 PhD students funded from other sources that are affiliated with WASP. In total WASP aims to produce more than 300 PhDs.

WASP also contains a substantial recruitment package. In total more than 50 new professors at different levels with international experience will be recruited to Sweden. Out of these 18 are professors in some subfield of autonomous systems and software and at least 22 are professors in AI or machine learning. At the beginning of 2019 12 of these are in place. So far, Lund University has obtained Volker Krüger, professor in computer science, and Christoph Reichenbach, associate professor in computer science. An assistant professor in mathematics is also under appointment.

The Department of Automatic Control currently has 8 WASP-funded PhD students, including two industrial PhD students from Ericsson and Axis. We have also been granted three postdoc positions, which currently are under appointment. Lund University in total has 30 WASP-funded PhD students out of which 10 are industrial PhD students and five postdocs or junior faculty. In addition, around 5 full-time professor equivalents are funded by WASP for PhD student supervision and WASP management in addition to the recruitments above.

The department is involved in the management of WASP at several levels. Karl-Erik Årzén is the chair of the WASP-AS (the autonomous systems and software part of WASP) Program Management Group, Anders Rantzer is a member of the Program Management Group for WASP-AI/MATH, and Bo Bernhardsson is a member of the Graduate School Management Group for WASP-AS.



The research in WASP can be visualized along two dimensions: Strategic Areas and Thematic Areas. The strategic perspective emphasizes areas of impact on individuals, society, and industry, whereas the aim of the thematic areas is to encapsulate the underlying scientific and technological challenges that are common to all types of autonomous systems. The strategic areas are (i) AI (ii) Autonomous Systems, and (iii) Software. The thematic areas are (a) Perception and Sensing (b) Control and Decision Making, (c) Machine Learning and Knowledge Representation, (d) Interaction and Collaboration, (e) Software Technologies and Methods, and (f) Mathematical Foundations and Theory.

HI2OT – NORDIC UNIVERSITY HUB ON INDUSTRIAL INTERNET OF THINGS

Reseachers: Karl-Erik Årzén, Martina Maggio, Anders Robertsson, Anton Cervin, Johan Eker, Tommi Nylander, Per Skarin, Alexandre Martins, Claudio Mandrioli, Nils Vreman, Albin Heimerson, Johan Ruuskanen, Marcus Thelander Andrén, Marcus Greiff

Partners: DTU – Technical University of Denmark, Lund University, KTH – Royal Institute of Technology, NTNU – Norwegian University of Science and Technology, Aalto University

Funding: NordForsk

The overall aim of HI2OT is to promote Nordic collaboration in Industrial Internet of Things (IIoT), which will increase the capacity of the participating organizations and create the critical mass needed to establish a world-leading Nordic research environment on IIoT.

There will be 50 billion "smart things" worldwide by 2020. When these become interconnected they form the Internet of Things, IoT. Industrial IoT (IIoT) is providing the infrastructure that underpins our Smart Society (Smart Energy Grid, Smart Cities, Smart and Green Mobility, Smart Manufacturing, etc.).

The proposal Nordic University (H)ub on (I)ndustrial (IoT) (HI2OT) is focused on Industrial IoT, a Nordic area of growth and a key technology enabler in solutions to several societal challenges. IIoT will only become a reality through the convergence of Operational and Information Technologies (OT & IT), which are currently separated. This will require multidisciplinary large-scale research effort. Hence, HI2OT brings together the strongest Nordic research groups in IIoT (8 groups at 5 universities) to form a long-term partnership for expanding IIoT cooperation in the Nordic region.

The overall aim of HI2OT is to promote Nordic collaboration in IIoT, which will increase the capacity of the participating organizations and create the critical mass needed to establish a world-leading Nordic research environment on IIoT. HI2OT provides a unique integration of expertise, generating the synergies required to support the convergence of IT and OT. HI2OT will build a platform and a community to strengthen and structure the IIoT research and innovation. This will enhance strengthen national research and innovation systems by increasing their capacity, increase the ability of Nordic nations to address European and global cooperation and competition in IIoT, as well as increasing their competitiveness and growth via research and innovation.

The current Nordic IIoT research efforts are fragmented and address local national industries, lacking the necessary mass to become an international area of excellence. Research infrastructures are not cost-efficient, and will require the pooling of resources through increased coordination. HI2OT will build a platform and a community to strengthen and structure the IIoT research and innovation. HI2OT fits perfectly with the objectives of the participating universities, who have explicit IIoT strategies and strategies for Nordic cooperation. HI2OT will enhance the competitiveness of participating institutions, strengthen national research and innovation systems by increasing their capacity, and increase the ability of Nordic nations to address European and global cooperation and competition in IIoT.

RESEARCH AREAS

The goal of the department is to provide students with a solid theoretical foundation combined with a good engineering ability. This is reflected in the research program which covers both theory and applications. The research activities can roughly be divided into three thematic areas:

LARGE-SCALE SYSTEMS AND LEARNING	AUTONOMOUS REAL-TIME SYSTEMS	INNOVATIVE CONTROL APPLICATIONS

Our major sources of funding for the research are currently

- Lund University faculty funding
- VR – Swedish Research Council
- KAW – Knut and Alice Wallenberg Foundation
- SSF – Swedish Foundation for Strategic Research
- Vinnova – Sweden's Innovation Agency

More details can be found in the chapter *Economy.*

LARGE SCALE SYSTEMS AND LEARNING

Dynamics, Information and Control in networks
Large-Scale Convex Optimization
Learning and Adaptation

DYNAMICS, INFORMATION AND CONTROL IN NETWORKS

Researchers: Carolina Bergeling, Martin Heyden, Gustav Nilsson, Richard Pates, Giacomo Como, Anders Rantzer

Funding: Swedish Research Council and Swedish Foundation for Strategic Research

Large-scale networks play a constantly increasing role in our modern society, e.g., affecting the access to essential services like mobility and energy, influencing the outcome of electoral polls, and determining the quality of the economic system.

The Department hosts a research group on Dynamics, Information and Control in Networks. The focus of this group is on the mathematical foundations of large-scale network systems with particular emphasis on issues related to their resilience, centrality and scalability. Applications include cyber-physical systems, transportation networks, as well as social and economic networks.

One project is focused on transportation networks, with publications about decentralized traffic signal control and distributed dynamic tolls.

Another project studies the interplay between economics and traffic flows in transport networks. We will study exchange equilibria in traffic networks and network dynamics in presence of human decision makers. The goal is to gain deeper understanding of, and be able to exploit, the interaction between node demands and network flows.

LARGE SCALE CONVEX OPTIMIZATION

Researchers: Pontus Giselsson, Mattias Fält, Martin Morin, Hamed Sadeghi

Funding: Swedish Foundation for Strategic Research

Large-scale optimization problems appear naturally in many engineering fields such as machine learning, signal processing, image reconstruction, control, and bioinformatics. The research in this group is focused on efficient algorithms for solving such problems. The primary focus is on deterministic and stochastic operator splitting methods as they can scale to solve very large problems. We analyze convergence and performance of existing methods and use this insight to devise new algorithms with improved performance.

LEARNING AND ADAPTATION

Researchers: Johan Grönqvist, Christian Rosdahl, Bo Bernhardsson, Anders Rantzer

Funding: Wallenberg AI, Autonomous Systems and Software Program

There are many important applications where classical physics based models need to be combined with machine learning tools. A good example is in autonomous driving, where automotive industry have extensive experience of control technology such as ABS braking, cruise control and ESP systems for vehicle stabilization. This technology now needs to be combined with machine learning methods to analyse traffic situations and human behavior. To do this in a safe and robust manner, it is essential to understand how learning algorithms for discrete sequential decision-making can interact with continuous physics based dynamics. Many other applications can be found. In the energy sector, well established control solutions for power networks and generators are increasingly being combined with learning algorithms for consumer behavior and decision-making, to minimize costs and optimize efficiency. In medicine, standard practice for disease therapies is combined with expert systems and sequential decision-making for medical diagnosis.

In our collaboration project with Alexandre Proutiere at KTH, the aim is to bridge the gap between machine learning and control engineering. These research fields have traditionally evolved more or less separately, but in recent years the intersections in terms of applications as well theoretical challenges have been growing. This project is concerned with sequential decision making in systems whose dynamics are initially unknown, i.e. with adaptive control or reinforcement learning. Statistical models are of fundamental importance in both areas, but while learning theory has been focused on sample complexity and regret, the corresponding control literature is discussing stability robustness and asymptotic performance. A important focus of our project is the tradeoff between exploration and exploitation, sometimes known as *dual control*. The optimal tradeoff strategy can be formulated as the solution to a dynamic programming problem. We study properties of the solution as well as computational schemes. Optimal strategies are compared with common heuristics, both in control and reinforcement learning.

AUTONOMOUS REAL-TIME SYSTEMS

Autonomous Cloud
Autonomous Datacenters – AutoDC
Co-Design of Robust and Secure Networked Embedded Control Systems
Event-Based Control and Estimation with Application to Server Systems
Feedback Computing in Cyber-Physical Systems
Testing of Autonomous Systems
Industrial Cloud Sandbox

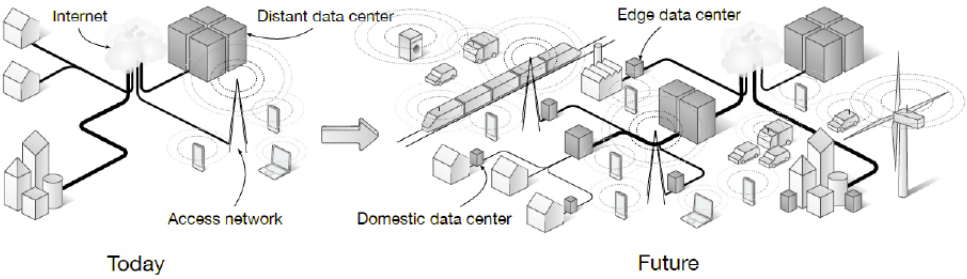
AUTONOMOUS CLOUD

Researchers: Karl-Erik Årzén, Martina Maggio, Johan Eker, Tommi Nylander, Per Skarin, Alexandre Martins, Victor Millnert, in collaboration with the Department of Electrical and Information Technology at LTH, Umeå University and KTH.

Funding: Wallenberg AI, Autonomous Systems and Software Program

Background
An increasing amount of computing and information services are moving to the cloud, where they execute on virtualized hardware in private or public data centers. Hence, the cloud can be viewed as an underlying computing infrastructure for all systems of systems. The architectural complexity of the cloud is rapidly increasing. Modern data centers consist of tens of thousands of components, e.g. compute servers, storage servers, cache servers, routers, PDUs, UPSs, and air-conditioning units, with configuration and tuning parameters numbering in the hundreds of thousands. The same increasing trend holds for the operational complexity. The individual components are themselves increasingly difficult to maintain and operate. The strong connection between the components furthermore makes it necessary to tune the entire system, which is complicated by the fact that in many cases the behaviors, execution contexts, and interactions are not known a priori. The term autonomous computing or autonomic computing was coined by IBM in the beginning of the 2000s for self-managing computing systems with the focus on private enterprise IT systems. However, this approach is even more relevant for the cloud. The motivation is the current levels of scale, complexity, and dynamicity which make efficient human management infeasible. In the autonomous cloud control, AI and machine learning/analytics techniques will be used to dynamically determine how applications should be best mapped onto the server network, how capacity should be automatically scaled when the load or the available resources vary, and how load should be balanced.

Currently there is also a growing interest in applying cloud techniques, such as virtualization and collocation, in the access telecommunication network itself. The unification of the telecom access network and the traditional cloud data centers, sometimes referred to as the distributed cloud, provide a single distributed computing platform. Here the boundary between the network and the data centers disappears, allowing application software to be dynamically deployed in all types of nodes, e.g. in base stations near end-users, in remote large-scale datacenters, or anywhere in between. In these systems the need for autonomous operation and resource management becomes even more urgent as hetero-



The following figure illustrates how the computations in the distributed cloud are migrating from back-end data centers out in the network.

geneity increases, when some of the nodes may be mobile with varying availability, and when new 5G-based mission-critical applications with harder requirements on latency, uptime, and availability are migrated to the cloud.

In the project distributed control and real-time analytics will be used to dynamically solve resource management problems in the distributed cloud. The management problem consists of deciding the types and quantities of resources that should be allocated to each application, and when and where to deploy them. This also includes dynamic decisions such as automatic scaling of the resource amount when the load or the available resources vary, and on-line migration of application components between nodes. Major scientific challenges include dynamic modeling of cloud infrastructure resources and workloads, how to best integrate real-time analytics techniques with model-based feedback mechanisms, scalable distributed control approaches for these types of applications and scalability aspects of distributed computing.

In order to develop efficient methods for resource management, it is crucial to understand the performance aspects of the infrastructure, what the workloads look like, and how they vary over time. Hence, Infrastructure modeling and Workload modeling for the distributed cloud are important topics. Due to user mobility and variations in usage and resource availability, applications using many instances are constantly subject to changes in the number of instances; the individual instances relocated or resized; the network capacity adjusted; etc. Capacity autoscaling is needed to determine how much capacity should be allocated for a complete application or any specific part of it; Dynamic component mapping to determine when, where, and how instances should be relocated, e.g. from a data center to a specific base station; and Optimized load mix management to determine how to "pack" different instances on individual servers or clusters. Since not all applications are equally important, e.g. due to differently priced service levels or due to some being critical to society (emergency, health care, etc.), the solutions to the three problems above must take into account Quality of Service differentiation. Finally, we address Holistic management to perform full-system coordination.

The primary software infrastructure will be based on Calvin, an open source application environment developed by Ericsson and aimed at distributed clouds for IoT services. Calvin is based upon on the well-established actor model, it scales well and it supports live migration of application components. We believe this infrastructure is suitable to investigate the application performance behavior of future commercial systems and validate our developed management solutions. It will enable accurate estimations of, for example, application latency and system loads.

The project results have the potential to be demonstrated in several WASP demonstrator arenas, including the Autonomous Research Arena (ARA), the Ericsson Research Data Center (ERDC); as well as in different university lab facilities.

AUTONOMOUS DATACENTERS – AUTODC

Researchers: Karl-Erik Årzén, Johan Eker and Albin Heimerson, in collaboration with KTH, Luleå University, Aalto University, Ericsson, RISE, and twelve other partners

Funding: Vinnova

With growth in the data centre market expected to continue, the cost of operating and maintaining the data centre footprint will increase. The aim of AutoDC is to provide an innovative design framework for autonomous data centres to enable ongoing operation and self-healing independent of contextual interference, e.g. intermittent power failure or overheating, without the need for any human intervention. Due to lower maintenance and operation costs, autonomous data centres can become key enablers of markets in developing countries.

The AutoDC project is led by Tor Björn Minde, Ericsson and consists of the following partners:

- Austria: AICo Software, Fluxguide
- Canada: Ericsson, Mariner Partners, Missing Link Technologies, Saint Mary's University
- Finland: Aalto University, Granlund Oy, kW-set Oy, Orbis Oy
- Sweden: 5 High Innovations, Clavister, Comsys, Ericsson, KTH, Luleå University of Technology, OP5, RISE, Swedish Modules, Swegon Operations

CO-DESIGN OF ROBUST AND SECURE NETWORKED EMBEDDED CONTROL SYSTEMS

Researchers: Nils Vreman, Martina Maggio, Anton Cervin and Karl-Erik Årzén, in collaboration with the Embedded Systems Lab at Linköping University and the Real-Time Systems Lab at Sant'Anna School of Advanced Studies in Pisa

Funding: eLLIIT

In the design of embedded control systems it is important to use the limited platform resources (e.g. CPU time, network bandwidth, energy) as efficiently as possible. At the same time, any optimistic assumptions at design time may lead to runtime failures caused by missed deadlines, lost controls, or energy depletion. In this project we aim to develop theory and co-design methodology for robust and secure embedded control systems that should operate efficiently also in the presence of uncertainties or unforeseen events. We will consider robustness towards, among other things, plant perturbations, malicious intrusion, execution-time overruns, and varying network capacity. One aspect of high interest is intrusion detection for highly resource-constrained control applications. In such a context, solutions have to deliver not only according to the traditional metrics of false-positive and false-negative, but also perform well according to new, specific quality metrics: detection latency, power consumption, processor load, and communication overhead.

During 2018, Nils Vreman joined the department as a PhD student and started to work in the project with Martina Maggio as main supervisor. The work is currently focused on mitigating side-channel attacks in real-time systems via schedule randomization. The idea is to in each hyperperiod choose randomly between a set of static schedules to hide the temporal execution. The minimal cardinality and the optimal diversity among the schedules have been studied.

In a parallel line of research, we have started to develop a new tool for analysis of real-time controller performance, called JitterTime. The tool has been used by visiting PhD student Paolo Pazzaglia to evaluate the performance of control tasks that experience deadline overruns.

EVENT-BASED CONTROL AND ESTIMATION WITH APPLICATION TO SERVER SYSTEMS

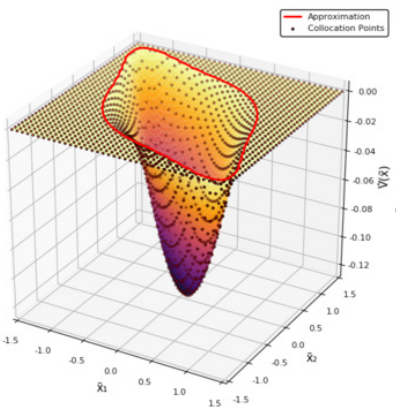
Researchers: Marcus Thelander Andrén, Johan Ruuskanen, Anton Cervin, Bo Bernhardsson, Kristian Soltesz

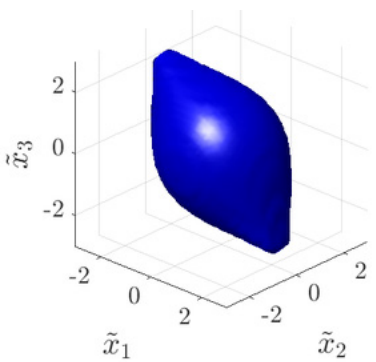
Funding: Swedish Research Council and Wallenberg AI, Autonomous Systems and Software Program

With the current strong trend towards networked and autonomous systems, it becomes less realistic to demand that all elements of a control loop should operate in a synchronous, time-triggered fashion. Above the lowest level of feedback control, it is often more natural and efficient to communicate, decide, and act based on events. Previous work show that event-triggered control can achieve both lower average sampling rates and better performance than standard, periodic control. However, there is not yet a coherent theory for analysis and synthesis of event-based controllers.

This project tackles both theoretical and practical problems related to event-based control and estimation. For linear reset systems, we study how events should optimally be generated and analyze the resulting trade-off between performance and event rates. We use particle filters and other nonlinear estimation methods to estimate states and parameters in event-based systems. As an application, we study server and cloud systems, both in simulations and in testbeds. Such systems are inherently event-driven as incoming connections and their responses occur as spontaneous events. The results can help to optimize resource usage (CPU, network, power consumption) in embedded and cloud systems.

During 2018 we have developed a numerical algorithm for solving a class of free boundary partial differential equations, whose solutions are key when designing optimal event-based sampling policies (see figures below). We have also developed an extension of the Auxilary Particle Filter for systems with event-based measurements. Finally, we have begun an investigation on how to optimally implement event-based PID controllers.





Numerical algorithm using radial basis functions (RBFs) to compute the optimal event-based sampling policy. Sampling should be triggered whenever the estimation error exceeds a threshold (red line to the left). The example to the right shows the optimal triggering policy for a third-order system.

FEEDBACK COMPUTING IN CYBER-PHYSICAL SYSTEMS

Researchers: Karl-Erik Årzén, Johan Eker, Martina Maggio, Victor Millnert and Gautham Nayak Seetanadi in collaboration with the Department of Computer Science at LTH and the University of Turin, Italy

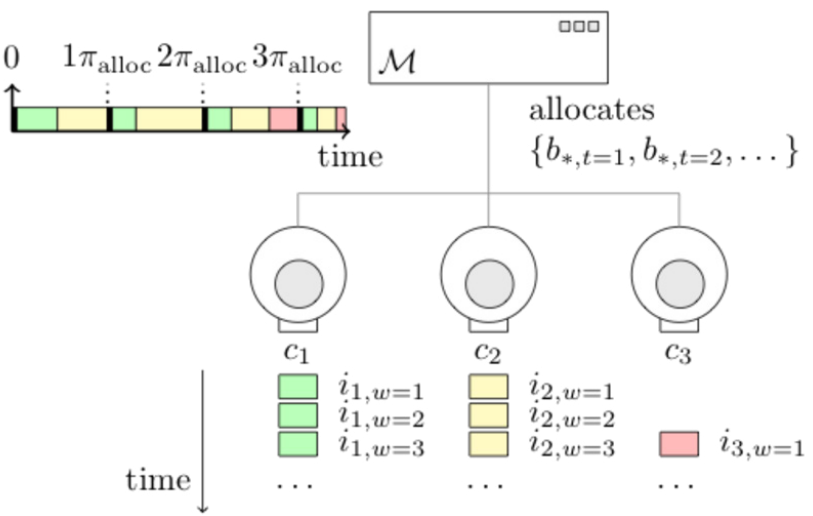
Funding: Swedish Research Council

Cyber-Physical Systems (CPS) have emerged as a unifying concept for systems whose computational aspects are tightly integrated with the physical world. CPSs have often a strong focus on resource-efficiency, i.e. power efficiency and thermal constraints are important. The close interaction with the physical environment and humans also lead to a high level of uncertainty, i.e. it is difficult to specify how the system will be used, what the requirements are, and what the load will be. This has consequences for the computational parts of CPS. Static designs are unrealistic. Instead, the systems must dynamically react to changing conditions. They need to take action based on on-line measurements of performance, resource consumption etc., i.e. they must be based on feedback.

The objective is to develop a unified approach to feedback computing that covers: embedded systems, massively parallel manycores, desktop systems, and distributed systems. The aim of the control is either to improve performance, e.g. reduce latency or increase throughput, or to reduce resource consumption. The project emphasizes the development of generic techniques that can be employed within several or all of the four areas mentioned above.

The project is divided into three parts:

- Feedback computing for the distributed cloud (Johan Eker, Victor Millnert, Enrico Bini)
- Feedback computing for distributed camera systems (Martina Maggio, Gautham Nayak Seetanadi, Karl-Erik Årzén)
- Feedback Computing for manycores (Jorn Janneck)



TESTING OF AUTONOMOUS SYSTEMS

Researchers: Claudio Mandrioli, Martina Maggio

Funding: Wallenberg AI, Autonomous Systems and Software Program

Many cyber-physical systems change their behaviour depending on environmental data and internal states. This is the case of control systems, that compute a control signal that depends on input values like a desired position, measured values like the current position, and internal states like the previous control action. This is also the case of systems embedding machine learning algorithms, that receive new samples and incorporate what they learnt using these new samples into a policy that determines how to behave in new conditions. All these systems are adaptive, in that their behaviour changes over time in a prescribed - but a priori unpredictable - way. This project is about testing and comparing systems that incorporate some adaptivity.

Testing systems whose behaviour varies over time is difficult. Think of a machine learning algorithm: how many and which samples should we give to the system before we can consider its behaviour testable? And what is the correct outcome? Of course we can apply unit testing to each function in the code, check for coverage, select a few cases in which the ideal behaviour of the code is known. But this does not give us any guarantee that the code is behaving correctly for the task it has to complete in the physical environment.

We advocate that a formal and rigorous methodology is needed to test systems with adaptivity like self-adaptive software. This methodology should be used in conjunction with other forms of testing (e.g., unit testing) to provide guarantees on the cyber-physical system behaviour.

When learning is involved, it is impossible to provide any deterministic guarantees, since the function to be learnt may not have been explored. In such cases, drawing any general conclusion is impossible (and undesirable), unless probabilistic guarantees are targeted. We are convinced that this is true also for adaptive software and a paradigm shift is necessary for its testing: guarantees deriving from the tests' execution should be provided in the probabilistic space rather than in the deterministic one.
In the probabilistic space, we plan to investigate three alternatives methods to analyze testing data and provide guarantees:

- Monte Carlo experiments
- Extreme Value Theory
- Scenario Theory

Since the project start in 2018, the first activity has been the investigation of the theoretical tools that can be used, with a particular focus on the scenario theory. Secondly, we implemented a simulated infrastructure for testing a self-adaptive application (the Tele Assistance System) in Matlab. We plan to use this as a benchmark example to illustrate our ideas.

INDUSTRIAL CLOUD SANDBOX

Researchers: Johan Eker and Charlotta Johnsson in collaboration with Ericsson and Umeå University

Funding: Vinnova

Industrial Cloud Sandbox (ICS) is a national cloud environment for Swedish industry and academia, enabling collaboration around research and innovation in AI, IoT and industrial applications. The vision of the environment is to provide knowledge and cloud resources supporting the digitalization of Swedish industry.

INNOVATIVE CONTROL APPLICATIONS

Robotics Lab
Semantic Mapping and Visual Navigation for Smart Robots
Smart Assembly Robots with Advanced Functionalities (SARAFun)
The Surgeon's Perspective
Autonomous Flight (LUAV@Lund)
Control of the European Spallation Source
Closed-Loop Combustion Control
Decentralized Control Structures for Process Control
Anesthesia in Closed-Loop
Hemodynamic Stabilization
On Humans for Humans
Ventilator for Improved Cardiopulmonary Resuscitation
Strategies and Standards for Smart Swedish Industry
Mind Methodology

The department has many research projects related to automatic control. In this section we are listing the Innovative Control Applications, i.e. the ones that are 1) ongoing, 2) target a clear application, and 3) includes innovation.

Innovation is defined as the introduction of something new or different. The act of innovation leads to the introduction of new ideas, devices and methods. Innovation is crucial for economic growth and development of countries as well as organisations.

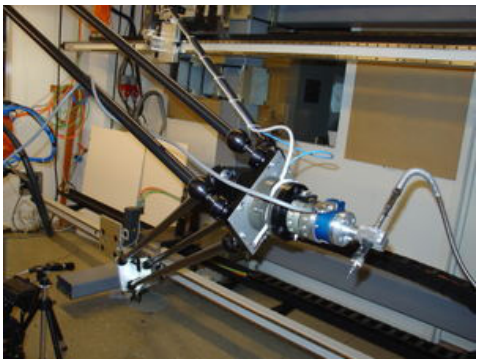
Our application areas are:

- Robotics
- Health care
- Process industry
- Industry 4.0 / Smart Manufacturing
- Standardisation
- Drones
- Combustion engines

The majority of the Innovative Control Applications are co-funded by industrial partners.

The innovative control applications are driven by the desire to benefit the world and our future society:

We adress all five Benefit-areas of LTH's vision (see left figure). We want our projects to contribute to the benefit of Life / Industry / Digitalization / Climate / Society.



ROBOTICS LAB

The Robotics Lab at LTH is an experimental arena shared by the Department of Automatic Control and the Department of Computer Science. Robotics is a multi-disciplinary topic, and we collaborate with both national and international robotics colleagues regarding different aspects of robotics and we also have a close cooperation with industrial partners. Our main research is in motion and compliance control, control system architectures and different sensor fusion problems with application mainly to industrial manipulators. We use mainly modified industrial robot systems and mobile robots including UAVs as experimental platforms.

The purpose of past and present research projects is to show how to organize open robot control systems and to verify these ideas by means of experimental verification. As a part of this research, we have developed several experimental open robot control systems. The systems are built around industrially available robots that have been reconfigured for experimental purposes.

The developed specific robot interfaces and the integration of the robots into a complete system forms a unique environment for testing and development of algorithms for improvement of performance, sensor integration, programming automation and autonomous operation. New sensor interfaces with modification of hardware and realtime software architectures have been developed to accommodate the use of force control algorithms based on workspace sensing. The research in this area has been awarded with e.g., the EURON Technology Tranfer award and an ICRA Best Automation paper.

Current robotics-related projects at the department include:

- SARAFun – Smart Assembly Robots with Advanced FunctionalitiesSemantic
- Mapping and Visual Navigation for Smart Robots
- The Surgeon's Perspective
- Autonomous Flight

SEMANTIC MAPPING AND VISUAL NAVIGATION FOR SMART ROBOTS

Researchers: Marcus Greiff, Bo Bernhardsson, Anders Robertsson with colleagues from the Centre for Mathematical Sciences and Chalmers University of Technology

Funding: Swedish Foundation for Strategic Research

Why is it that today's autonomous systems for visual inference tasks are often restricted to a narrow set of scene types and controlled lab settings? Examining the best performing perceptual systems reveals that each inference task is solved with a specialized methodology. For instance, object recognition and 3D scene reconstruction, despite being strongly connected problems, are treated independently and an integrated theory is lacking. We believe that in order to reach further, it is necessary to develop smart systems that are capable of integrating the different aspects of vision in a collaborative manner. We gather expertise from computer vision, machine learning, automatic control and optimization with the ambitious goal of establishing such an integrated framework.

The research is structured into four work packages:

- Scene modelling
- Visual recognition
- Visual navigation
- System integration to achieve a perceptual robotic system for exploration and learning in unknown environments

As a demonstrator, we will construct an autonomous system for visual inspection of a supermarket using small-scale, low-cost quadcopters. The system goes well beyond the current state-of-the-art and will provide a complete solution for semantic mapping and visual navigation. The basic research outcomes are relevant to a wide range of industrial applications including self-driving cars, unmanned surface vehicles, street-view modelling and flexible inspection in general.

SARAFUN - SMART ASSEMBLY ROBOTS WITH ADVANCED FUNCTIONALITIES

Researchers: Rolf Johansson, Anders Robertsson, Fredrik Bagge Carlson, Martin Karlsson

Funding: European Community's Framework Programme Horizon 2020

The Smart Assembly Robots with Advanced Functionalities (SARAFun) project has been formed to enable a non-expert user to integrate a new bi-manual assembly task on a robot in less than a day. This will be accomplished by augmenting the robot with cutting edge sensory and cognitive abilities as well as reasoning abilities required to plan and execute an assembly task.

The research, leading to these results, has received funding from the European Community's Framework Programme Horizon 2020 – under grant agreement No 644938 – SARAFun.

Over the last 30 years, robots have brought remarkable efficiency gains to industrial manufacturers, mainly in the automotive industry. Traditional industrial robots perform their assignments in cages and are heavily dependent on hard automation that requires pre-specified fixtures and time-consuming programming and reprogramming performed by experienced software engineers. The assembly application has always been considered as a promising robotic application but in reality it has proven challenging to automate due to e.g. complex materials, precise grasping requirements, part variations, operations requiring high precision (snap fits), operations requiring special motions (twist insertions) and wear and tear of the assembly equipment. While robotic assembly does exist, it has only been applied in a fraction of the potential cases. As a result, nowadays even expensive products produced in fairly large volumes, are still assembled manually in low wage countries under harsh conditions.

There is also a clear trend towards a shorter product lifetime. In order to be able to handle "burst" production (i.e. ramp up to full volume in very short time, run production for 3-12 months, and then change to new model) the lead time for setting up a production line/cell must be drastically reduced.

SARAFun Final Review successfully took place in Västerås on April 12, 2018.

THE SURGEON'S PERSPECTIVE

Researchers: Charlotta Johnsson, Anders Robertsson and Martin Karlsson in collaboration with colleagues at Linköping University, Skåne University Hospital, Business Region Skåne, Cognibotics...

Funding: Vinnova

Today's surgical reports consists of a written textual presentation which only the surgeon and the corresponding core-team can understand. One goal is to improve tomorrow's surgical reports by replacing it with a film with 3D-images in high resolution. In this way, the report will be more complete and understandable for a larger audience. In addition, they can serve as a learning plattform useful for e.g. students in medicine, and practicing surgeons preparing for a similar operation. Robotics is needed when collecting the film material and 3D-images, in order to track the precise perspective of the surgeon. Our vision is to provide the hospitals with modern surgical reports, which also facilitates for improved learning in surgical operations and healthcare.

The live surgical field, as the surgeon visually perceives it, contains invaluable image information needed for surgical training, clinical consultations and support the development of surgical robots. How ever, access to the surgeon's view of the reality is highly restricted because there are currently no technical solutions to collect, reproduce, and share this 3-D image information. At the present, only the surgeon can see the organs and pathologies that need surgical attention.

The goal of this project is to develop technical solutions to collect image data during open heart surgery, and to reproduce 3-D heart models that can be used for education, clinical consultations, and in the future advance the development of autonomous robotic systems. The overall goal is to achieve increased safety and quality in surgical care.

Components that will be developed:

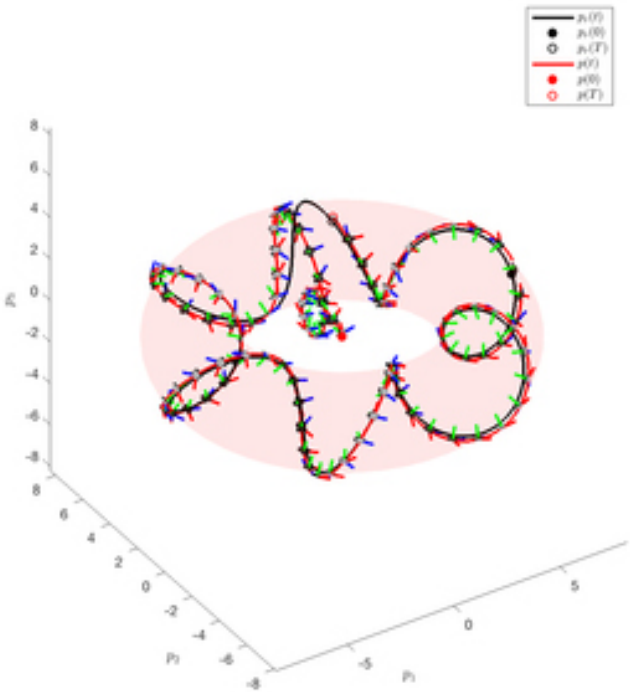
- A camera system for collection of 3-D video images
- A platform for interactive visualisation of the surgical field
- A database that within 3 years will collect data from 5000-10000 surgical cases, for use in machine learning algorithms, augmented reality, and ultimately robotic surgery

AUTONOMOUS FLIGHT (LUAV@LUND)

Researchers: Rolf Johansson, Marcus Greiff, Anders Robertsson and Zhiyong Sun in cooperation with partners at 17 other departments at Lund University

Funding: Lund University cooperation grant

The project aims at strengthening the capacity within Lund University to address the societal needs by establishing an interdisciplinary platform for the development and application of autonomous drone systems for a variety of societal sectors. Within the platform, the aim is to connect and tie together established technology development (e.g. robotics, AI, image processing), research application (e.g. remote sensing and the study of cultural heritage) and applications in different societal sectors (e.g. forestry, agriculture, energy, construction, rescue operations) to make them inform of each other in a collaborative learning environment and create new synergies. We also aim to incorporate and integrate user views and perspectives to enable the development of knowledge and innovation directed towards private companies as well as the public sector. The project is expected to result in an increased network of collaborating partners, interdisciplinary grants for research and demonstrable applications for autonomous drone operations in the selected areas.



CONTROL OF THE EUROPEAN SPALLATION SOURCE

Researchers: Bo Bernhardsson, Rolf Johansson, Olof Troeng, Björn Olofsson in collaboration with the Department of Electrical and Information Technology

Funding: European Spallation Source

The European Spallation Source will be a major user facility at which researchers from academia and industry will investigate scientific questions using neutron beams.

Neutron methods provide insights about the molecular building blocks of matter not available by other means. Applications include research in life science, soft condensed matter physics, chemistry of materials, fundamental particle physics and engineering materials.

The need of cavity field control

The protons will be accelerated by oscillating electromagnetic fields confined in metal structures called RF cavities. In total there will be 155 RF cavities of six different types along the more than 400 meters long linear accelerator. In terms of average power, the ESS accelerator will be the world's most powerful.

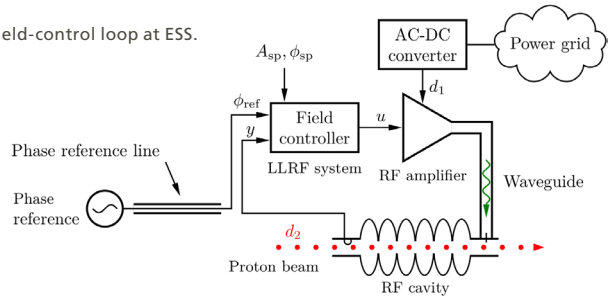
To properly accelerate the protons it is crucial to accurately control the amplitudes of the electromagnetic fields, as well as their phases relative to the protons. Otherwise, the protons get the wrong velocity, and get deflected into the cavity walls, causing radioactivation.

Cavity Field Control

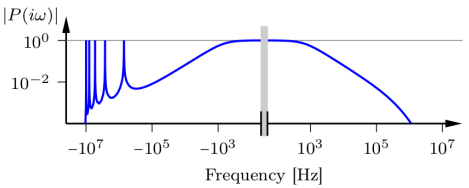
To conrol the cavity fields, feedback loops with sampling frequencies of 10 MHz will be used. Our department is involved in system modeling and controller design for the these loops, as well as supporting the requirement engineering for RF system components. The work is coordinated by this group at the Department of Electrical and Information Technology.

Our analysis of the field-control loop has been based on an equivalent complex-valued baseband representation of the system dynam-

Schematic of the field-control loop at ESS.



Bode magnitude diagram for the 6-cell, ESS medium-beta cavity. Note that parasitic resonances only occur at negative frequencies, manifesting the complex-coefficient nature of the system.



ics. This representation is well known, but it has not previously been used for control design. With the complex-valued representation, the cavity dynamics takes the form of a single-input single-output system, which greatly simplifies the analysis.

Temperature Control of Phase-Reference Line

In order to distribute the reference phase from the master oscillator to the beam position monitors and the 155 cavity field control loops with sufficiently small drift, requires that the more than 500 meters long phase distribution line is temperature stabilized to less than a tenth of a degree.

Our department is involved in the design and development of the temperature control system for the phase distribution line. The research performed includes modeling and simulation of the control system as well as experimental evaluations on a prototype of the phase-reference distribution system.

Compensation of Lorenz-Force Detuning

The high strengths of the electro-magnetic fields in the super conducting cavities leads to mechanical deformation cavity wall, which changes their fundamental resonance frequency. This leads to reduced efficiency and makes the RF field control problem harder. Our department will, together with collaborating European universities, design the control algorithm for the piezo-electric compensation system that will be used to counter-act the Lorenz force detuning. The work is coordinated by this group at the Department of Electrical and Information Technology.

OTHER INVESTIGATIONS

Simulations of Cryogenic Distribution Line at ESS

The cryogenic system at ESS has been modeled in Dymola. Simulations have been made of the cool-down and warm-up of the superconducting section of the linear accelerator. Also the required capacity of the helium safety discharge system has been investigated.

CLOSED-LOOP COMBUSTION CONTROL

Researchers: Rolf Johansson and Gabriel Turesson in cooperation the Division of Combustion Engines, Lund University

Funding: Competence Center Combustion Processes (KCFP)

A fourth term of has now been granted Competence Center of Combustion Processes (KCFP) for the time interval 2018-2021 with a budget of 30MSEK per year. Previous KCFP program terms covered the years 2006-2009, 2010-2013 and 2014-2017. In May 2018, Gabriel Turesson defended his PhD thesis.

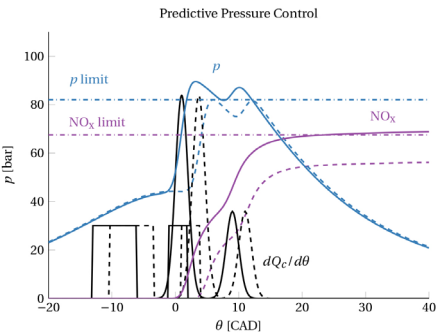
KCFP focuses on research of combustion processes between HCCI (Homogeneous Charge Compression Ignition) and classical Otto and Diesel engines.

Project aims:

- Reducing emissions, improving efficiency and repeatability of HCCI and partially premixed combustion (PPC) using closed-loop control
- Control-oriented modeling and simulation of combustion processes
- Model-based control and optimization evaluated on test beds

During the project phase from 2014 to 2017, research has been focused on implementing PPC in a multi-cylinder heavy-duty engine with the objective of advancing the concept from manual operation in steady state towards autonomous and transient operation. Controllers have been designed to regulate ignition delay and pressure-rise rate and to improve low-load operation. The ignition delay determines the degree of premixed combustion and is essential for successful PPC operation. Premixed combustion can give rise to violent combustion and high pressure-rise rates. This can be avoided with the use of small pilot fuel injections. Pilot-injection adjustment with feedback control was used to keep the pressure-rise rate below specified levels. It has also been found that pilot injections are necessary for improvement of charge ignitability at low engine load where PPC traditionally have had difficulties to operate with sufficient reliability. The designed controllers have been evaluated experimentally in the engine laboratory at Lund University.

During 2017, model predictive control has been used to efficiently fulfill constraints on cylinder pressure, NOx emissions and exhaust temperature with multiple injections. It has been shown that multiple injections can be used to increase efficiency with 2 to 4 % if restrictive constraints are imposed. The principle of this control method is to utilize a linearized cylinder pressure model and a novel heat-release detection method, in order to predict how cylinder pressure and NOx emissions vary with fuel-injection timings, see Fig.1.



Model predictive control has been utilized to efficiently fulfill constraints on cylinder pressure and NOx emissions with the use of multiple injections. This figure illustrates how the controller predicts a deviation in pressure, NOx formation and heat release rate (dashed) from the previous cycle data (solid).

DECENTRALIZED CONTROL STRUCTURES FOR PROCESS CONTROL

Researcher: Tore Hägglund

Funding: Vinnova

This project aims to revise, improve, and develop new basic control strucrures for decentralized control used in the regulatory control layer in process control. However, the ideas to be investigated in this project are relevant in other application areas as well.

Low-order Feedforward Controllers

Feedforward is a powerful method to improve the performance of feedback loops. Feedforward can be made both from setpoint and measurable load disturbances. In this project, the goal is to improve both structures and design methods for feedforward control from load disturbances.

The basic idea for design of feedforward compensators is simple. The ideal compensator is formed as the dynamics between the load disturbance and the process output, divided by the dynamics between the control signal and the process output, with reversed sign. However this ideal compensator is seldom realizable. Therefore, there is a need for design methods for feedforward controllers.

In a first phase, new simple tuning rules for feedforward compensators have been derived. The design objective is to minimize IAE without getting any overshoot in step load disturbance responses. This work has been done in collaboration with University of Almeria. This collaboration continues, and University of Brescia has also been involved in the project where e.g. performance indices for feedforward control have been developed.

Using a structure that decouples feedback and feedforward action, optimal design rules that minimizes ISE has been developed. The used structure simplifies tuning of the feedforward controller by allowing the controller to be tuned with respect to the open-loop system while maintaining its properties and performance when used in a closed-loop setting. The structure also enables independent re-tuning of both the feedback and the feedforward controller. Work has also been done concerning characterization of optimal low-order feedforward controllers and practical considerations for implementation.

PID controllers is often implemented with set-point weighting to improve the response to changes in the reference. By using convex optimization techniques the parameters for the set-point weights can be found efficiently, fast as well as be guaranteed to be globally optimal. By solving an optimization problem to find the optimal set-point weights for a large batch of processes, tuning rules have been found that minimizes IAE. The same optimization framework and formulations can also been used to tune feedforward controllers from measurable disturbances.

Ratio Control

In ratio control, the control objective is to keep the ratio between two signals, normally flow measurements, at a desired value in spite of variations in the setpoints, load disturbances, and possible control signal saturations. It is also desirable to keep the ratio also in situations when one of the controllers is switched to local setpoint or manual control. Ratio control is a very common problem in process control. It is estimated that about 15% of all controllers in a process control plant are used for ratio control.

The industry standard today is to use either a parallell ratio station or a series ration station. These methods can only handle a few of the disturbances mentioned above.

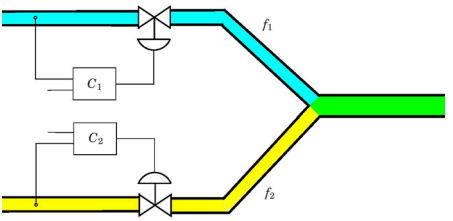
In the project we have derived a new method, the Tracking Ratio Station, that handles all dis-

turbances. It has been field tested in a paper mill and is able to track the ratio during setpoint changes, load disturbances in both loops, saturations in both loops, and also the situation when one of the controllers is switched to local setpoint or manual control.

Feedforward Mid-Ranging Control

Mid-ranging control is a control strategy that is used when there are more than one manipulated variable available to control a process variable. Mid-ranging control handles the redundancy by coordinating the roles of the different manipulated variables. The most common approach is to introduce valve position controllers (VPC) that control the steady-state position of manipulated variables. There are, unfortunately, some severe drawbacks with the VPC approach that makes it unsuitable for many industrial applications.

In this project a new approach to mid-ranging



control is investigated. The new strategy uses feedforward control to obtain desired steady-state values of the manipulated variables. The approach avoids the drawbacks associated with the VPC approach. The project is sponsored by PiiA-Vinnova and is performed in collaboration with ABB.

ANESTHESIA IN CLOSED LOOP

Reseachers: Kristian Soltesz, Anton Cervin, Olof Troeng and Fredrik Bagge Carlson in collaboration with University of British Columbia (UBC)

Computer controlled, or automatic, drug delivery is the process of administering a therapeutic regime to a patient with computer assistance for calculation of optimal dose and delivery schedules. Computer control can improve drug therapy by reducing drug usage and costs, by permitting health care staff to work more efficiently and to provide better standard of care, by allowing the safe use of drugs that are difficult to administer, and by compensation for human failings with computer strengths, such as unlimited attention span and patience, and capacity for quick, accurate and redundant calculation. Our goal is to develop an automatic control system for anesthesia and to demonstrate its efficacy, safety and benefits in an operating room. Although closed-loop anesthesia has previously been proposed and tested, it has yet to have a significant impact on clinical practice. Recent developments in sensing for anesthesia have opened new possibilities for closing the loop. Our research will focus on the deployment of new sensors optimized for controlled drug delivery, robust control methodology and extensive clinical validation. Clinical partner in the project is the Department of Anesthesia at the British Columbia Children's Hospital (BCCH), Vancouver, Canada, where patient modeling data is collected and clinical trials of the control system are conducted.

During 2018, we have hosted a PhD student from Spain, who has collaborated with local PhD students and department faculty, to compare simple and optimal controllers for closed-loop drug delivery. The conclusion of this work is in the presence of inter-patient variability and model parameter uncertainties stemming from high signal-to-noise ratio and lack of excitation in available identification data, there is little to gain on using more advances strategies. A journal manuscript is in preparation.

We have also authored and submitted a journal manuscript with the UBC group. In this paper, we disclose and discuss the approach and metodology that was used in the development and clinical evaluation of the closed-loop controlled anesthesia delivery system.

HEMODYNAMIC STABILIZATION

Researchers: Kristian Soltesz and Henry Pigot in collaboration with Igelösa Life Science

Funding: Vinnova and Swedish Research Council

Intensive care patients often rely on a combination of drug, fluid, and other therapies to achieve and maintain stable hemodynamics. This projects investigates how pharmacology, mathematical modeling, signal processing and closed-loop control can be combined to control hemodynamic entities such as blood pressure, heart rate, and vascular resistance, as well as related entities such as diuresis. The research relies on close inter-disciplinary collaboration between medical and control systems researchers. It is conducted in a systems engineering framework and comprises the development of both methods and dedicated equipment for clinical verification.

The aim of the project is to develop methods for hemodynamic stabilization of intensive care patients. It comprises closed-loop control of readily measurable signals, including heart rate, arterial and venous blood pressure. Furthermore, the project aims at optimizing hemodynamic parameters, which are not directly measurable, such as cardiac output and responsiveness to volume expansion.

The aim of the project is to develop a generic platform for closed-loop intravenous drug delivery. Apart from being used in research, such a platform can be adapted to a multitude of medical treatment scenarios, foremost in intensive care, where it has the potential to increase the availability of specialized physicians.

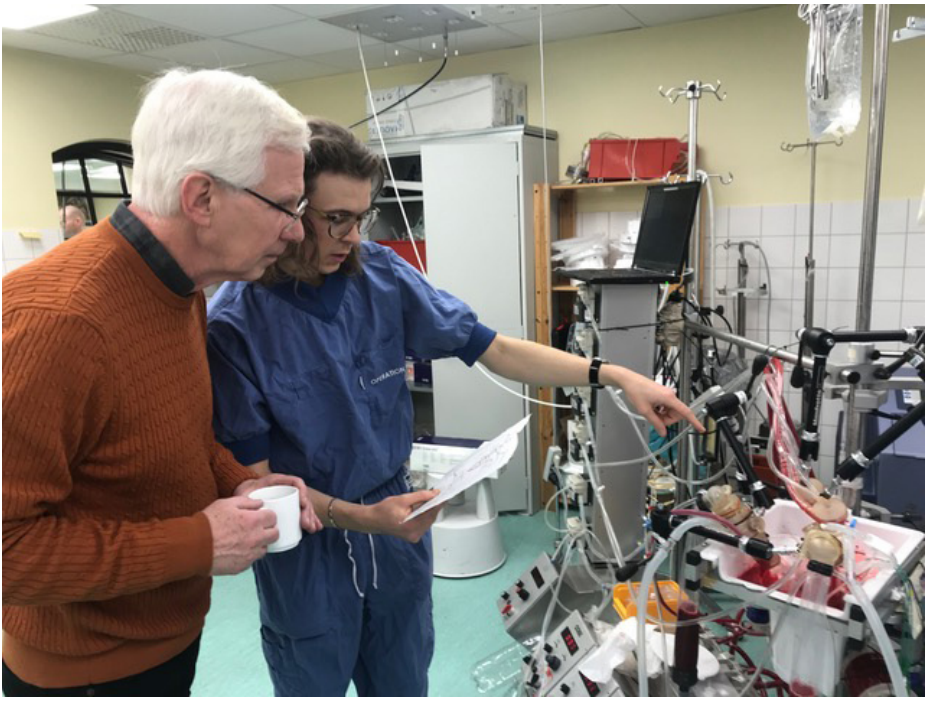
The aim of the project is to provide physicians with an 'auto pilot' for hemodynamic stabilization and optimization. The initially considered patient group are heart-beating braindead patients under intensive care (potential organ donors). Due to the complete loss of vasomotor center function, hormonal and fluid therapy is required to establish hemodynamic stability within this group

We combine automatic control methods with medical insight, to develop closed-loop controlled therapies. Developed methods are implemented on our in-house developed control system comprising sensors for invasive blood pressure measurement, and urination rate, as well as syringe and volumetric infusion, pumps for closed-loop controlled intravenous drug and fluid administration.

The methods are pre-clinically evaluated in collaboration with the project partner Igelösa Life Science AB.

In 2018, Henry Pigot joined the team as PhD student. His project is strongly related to the above project, but with ex vivo heart evaluation as application scenario. Henry and other collaborators are currently developing a research setup enabling the evaluation of hearts ex vivo, with the purpose of classifying whether they are suitable for transplantation. The same setup will also be a valuable tool in basic physiology and pharmacology research, in conjecture with the aforementioned closed-loop drug delivery system.

Another project activity during 2018 was an extended research visit by PhD student José Cava Gonzales from Spain. José has made theoretical contributions to individualization of closed-loop intravenous therapies. A journal manuscript intended for IEEE Transactions on Control Systems Technology is in preparation.



Research setup for ex vivo evaluation and hemodynamic stabilization of hearts. The setup relies on soft sensors for state estimation and feedback control for robust performance.

ON HUMANS FOR HUMANS

Researchers: Charlotta Johnsson in collaboration with Skåne University Hospital, Vävnadsbanken, Cognibotics, and Robovision BVBA

Funding: Vinnova

By continuous development of new technology for surgical methods our healthcare is improved. Our vision of the project "From Humans to Humans" is to build a new testbed for groundbreaking robotics surgery, consisting of an operating theater with a nearby preparation and control room. The testbed will be located close to Vävnadsbanken in Lund, which is the largest tissue bank in Scandinavia. Novel methods in collaborative robotics will be evaluated and could eventually, after careful testing, be scaled up and reach the development regions of the world.

VENTILATOR FOR IMPROVED CARDIOPULMONARY RESUSCITATION

Researchers: Kristian Soltesz and Henry Pigot in collaboration with Igelösa Life Science

Funding: Vinnova

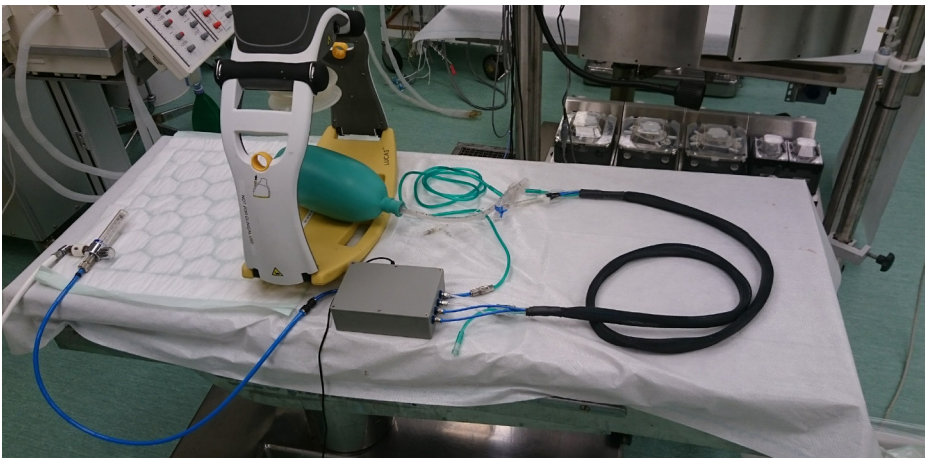
Sudden cardiac arrest is the second most common cause of death in Sweden, following tumors. Annually, 10 000 persons are subject to sudden cardiac arrest outside of hospitals in the country. In 2015, 585 persons survived through resuscitation, which is the highest number since the 1992 establishment of the Swedish cardiopulmonary resuscitation registry.

Following cardiac arrest, blood circulation in the body seizes, and the brain is subject to irreversible damage within minutes. To counteract this, treatment of sudden cardiac arrest consists mainly in mechanical chest compressions - to circulate blood, combined with artificial gas exchange in the lungs - to deliver oxygen and ventilate carbon dioxide.

The clinical need addressed by this project is to improve survival statistics associated with sudden cardiac arrest. Pre-clinical pilots have demonstrated that it is possible to achieve improved circulation, combined with an increased coronary perfusion pressure when the gas flow to the patient's lungs is automatically controlled based on the phase of the chest compression cycle. We have developed this idea into a research prototype of a mobile ventilator, specifically intended to be used in cardiopulmonary resuscitation.

The objective of this project is to investigate the efficiency of the new method through randomized pre-clinical studies and to further develop our research prototype. The long-term project goal is to achieve a decrease in deaths caused by sudden cardiac arrest.

During 2018, the results from a porcine study comparing our novel ventilation method to the state of the art were compiled into a manuscript, which has been submitted to Elsevier Resuscitation (a revised version has recently been submitted, following reviewer feedback). There are ongoing plans to incorporate the method into a commercial product and to initiate a human study.



Our ventilator research prototype (gray box with tubing) together with the commercially available LUCAS chest compression device, developed at Igelösa.

STRATEGIES AND STANDARDS FOR SMART SWEDISH INDUSTRY

Researchers: Charlotta Johnsson in collaboration with colleagues at Lund University, Blue Institute, SIS, SEK, PiiA and Prod2030

Funding: Vinnova

Initiatives related to industrial digitalisation are ongoing around the globe. Also for Sweden, digitalisation and the concept of Smart industry is of importance. The Swedish government has selected "Connected Industry and New materials (also called Smart Industry)" as one of five co-operation programs. The vision is to apply new advanced technology to industrial production, with expected outcome of e.g. custom made individual products, and increased transparency (sustainability and work-ethics) of how each product was made.

In order to make this happen, collaboration in two forms, is needed. First, between the technical applications involved in the value-chains that the product is related to (design to product, raw material to product and reuse, etc). This requires international standards that the technical solutions can be based on. Second, collaboration between people, at national and international level, in order to develop these standards. This project aims at igniting the Swedish engagement, and enable Swedish industry related research results to become international standards. The project aims at intertwining, on one hand the Swedish industry related research related to Smart industry, and on the other hand the Swedish standardisation organisations with their channels to the international arena. This is an example of novelty and hands on activities that have not been done before. This collaboration and joint effort is needed in order to generate a Swedish engagement and take an international position as a leading nationality in the area of Smart Industry.

MIND METHODOLOGY

In a global context, education is seen as a main driving force for social development, and the pen as the best tool for shaping it's future. This also applies to engineering and STEM education. However, traditional pedagogical approaches in teaching and learning are entered around theory and practice "to know how to do engineering and apply technology". The mindset part, to "become an engineer and belong in the tech community" and "to feel how you can create value for society" is often left out. The proposed new pedagogical methodology, called Mind Methodology, includes game-based and student-centred activities related to mindset and personal development of the students. Our vision for this novel methodology is to enhance and broaden traditional engineering and STEM education and, hence, to increase quality in education.

TOOLS AND SOFTWARE

Julia packages
JGrafchart
Jitterbug: A Matlab toolbox for real-time control performance analysis
TrueTime: Simulation of Networked and Embedded Control Systems
MPCtools

JULIA PACKAGES

Researchers at the department, in particular Fredrik Bagge Carlson and Mattias Fält, have contributed to several registered packages for the Julia programming language:

- ControlSystems.jl –A control systems toolbox for Julia (Several add-on packages are available)
- BasisFunctionExpansions.jl – Basis function expansions for Julia
- DeterministicPolicyGradient.jl – Reinforcement learning with deterministic policy gradient methods
- DifferentialDynamicProgramming.jl – A package for solving differential dynamic programming and trajectory optimization problems
- DynamicMovementPrimitives.jl – Learning dynamic movement primitives in Julia
- LPVSpectral.jl - A toolbox for least-squares spectral estimation and (sparse) LPV spectral decomposition
- SingularSpectrumAnalysis.jl – A package for performing singular spectrum analysis
- CholmodSolve2.jl – Package for solving linear systems given an LDLt factorization
- FirstOrderSolvers.jl – Large scale convex optimization solvers in Julia

JGRAFCHART

Grafchart is a language for supervisory level sequence control and procedure handling that has been developed at the department since 1991. Grafchart is based on ideas from Grafcet/Sequential Function Charts, Petri nets, Statecharts, and object-oriented programming.

The original implementation of Grafchart had the same name and was developed in G2 from Gensym Corporation. Using this platform Grafchart was used for batch recipe control, diagnosis of mode-changning processes, alarm filtering, implementation of operator decision support systems, and implementation of robot cells. In 2001 an open implementation of Grafchart was made in Java. It is called JGrafchart and is used in our laboratory exercises on logical sequence control and batch control as well as in several research projects.

JITTERBUG: A MATLAB TOOLBOX FOR REAL-TIME CONTROL PERFORMANCE ANALYSIS

Jitterbug is a MATLAB-based toolbox that allows the computation of a quadratic performance criterion for a linear control system under various timing conditions. Using the toolbox, one can easily and quickly assert how sensitive a control system is to delay, jitter, lost samples, etc., without resorting to simulation. The tool is quite general and can also be used to investigate jitter-compensating controllers, a periodic controllers, and multi-rate controllers. As an additional feature, it is also possible to compute the spectral density of the signals in the control system. The main contribution of the toolbox, which is built on well-known theory (LQG theory and jump linear systems), is to make it easy to apply this type of stochastic analysis to a wide range of problems.

TRUETIME: SIMULATION OF NETWORKED AND EMBEDDED CONTROL SYSTEMS

TrueTime is a Matlab/Simulink-based simulator for real-time control systems. Offering Simulink blocks that model real-time kernels and wired/wireless networks, TrueTime facilitates co-simulation of scheduling algorithms, control tasks, network protocols, and continuous plant dynamics.

TrueTime has been developed at the Department of Automatic Control since 1999. It is open source, written in C++, and can easily be extended with new functionality. TrueTime has been used in wide range of research projects and has also found use in university courses and in industry.

MPCTOOLS

MPCtools is a freely available Matlab/Simulink-based toolbox for simulation of MPC controllers. MPCtools provides easy to use functions to create and simulate basic MPC controllers based on linear state space models.

The key features of the toolbox include:

- Support for linear state space models for prediction
- Quadratic cost function
- Linear inequality constraints on states and controls
- Observer support for state and disturbance estimation
- Integral action by means of disturbance estimation
- Two different QP solvers for solving the optimization problem

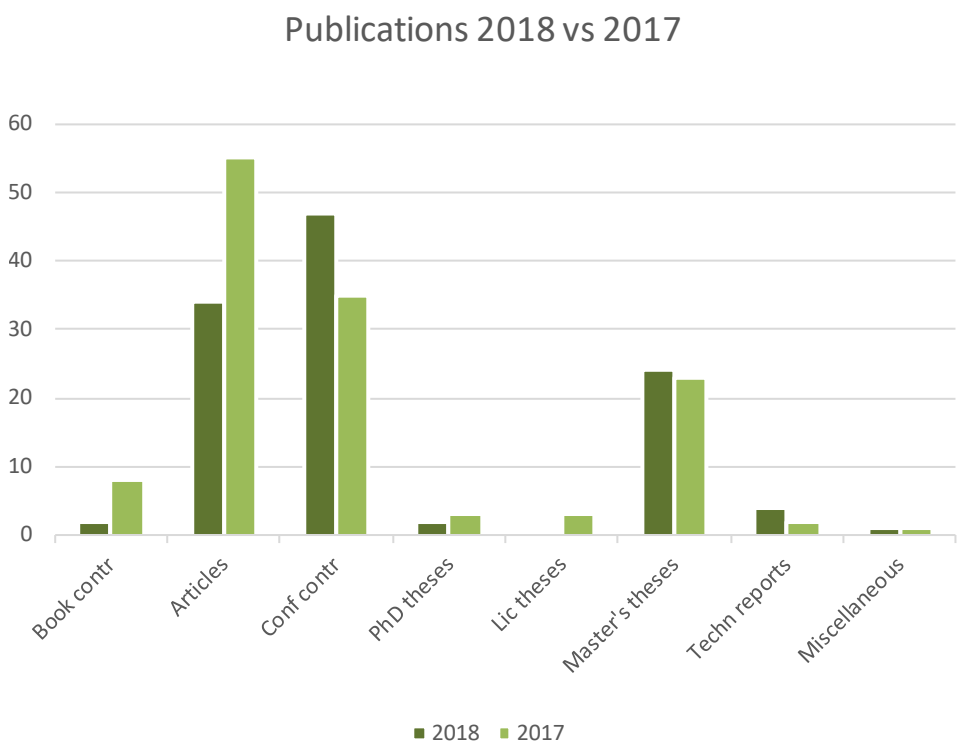
Publications and seminars

This chapter contains a list of publications and seminars during 2018

PUBLICATIONS 2018

You can find references to all the publications on www.control.lth.se/publications and almost all of them can be downloaded from this site. Any of the reports may, however, be borrowed through your library service or from the following libraries in Sweden:

- Göteborgs universitetsbibliotek
- Kungliga Biblioteket
- Linköpings universitetsbibliotek
- Lunds universitetsbibliotek
- Stockholms universitetsbibliotek
- Umeå universitetsbibliotek
- Uppsala universitetsbibliotek



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Yamamoto, Kaoru; Yamamoto, Yutaka; Nagahara, Masaaki; *Hypertracking beyond the Nyquist Frequency;* In: Tempo, Roberto; Yurkovich, Stephen; Misra, Pradeep (Eds); *Emerging Applications of Control and Systems Theory,* Lecture Notes in Control and Information Sciences, Springer Verlag, pp. 369–379, 2018.

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Ghazaei Ardakani, M. Mahdi; Olofsson, Björn; Robertsson, Anders; Johansson, Rolf; *Model Predictive Control for Real-Time Point-to-Point Trajectory Generation*; IEEE Transactions on Automation Science and Engineering, 2018.

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Grussler, Christian; Rantzer, Anders; Giselsson, Pontus; *Low-Rank Optimization with Convex Constraints*; IEEE Transactions on Automatic Control, 63:11, pp. 4000–4007, 2018.

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Scepanovic, Petar; Alanio, Cécile; Hammer, Christian; Hodel, Flavia; Bergstedt, Jacob; Patin, Etienne; Thorball, Christian W., *et al.*; *Human Genetic Variants and Age Are the Strongest Predictors of Humoral Immune Responses to Common Pathogens and Vaccines*; Genome Medicine, 10:1, 2018.

Shevtsov, Stepan; Berekmeri, Mihaly; Weyns, Danny; Maggio, Martina; *Control-Theoretical Software Adaptation: A Systematic Literature Review*; IEEE Transactions on Software Engineering, 44:8, pp. 784–810, 2018.

Soltesz, Kristian; Sjöberg, Trygve; Jansson, Tomas; Johansson, Rolf; Robertsson, Anders; Paskevicius, Audrius; Liao, Qiuming; Qin, Guangqi; Steen, Stig; *Closed-Loop Regulation of Arterial Pressure after Acute Brain Death*; Journal of Clinical Monitoring and Computing, 32:3, pp. 429–437, 2018.

Soltesz, Kristian; Cervin, Anton; *When is PID a Good Choice?*; IFAC-PapersOnLine, 51:4, pp. 250–255, 2018.

Soltesz, Kristian; *Robust Computation of Pulse Pressure Variations*; Biomedical Signal Processing and Control, 39, pp. 197–203, 2018.

Sun, Zhiyong; Yu, Changbin Brad; *Dimensional-Invariance Principles in Coupled Dynamical Systems: A Unified Analysis and Applications*; IEEE Transactions on Automatic Control, 2018.

Sun, Zhiyong; Sugie, Toshiharu; *Identification of Hessian Matrix in Distributed Gradient-Based Multi-Agent Coordination Control Systems*; Numerical Algebra, Control and Optimization, pp. 1–22, 2018.

Suttner, Raik; Sun, Zhiyong; *Formation Shape Control Based on Distance Measurements Using Lie Bracket Approximations*; SIAM Journal on Control and Optimization, 56:6, pp. 4405–4433, 2018.

Turesson, Gabriel; Yin, Lianhao; Johansson, Rolf; Tunestål, Per; *Predictive Pressure Control with Multiple Injections*; IFAC-PapersOnLine, 51:31, pp. 706–713, 2018.

Varisco, Martina; Johnsson, Charlotta; Mejvik, Jacob; Schiraldi, Massimiliano M.; Zhu, Li; *KPIs for Manufacturing Operations Management: Driving the ISO22400 Standard Towards Practical Applicability*; IFAC-PapersOnLine, 51:11, pp. 7–12, 2018.

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Yin, Lianhao; Turesson, Gabriel; Yang, Tianhao; Johansson, Rolf; Tunestål, Per; *Partially Premixed Combustion (PPC) Stratification Control to Achieve High Engine Efficiency*; IFAC-PapersOnLine, 51:31, pp. 694–699, 2018.

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CONFERENCE CONTRIBUTIONS

Årzén, Karl-Erik; Skarin, Per; Tärneberg, William; Kihl, Maria; *Control over the Edge Cloud – An MPC Example*; In 1st International Workshop on Trustworthy and Real-Time Edge Computing for Cyber-Physical Systems, Nashville, United States, December 2018.

Bagge Carlson, Fredrik; Robertsson, Anders; Johansson, Rolf; *Identification of LTV Dynamical Models with Smooth or Discontinuous Time Evolution by Means of Convex Optimization*; In The 14th IEEE International Conference on Control and Automation 2018, Anchorage, Alaska, United States, June 2018.

Blanchini, Franco; Cuba Samaniego, Christian; Franco, Elisa; Giordano, Giulia; *Aggregates of Positive Impulse Response Systems: A Decomposition Approach for Complex Networks*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, December 2018.

Cervin; Anton; *Event-Based Control and Estimation of Server Systems*; In 4th International Conference on Event-Based Control, Communication, and Signal Processing, EBCCSP 2018, Perpignan, France, June 2018.

Chong, Michelle S.; Postoyan, Romain; Khong, Sei Zhen; Nesic, Dragan; *Supervisory Observer for Parameter and State Estimation of Nonlinear Systems Using the DIRECT Algorithm;* In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, December 2018.

Chong,Michelle; Sandsten, Maria; Rantzer, Anders; *Estimating the Wigner Distribution of Linear Time-Invariant Dynamical Systems*; 2018 European Control Conference, 2018.

Edpalm, Viktor; Martins, Alexandre; Årzén, Karl-Erik; Maggio, Martina; *Camera Networks Dimensioning and Scheduling with Quasi Worst-Case Transmission Time*; In 30th Euromicro Conference on Real-Time Systems, ECRTS 2018, Barcelona, Spain, June 2018.

Ghazaei Ardakani, Mahdi; Karlsson, Martin; Nilsson, Klas; Robertsson, Anders; Johansson, Rolf; *Master-Slave Coordination Using Virtual Constraints for a Redundant Dual-Arm Haptic Interface*; In 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems, Madrid, Spain, October 2018.

Greiff, Marcus; *A Time-Warping Transformation for Time-Optimal Movement in Differentially Flat Systems*; In 2018 Annual American Control Conference, ACC 2018, Milwauke, United States, June 2018.

Greiff, Marcus; Berntorp, Karl; *Evaluation of the Discrete Time Feedback Particle Filter for IMU-Driven Systems Configured on SE(2)*; In 2018 Annual American Control Conference, ACC 2018, Milwauke, United States, June 2018.

Greiff, Marcus; Robertsson, Anders; *Incremental Reference Generation for Nonsingular Control on SE (3)*; In 2nd IEEE Conference on Control Technology and Applications, CCTA 2018, Copenhagen, Denmark, August 2018.

Grussler, Christian; Umenberger, Jack; Manchester, Ian R.; *Identification of Externally Positive Systems*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, January 2018.

Grussler, Christian; Giselsson, Pontus; *Local Convergence of Proximal Splitting Methods for Rank Constrained Problems*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, January 2018.

Heyden, Martin; Pates, Richard; Rantzer, Anders; *A Structured Linear Quadratic Controller for Transportation Problems*; In 2018 European Control Conference, 2018.

Jiang, Yan; Pates, Richard; Mallada, Enrique; *Performance Tradeoffs of Dynamically Controlled Grid-Connected Inverters in Low Inertia Power Systems*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, January 2018.

Karlsson, Martin; Robertsson, Anders; Johansson, Rolf; *Convergence of Dynamical Movement Primitives with Temporal Coupling*; In 2018 European Control Conference, Limassol, Cyprus, June 2018.

Karlsson, Martin; Robertsson, Anders; Johansson, Rolf; *Detection and Control of Contact Force Transients in Robotic Manipulation without a Force Sensor*; In 2018 IEEE International Conference on Robotics and Automation , Brisbane, Australia, May 2018.

Lidström, Carolina; Pates, Richard; Rantzer, Anders; *H-infinity Optimal Distributed Control in Discrete Time*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, January 2018.

Mandrioli, Claudio; Leva, Alberto; Maggio, Martina; *Dynamic Models for the Formal Verification of Big Data Applications via Stochastic Model Checking*; In 2nd IEEE Conference on Control Technology and Applications, CCTA 2018, Copenhagen, Denmark, August 2018.

Millnert,Victor; Eker, Johan; Bini, Enrico; *Achieving Predictable and Low End-to-End Latency for a Network of Smart Services*; In IEEE GLOBECOM 2018, December 2018.

Nayak Seetanadi, Gautham; Maggio, Martina; Årzén, Karl-Erik; Almeida, Luis; Camara, Javier; *Event-Driven Bandwidth Allocation with Formal Guarantees for Camera Networks*; In 38th IEEE Real-Time Systems Symposium, 2017, Paris, France, October 2018.

Nylander, Tommi; Klein, Cristian; Årzén, Karl-Erik; Maggio, Martina; *BrownoutCC: Cascaded Control for Bounding the Response Times of Cloud Applications*; In American Control Conference 2018, Milwaukee, Wisconsin, United States, June 2018.

Nylander, Tommi; Thelander Andrén, Marcus; Årzén, Karl-Erik; Maggio, Martina; *Cloud Application Predictability through Integrated Load-Balancing and Service Time Control*; In 15th IEEE International Conference on Autonomic Computing, Trento, Italy, September 2018.

Nilsson, Gustav; Como, Giacomo; *Evaluation of Decentralized Feedback Traffic Light Control with Dynamic Cycle Length*; In 15th IFAC Symposium on Control in Transportation Systems (CTS 2018), Savona, Italy, June 2018.

Nilsson, Gustav; Grover, Piyush; Kalabic, Uros; *Assignment and Control of Two-Tiered Vehicle Traffic;* In 57th IEEE Conference on Decision and Control, Miami Beach, United States, December 2018.

Ojer de Andrés, Marco; Ghazaei Ardakani, Mahdi; Robertsson, Anders; *Reinforcement Learning for 4-Finger-Gripper Manipulation*; In International Conference on Robotics and Automation (ICRA) 2018, Brisbane, Australia, May 2018.

Olofsson, Björn; Bernhardsson, Bo; Zeng, Rihua; Andersson, Pontus; Johansson, Rolf; *Temperature Stabilization of the Phase-Reference Line at the European Spallation Source*; In 2nd IEEE Conference on Control Technology and Applications, CCTA 2018, Copenhagen, Denmark, August 2018.

Orlov, Yury; Rantzer, Anders; Aguilar, Luis T.; *Adaptive H-infinity Synthesis for Linear Systems with Uncertain Parameters*; In 57th IEEE Conference on Decision and Control, Miami Beach, United States, December 2018.

Papadopoulos, Allessandra Vittorio; Krzywda, Jakub; Elmroth, Erik; Maggio, Martina; *Power-Aware cloud Brownout: Response Time and Power Consumption Control*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, January 2018.

Papadopoulos, Alessandro Vittorio; Maggio, Martina; *Challenges in High Performance Big Data Frame-works*; In 16th International Conference on High Performance Computing and Simulation, HPCS 2018, Orleans, France, July 2018.

Pates, Richard; Yamamoto, Kaoru; *Scale Free Bounds on the Amplification of Disturbances in Mass Chains*; In 2018 Annual American Control Conference, ACC 2018, Milwauke, United States, June 2018.

Pates, Richard; Lidström, Carolina; Rantzer, Anders; *Control Using Local Distance Measurements Cannot Prevent Incoherence in Platoons*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, January 2018.

Pigot, Henry; Soltesz, Kristian; Paskevicius, Audrius; Liao, Qiuming; Sjöberg, Trygve; Steen, Stig; *Ventilator for Improved Cardiopulmonary Resuscitation*; In Medicinteknikdagarna 2018, Umeå, Sweden, October 2018.

Pigot, Henry; *A Self-Sustaining Model for Peer-to-Peer Engineering Education Among Children in Low Resource Environments*; In LTHs 10:e Pedagogiska Inspirationskonferens, Lund, Sweden, December 2018.

Rantzer, Anders; *Concentration Bounds for Single Parameter Adaptive Control*; In American Control Conference 2018, Milwaukee, Wisconsin, United States, June 2018.

Rosdahl, Christian; Nilsson, Gustav; Como, Giacomo; *On Distributed Optimal Control of Traffic Flows in Transportation Networks*; In IEEE Conference on Control Technology and Applications, CCTA 2018, Copenhagen, Denmark, August 2018.

Ruuskanen, Johan; Cervin, Anton; *Internal Server State Estimation Using Event-Based Particle Filtering*; In Proceedings of the 4th International Conference on Event-Based Control, Communication, and Signal Processing, EBCCSP 2018, Perpignan, France, June 2018.

Sidhu, Ikhlaq; Fred-Ojala, Alexander; Iqbal, Sana; Johnsson, Charlotta; *Applying Entrepreneurial Teaching Methods to Advanced Technical STEM Courses*; In 2018 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2018, Stuttgart, Germany, June 2018.

Sigfridsson, Sara; Li, Lixiang; Runvik, Håkan; Gohl, Jesse; Joly, Antonin; Soltesz, Kristian; *Modeling of Fuel Cell Hybrid Vehicle in Modelica: Architecture and Drive Cycle Simulation*; In 2nd Japanese Modelica Conference, Tokyo, Japan, May 2018.

Skarin, Per; Tärneberg, William; Årzén, Karl-Erik; Kihl, Maria; *Towards Mission-Critical Control at the Edge and Over 5G*; In IEEE Edge, San Francisco, United States, July 2018.

Troeng, Olof; Bernhardsson, Bo; *An Intuitive Design Method for Disturbance-Rejecting Peak Filters;* In The 14th IEEE International Conference on Control and Automation 2018, Anchorage, Alaska, United States, June 2018.

Yamamoto, Kaoru; Nagahara, Masaaki; Yamamoto, Yutaka; *Signal Reconstruction with Generalized Sampling*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, January 2018.

Varisco, Martina; Johnsson, Charlotta; Schiraldi, Massimiliano M.; *Proposal for a Classification of ISO22400 KPIs for Manufacturing Operations Management*; In 23rd Summer School "Francesco Turco" – Industrial Systems Engineering 2018, Palermo, Italy, September 2018.

Xu, Yang; Cervin, Anton; Årzén, Karl-Erik; *Jitter-Robust LQG Control and Real-Time Scheduling Co-Design*; In American Control Conference 2018, Milwaukee, Wisconsin, United States, June 2018.

Zhu, Li; Meivik, Jacob; Johnsson, Charlotta; Bengtsson, Kristofer; Pettersson, Håkan; Varisco, Martina; Schiraldi, Massimiliano M.; *Key Performance Indicators in Manufacturing Operations Management : A Case Study of the IS022400-Standard Applied at Volvo Cars*; In 23rd IEEE International Conference on Emerging Technologies and Factory Automation, ETFA 2018, Torino, Italy, September 2018.

Zhu, Li; Johnsson, Charlotta; Mejvik, Jacob; Varisco, Martina; Schiraldi, Massimiliano; *Key Performance Indicators for Manufacturing Operations Management in the Process Industry*; In 2017 IEEE International Conference on Industrial Engineering and Engineering Management, IEEM 2017, Singapore, Singapore, January 2018.

Zorzan, Irene; Rantzer, Anders; *L1 and H-infinity Optimal Control of Positive Bilinear Systems*; In 56th IEEE Annual Conference on Decision and Control, CDC 2017, Melbourne, Australia, January 2018.

PHD THESES

Bergstedt, Jacob*; Statistical Modeling and Learning of the Environmental and Genetic Drivers of Variation in Human Immunity;* PhD Thesis TFRT-1121, Department of Automatic Control, Lund University, Sweden, December 2018.

Turesson, Gabriel*; Model-Based Optimization of Combustion-Engine Control;* PhD Thesis TFRT-1120, Department of Automatic Control, Lund University, Sweden, June 2018.

TECHNICAL REPORTS

Millnert, Victor; Eker, Johan; Bini, Enrico; *Achieving predictable and low end-to-end latency for a cloud-robotics network*; Technical Report TFRT-7655, Department of Automatic Control, Lund University, Sweden, April 2018.

Edpalm, Viktor; Martins, Alexandre; Maggio, Martina; Årzén, Karl-Erik; *H.264 Video Frame Size Estimation*; Technical Report TFRT-7654, Department of Automatic Control, Lund University, Sweden, March 2018.

Hägglund, Tore; Rasmusson, Monika (Eds); *Activity Report 2017*; Annual Report TFRT-4045, Department of Automatic Control, Lund University, Sweden, April, 2018.

Soltesz, Kristian; Cervin, Anton (Eds.); *Projects in Automatic Control 2017*; Technical Report TFRT-7653, Department of Automatic Control, Lund University, Sweden, February 2018.

MASTER'S THESES

Bai, Richard; Erliksson, Karl Fredrik; *Motion Planning Using Positively Invariant Sets on a Small-Scale Autonomous Vehicle*; Master's Thesis TFRT-6053, Supervisors: Berntorp, Karl; Olofsson, Björn; Robertsson, Anders; Department of Automatic Control, Lund University, Sweden, August 2018.

Basic Knezevic, Damir; Heimerson, Albin; *Statistical and Machine Learning Methods for Classification of Episodic Memory*; Master's Thesis TFRT-6056, Supervisors: Bernhardsson, Bo; Cervin, Anton; Department of Automatic Control, Lund University, Sweden, June 2018.

Bring, Björn; *Calibration and Implementation of Robot for Detection of X-rays*; Master's Thesis TFRT-6050, Supervisors: Johansson, Ulf; Robertsson, Anders; Johansson, Rolf; Department of Automatic Control, Lund University, Sweden, June 2018.

Ekelund, Jonatan; *Balancing and Locomotion of a Hexapod Robot Traversing Uneven Terrain*; Master's Thesis TFRT-6047, Supervisors: Gundersen, Jasper; Robertsson, Anders; Maggio, Martina; Department of Automatic Control, Lund University, Sweden, January 2018.

Ferling, Olle; *Modeling, Analysis and Control of Underwater Vehicle SROV*; Master's Thesis TFRT-6049, Supervisors: Andersson, Jonas; Johansson, Rolf; Bernhardsson, Bo; Department of Automatic Control, Lund University, Sweden, May 2018.

Fryklund, Henrik; *Principles for Tuning Heat Zone Controllers in a Belt Furnace Through Modeling and Simulation*; Master's Thesis TFRT-6068, Supervisors: Löfgren, Ola; Hägglund, Tore; Johnsson, Charlotta; Department of Automatic Control, Lund University, Sweden, October 2018.

Jabbar, Sam; *Scheduling Strategies for the Calvin IoT Environment*; Master's Thesis TFRT-6065, Supervisors: Persson, Per; Årzén, Karl-Erik; Cervin, Anton; Department of Automatic Control, Lund University, Sweden, September 2018.

Jonsson, Peter; *Physical Modeling of a Heavy-Duty Engine for Test-Cycle Simulations in Modelica*; Master's Thesis TFRT-6054, Supervisors: Nylén, Anders; Turesson, Gabriel; Johansson, Rolf; Department of Automatic Control, Lund University, Sweden, June 2018.

Jovanovski, Daniel; *Semi-Automation of a Spray Painting Robot*; Master's Thesis TFRT-6064, Supervisors: Lindstedt, Gunnar; Robertsson, Anders; Johansson, Rolf; Department of Automatic Control, Lund University, Sweden, December 2018.

Kjellqvist, Olle; *Laguerre Bases for Youla-Parametrized Optimal-Controller Design: Numerical Issues and Solutions*; Master's Thesis TFRT-6061, Supervisors: Troeng, Olof; Giselsson, Pontus; Cervin, Anton; Department of Automatic Control, Lund University, Sweden, June 2018.

Lindqvist, Johan; Sollenberg, Martin; *Real-Time Multiple Audio Beamforming System*; Master's Thesis TFRT-6055, Supervisors: Lopez Valdes, Alejandro; Lunner, Thomas; Sandsten, Maria; Bernhardsson, Bo; Robertsson, Anders; Department of Automatic Control, Lund University, Sweden, June 2018.

Ottenklev, Martin; *Evaluating Motion Capture as a Means of System Identification of a Quadcopter*; Master's Thesis TFRT-6058, Supervisors: Bergman, Kristoffer; Robertsson, Anders; Årzén, Karl-Erik; Department of Automatic Control, Lund University, Sweden, October 2018.

Paulsson, Simon; *Tuning Feedback-Based Traffic Signal Controls*; Master's Thesis TFRT-6067, Supervisors: Nilsson, Gustav; Como, Giacomo; Cervin, Anton; Department of Automatic Control, Lund University, Sweden, October 2018.

Peterson, Marcus; *Vibration Reduction in a Gantry Robot;* Master's Thesis TFRT-6075, Supervisors: Sörnmo, Olof; Robertsson, Anders; Johansson, Rolf; Department of Automatic Control, Lund University, Sweden, December 2018.

Rosenberg, Isabelle; Svensson, Viktor; *On Shock Propagation in Financial Networks*; Master's Thesis TFRT-6062, Supervisors: Como, Giacomo; Rantzer, Anders; Department of Automatic Control, Lund University, Sweden, July 2018.

Rådberg, David; *Optimal Real Time Bidding in Online Advertising*; Master's Thesis TFRT-6060, Supervisors: Grund, Carl-Johan; Larsson, Rasmus; Årzén, Karl-Erik; Maggio, Martina; Rantzer, Anders; Department of Automatic Control, Lund University, Sweden, June 2018.

Sigfridsson, Sara; *Fuel Cell Hybrid Vehicle Modeling in Modelica*; Master's Thesis TFRT-6052, Supervisors: Runvik, Håkan; Soltesz, Kristian; Årzén, Karl-Erik; Department of Automatic Control, Lund University, Sweden, May 2018.

Sjöberg, Jonny; *Robot Tool Calibration of an Active Pen with Python Using an Enabled Surface from Anoto Technology*; Master's Thesis TFRT-6051, Supervisors: Lidström, Per; Robertsson, Anders; Johansson, Rolf; Department of Automatic Control, Lund University, Sweden, May 2018.

Stålberg, Rasmus; *On Robustness of Equilibria in Transportation Networks*; Master's Thesis TFRT-6066, Supervisors: Rosdahl, Christian; Nilsson, Gustav; Como, Giacomo; Rantzer, Anders; Department of Automatic Control, Lund University, Sweden, September 2018.

Tran, Lloyd; Barbulovic, David; *Real-Time Control of Industrial Robot Cell with PowerLink*; Master's Thesis TFRT-6048, Supervisors: Robertsson, Anders; Johansson, Rolf; Department of Automatic Control, Lund University, Sweden, March 2018.

Tvede-Möller, Christopher; *Robot-Held Camera Platform for Medical Applications;* Master's Thesis TFRT-6070, Supervisors: Robertsson, Anders; Johnsson, Charlotta; Department of Automatic Control, Lund University, Sweden, November 2018.

Vladu, Emil*; Controller Design for Multistorey Buildings via Convex Optimisation;* Master's Thesis TFRT-6069, Supervisors: Yamamoto, Kaoru; Rantzer, Anders; Department of Automatic Control, Lund University, Sweden, October 2018.

Vreman, Nils*; Minimizing Side-Channel Attack Vulnerability via Schedule Randomization;* Master's Thesis TFRT-6059, Supervisors: Maggio, Martina; Årzén, Karl-Erik; Department of Automatic Control, Lund University, Sweden, August 2018.

Åberg, Anna; Sjölander, Christine; *Building Data Classification and Association*; Master's Thesis TFRT-6057, Supervisors: Nilsson, Oskar; Bernhardsson, Bo; Rantzer, Anders; Department of Automatic Control, Lund University, Sweden, July 2018.

MISCELLANEOUS

Rantzer, Anders; Johnsson, Charlotta; Westin, Eva (Eds.); *In Control of Complexity: Linnaeus Research Environment LCCC 2008–2018;* Department of Automatic Control, Lund University, Sweden, 2018.

SEMINARS AT THE DEPARTMENT

January

26 *Progressive Classification and Learning: From Analytics for Deep Neural Networks to Cortex-on-a-Chip*, John S. Baras, University of Maryland College Park.

30 *Design challenges for parallel optimization algorithms: asynchrony, problem structure and information exchange*, Mikael Johansson, KTH.

February

13 *The Statistical Foundations of Learning to Control,* Benjamin Recht, UC Berkeley.

16 Master's thesis presentation: *Fuel Cell Hybrid Vehicle Modeling in Modelica*, Sara Sigfridsson.

28 *Performance Limitations of Large-Scale Networks with Distributed Dynamic Feedback*, Emma Tegling, KTH.

28 Master's thesis presentation: Modeling, *Analysis and Control of Underwater Vehicle*, Olle Ferling.

March

02 *Stability Analysis and Control Synthesis for Networked Control Systems: Using Weakly Hard Real-Time Constraints to Model the Data Loss*, Steffen Linsenmayer, University of Stuttgart.

13 *Control of Population Systems: Equilibria and Distributed Algorithms*, John Lygeros, ETH Zürich.

16 Master's thesis presentation: *Object Detection and Avoidance Using LIDAR on a Hydrofoil Boat*, Erik Söderberg.

27 *Formal Verification of Complex Systems: Model-Based and Data-Driven Methods*, Alessandro Abate, Oxford University, UK.

April

10 *Lessons Learned Implementing "industry 4.0" at Volvo Cars,* Kristofer Bengtsson, Sekvensa AB.

17 *A Time-Delay Approach to Sampled-Data and Network-Based Control*, Emilia Fridman, Tel Aviv University.

24 *Proximal Envelopes*, Panos Patrinos, KU Leuven, Belgium.

May

08 *Learning Better Models for Inverse Problem in Imaging,* Thomas Pock, Institute of Computer Graphics and Vision, Graz University of Technology.

14 *Constrained Control of Uncertain Linear Time-Invariant Systems: An Interpolation Based Approach*, Per-Olof Gutman, Technion – Israel Institute of Technology, Haifa 32000, Israel.

15 *Closed-Loop and Safety-Preserving Control in Anesthesia*, Klaske Van Heusden, University of British Columbia, Vancouver, Canada.

22 *The Future of Real-Time Systems*, Marko Bertogna, University of Modena, Italy.

25 Master's thesis presentation: *Laguerre Bases for Youla-Parametrized Optimal-Controller Design – Numerical Issues and Solutions*, Olle Kjellqvist.

29 *Automated Design of First-Order Optimization Metho,* Adrien Taylor.

30 *Research Activities on Conventional and Alternative Vehicles at the Energy and Propulsion Laboratory of the University of Salerno*, Gianfranco Rizzo, Department of Industrial Engineering, University of Salerno, Italy.

June

01 Defence of doctoral dissertation: *Model-Based Optimization of Combustion-Engine Control,* Gabriel Turesson.
01 Master's thesis presentation: *Motion Planning Using Positively Invariant Sets on a Small-Scale Autonomous Vehicle*, Karl Fredrik Erliksson, Richard Bai.
07 Master's thesis presentation: *Minimizing Side-Channel Attack,Vulnerability via Schedule Randomization*, Nils Vreman.
07 Master's thesis presentation: *Controller Design in Multistory Buildings via Convex Optimization*, Emil Vladu.
07 Master's thesis presentation: *Real-Time Beamforming System with Microphone Array*, Johan Lindqvist, Martin Sollenberg.
07 *Control Design Tools for Non-Controllable" Systems: Demands of Novel Robotic Applications*, Anton Shiriaev, NTNU, Trondheim.
08 Master's thesis presentation: *Physical Modeling of a Heavy-Duty Engine for Test-Cycle Simulations in Modelica*, Peter Jonsson.
12 Master's thesis presentation: *Optimal Real Time bidding*, David Rådberg.
12 Master's thesis presentation: *Evaluating Motion Capture as a Means of System Identification of a Quadcopter*, Martin Ottenklev.
12 Master's thesis presentation: *Statistical and Machine Learning Methods for Classification of Episodic Memory*, Albin Heimersson, Damir Knezevic.
12 Master's thesis presentation: *Scheduling Strategies for the Calvin IoT Environment*; Sam Jabbar.
12 *Robot Skill Learning*, Jan Peters, TU Darmstadt.
13 Master's thesis presentation: *Distributed Heating Networks*, Rijad Alisic.
13 Master's thesis presentation: *Building Data Classification and Association*, Anna Åberg, Christine Sjölander.
14 Master's thesis presentation: *On Shock Propagation in Financial Networks*, Isabelle Rosenberg, Viktor Svensson.

August

20 *Object-Oriented Modeling and Control of Next-Generation HVAC Systems*, Scott A. Bortoff, Mitsubishi Electric Research Laboratories, Cambridge, USA.
20 *Transforming the Pose Estimation Problem into a Linear Least Squares Problem*, James Richard Forbes, McGill University, Canada.
28 *Coordination Control of Multiple Fixed-Wing UAVs with Constant Speeds*, Zhiyong Sun, Dept. of Automatic Control, Lund University.
29 Master's thesis presentation: *Principles for Tuning Heat Zone Controllers in a Belt Furnace Through Modeling and Simulation*, Henrik Fryklund.
29 *From Flexible Production to Cognitive Automation*, Ulrike Thomas, Robotics and Human-Machine-Interaction Lab, TU Chemnitz.
31 *Accelerator Control at TRIUMF,* Melika Shahriari, UBC, Vancouver.

September

04 *Rapprochement Between Formal Methods and Control Theory,* Richard Murray, Caltech.
12 Master's thesis presentation: *Robustness of Equilibria in Transportation Networks*, Rasmus Stålberg.
19 Master's thesis presentation: *Implementation of a Simulation Module for Adaptive Charging Algorithms for Electrical Vehicles*, Daniel Johansson.
21 Master's thesis presentation: *Tuning Feedback-Based Traffic Signal Controls*, Simon Paulsson.

October

08 Master's thesis presentation: *Robot-Held Camera Platform for Medical Applications*, Christopher Tvede-Möller.
09 *Mathematical Modeling of Muscular Force Generation and Electromyography – A Systems Perspectiv,* Eike Petersen, Lübeck University.
09 *Event-Based MPC with Adaptive Horizon for Nonlinear Systems*, Zhongqi Sun, Beijing Institute of Technology.
11 *Natural Dynamic Controllers for Legged Robots*, Miriam Zacksenhouse, Technion.
11 *Iterative Learning of Energy-Efficient Dynamic Walking Gaits*, Felix Kong, Sydney University.
17 *Unsupervised Control*, Maximiliam Karl, Technical University of Munich.
17 *Reinforcement Learning for Control of Continuous-Time Systems*, Farnaz Adib Yaghmaie, Linköping University.
18 *Biologically Plausible Observer Neural Network Models of Brain Areas Involved in Spatial Navigation*, Adrianna R. Loback, University of Cambridge.
18 *Performance Limitations in Sensorimotor Control: Tradeoffs between Neural Computing and Accuracy in Tracking Fast Movements*, Shreya Saxena, Columbia University.
19 Master's thesis presentation: *Optimization of Reverse Osmosis Performance*, Pontus Lundberg, Angelica Persson.
19 *Robotics and Technology Assisted Neurorehabilitation for Translational Research*, Natalia Martina López Celani, Universidad Nacional de San Juan.
23 *Collision Avoidance: A Line-of-Sight and Time-to-Collision Approach*, Thiago Marinho, University of Illinois UC.
23 *Lower Bounds on the Complexity of Solving Two Classes of Non-Cooperative Games*, Ehsan Nekouei, KTH.
29 *On Container Cranes Control: Four Weddings and a Funeral*, Jonas Öhr, ABB Ports.

November

01 *Probabilistic Approaches to Problems in Robotics – an Overview of Robotics Research at Stellenbosch University, South Africa*, Corné van Daalen, University of Stellenbosch, Sydafrika.
02 *Robot Assisted Training to Support Motor Learning for Different Skill Level,* Ekin Basalp, ETH Zürich.
02 *A Theoretic Framework Connecting Speed and Accuracy Heterogeneity at the System and Component Levels*, Yorie Nakahira, Caltech.
06 *Corticostriatal Circuits Encode Behavioral Transitions in Natural Behavior*, Joel Sjöbom, Lund University.
06 *Efficient Predictive Model-Based and Fuzzy Control*, Anahita Jamshidnejad, Technical University of Delft.
07 *Partial Synchronization and Model Reduction of Nonlinear Biological Networks*, Yu Kawano, University of Groningen.
07 *Learning Convex Bounds for Linear Quadratic Control Policy Synthesis*, Jack Umenberger, Uppsala University.
08 *Model Reduction by Balanced Truncation of Dominant Systems*, Alberto Padoan, University of Cambridge.
08 *Differentially Private Contextual Linear Bandits*, Roshan Shariff, University of Alberta.
15 *Time-Frequency Reassignment,* Digit@LTH - Maria Sandsten, Mathematical Statistics, LTH.
16 Master's thesis presentation: *Vibration Reduction in a Gantry Robot*, Marcus Peterson.

December

05 Master's thesis presentation: *Semi-Automation of a Spray Painting Robot*, Daniel Jovanovski.
14 Defence of doctoral dissertation: *Statistical Modeling and Learning of the Environmental and Genetic Drivers of Variation in Human Immunity*, Jacob Bergstedt, Department of Automatic Control, Lund University.
19 Master's thesis presentation: *Reinforcement Learning – Intelligent Weighting of Monte Carlo and Temporal Differences*, Martin Christiansson.
21 Master's thesis presentation: *Embedded RTOS-Adaptive Control System with Optical Signals*, Sebastian Elm.

External Contacts

External contacts of importance to our projects during 2018, both academic and industrial

Together with external contacts and partners the goal is to solve real control problems. A mix of fundamental and applied work is a cornerstone of our activities. In these kind of projects the problems are approached with an open mind without glancing at particular methods. One purpose is to learn about real problems, another is to learn about new problems that are suitable for theoretical research. An important role for universities is to organize knowledge in such a way that the results can easily be digested by engineers in industry.

Lund / Academia
Lund University, Dept Clinical Sciences Lund, Biomedical Engineering, Lund
Lund University, Dept of Chemical Engineering, Lund
Lund University, Dept of Computer Science, Sweden.
Lund University, Dept of Mathematics, LTH, Lund
Lund University, Dept of Electrical and Information Technology, Lund
Lund University, Div. Combustion Engines, Dept of Heat and Power Engineering, Lund.
Lund University and Skåne University Hopital, Dept. Cardiothoracic Surgery, Lund
Skåne University Hospital, Medical Services, Lund

Lund / Industry & Society
Axis Communications AB
Business Region Skåne
Cognibotics
Ericsson
European Spallation Source (ESS)
Igelösa Life Science AB
Vävnadsbanken

Sweden / Academia
Chalmers University of Technology
KTH - Royal Institute of Technology
Linköping University
Luleå University of Technology
Umeå University
Uppsala University

Sweden / Industry & Society
5 High Innovations
ABB, Sweden
ABB Corporate Research, Västerås, Sweden
Blue Institute, Sweden
Clarister
Comsys
Corebon, Sweden
Gustaf Fagerberg AB, Sweden
OP5 RISE
Perstorp AB, Sweden

PiiA
Prod2030
SAAB AB, Linköping, Sweden
SAAB Bofors Dynamics, Linköping, Sweden
Scania, Södertälje, Sweden
Schneider Electric
Sectra Imtec
Sekvensa AB
SEK
SIS
Swedish Energy Agency
Swedish Modules
Swegon Operations

Nordic countries / Academia
Aalto University, Finland
DTU - Technical University of Denmark
Jyväskylä University, Finland. Mari Suoranta
NordForsk - Nordic University of Hubs
NTNU - Norwegian University of Science and Technology, Dept of Engineering Cybernetics

Nordic countries / Industry & Society
Granlund OY
kW-set OY
Orbis OY

Europe / Academia
ETH Zürich, Switzerland.
European Innovation Academy, EU.
Graz University of Technology - Institute of Computer Graphics and Vision, Austria
KU Leuven, Belgium
Lübeck University, Germany
Oxford University, UK
Max Planck Institute for Software Systems, Germany
Politecnico di Milano, Italy
Politecnico di Torino, Italy
Sant'Anna School of Advance studies, Real-Time Systems Labs, Pisa, Italy
Technion - Israel Institute of Technology, Haifa
Tel Aviv Univeristy, Israel
TU Chemnitz - Robotics and Human-Machine-Interaction Lab
TU Darmstadt, Germany
TU Delft, Netherlands
TU Munich, Germany
UNED, Spain
Universidad de Almeria, Spain
Universidad Nacional de San Juan, Spain

Università Luigi Bocconi, Milan, Italy
University Groningen, Belgium
University of Brescia, Italy
University of Cyprus, KIOS Research and Innovation Center of Excellence, Cyprus
University of Cambridge, UK
University of Ghent, Belgium
University of La Laguna (ULL), Spain
University of Modena, Italy
University of Salerno - Dept of Industrial Engineering, Italy

Europe / Industry & Society
AICo Software, Austria
AlfaEvolution Technology, Italy
EU Commission
Fluxguide, Austria
Institut Pasteur, Paris, France
SARAFun Consortium
SmartFactory, DFKI, Kaiserslautern, Germany.
TWI Ltd, UK

World / Academia
Beihang University, BUA, Beijing, China
California Institute of Technology, USA.
Caltech, USA
Hanyang University, Seoul, Korea
Massachusetts Institute of Technology, USA
McGill University, Canada
Saint Mary's University, Canada
Sydney University, Australia
Tsinghua University, Dept Precision Instruments and Mechanology, Beijing, China
UC Berkeley, USA
University of British Columbia (UBC), Electrical and Computer Engineering in Medicine (ECEM), Vancouver, Canada
University of California, Berkeley, CA, USA
University of Maryland College Park, USA
Zheijang University, Hangzhou, China

World / Industry & Society
Lawrence Berkeley National Laboratory, CA, USA
Mariner Partners, Canada
Missing Link Technologies, Canada
Mitsubishi Electric Research Laboratories, Massachusetts, USA
United Technologies, Hartford, USA

Economy

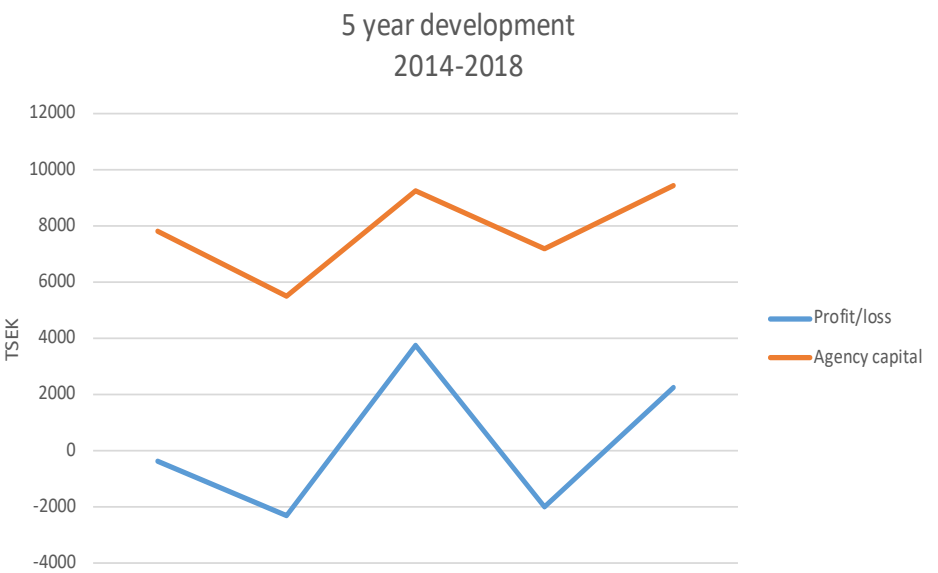
This chapter contains an overall view of the economy and funding

ECONOMY

The turnover for 2018 was 55 MSEK, an increase by 4 MSEK compared to 2017. About half of the income comes from Lund University and the remaining half from external grants.

The activities and the number of employees seem to have stabilized during the last years. The number of employees is currently 45 persons including part-time positions (42 full-time equivalents). The department participated in one project funded by the European Union, in Horizon 2020, which was terminated during 2018. The Swedish Foundation for Strategic Research (SSF), Swedish Research Council (VR), Knut and Alice Wallenberg Foundation (KAW) and Vinnova have also provided substantial support of our activities.

The block grants from VR, KAW and some of the SSF projects are long range. Several projects do, however, have a duration of only two years. To match these with the length of a PhD position, i.e. 5 years, we have a long-term internal research planning, and we are careful to bid on projects that fit into our research plan. This has proven efficient to match short-term funding, research planning and personnel.



Above: Profit/loss and agency capital development over the last 5 years

FUNDING

During 2018 we had the following external grants:

VR – Linnaeus Grant – Lund Center for Control of Complex Engineering Systems (LCCC)
VR – Feedback Computing in Cyber-Physical Systems
VR – Resilient Control of Dynamical Network Flows
VR – Control of Monotone Systems and Diffusions
VR – Large Scale Convex Optimization
VR – Hemodynamic Modeling and Control
VR – Event-Based Control and Estimation with Application to Server Systems
Vinnova – Line Information System Architecture 2 (LISA2)
Vinnova – Hemodynamic Stabilization
Vinnova – Bloqqi: An Open Module Source Language in Automation
Vinnova – Surgeon's Perspective 2
Vinnova – Ventilator for Improved Cardiopulmonary Resuscitation
Vinnova – ISOTC184/SC5 Chair – Swedish Impact
Vinnova – Strategies and Standards for Smart Swedish Industries
Vinnova – Development of New Method for Midranging Control
Vinnova – ITEA3, AutoDC
Vinnova – On Humans for Humans: Testbed for New Surgical Methods
Vinnova – Innovative Agile Construction for Globally Improved Sustainability (ACon4.0)
Vinnova – Connected Working Site (Uppkopplad byggplats)
SSF – Algorithms for Solving Large-Scale Convex Optimization Problems
SSF – Societal-Scale Cyber-Physical Transport Systems
SSF – Semantic Mapping and Visual Navigation for Smart Robots
EU Horizon 2020 – Smart Assembly Robot with Advanced FUNctionalities (SARAFun)
KAW – Wallenberg Artificial Intelligence, Autonomous Systems and Software Program (WASP)
ESS – Temperature Control of Phase Reference Line
eLLIIT – The Linköping–Lund Initiative on IT and Mobile Communication (eLLIIT)
SKB – Control of Stirwelding Process for Sealing
Swedish Energy Agency – Emissions Control for Low Climate Impact (KCFP3)
NordForsk – Nordic University Hub on Industrial Internet of Things (HI2OT)

Staff

In this chapter the personnel and its activities will be described.

Kick-off at Barsebäck in August 2018

STAFF

Professors
Årzén, Karl-Erik; director of undergraduate studies
Åström, Karl Johan; senior professor
Bernhardsson, Bo
Eker, Johan; adjunct professor
Hagander, Per; professor emeritus
Hägglund; Tore
Johansson, Rolf
Johnsson, Charlotta
Rantzer, Anders; head of department
Robertsson, Anders
Wittenmark, Björn; professor emeritus

Associate Professors
Cervin, Anton; deputy head of department
Como, Giacomo (25%)
Giselsson, Pontus
Maggio, Martina; director of graduate studies

Assistant Professor
Soltesz, Kristian

Research engineers
Andersson, Leif (30%)
Andersson, Pontus
Blomdell, Anders
Nilsson, Anders

Administrators
Edelborg, Cecilia
Nishimura, Mika
Rasmusson, Monika (70%)
Westin, Eva

Postdocs
Sun, Zhiyong (from June)
Yamamoto, Kaoru (until July)

Researchers
Olofsson, Björn
Pates, Richard
Pigot, Henry

PhD students
Ariu, Kaito (until November)
Bagge Carlson, Fredrik
Bergeling, Carolina
Bergstedt, Jacob (until December)
Fält, Mattias
Greiff, Marcus
Heimerson, Albin (from September)
Heyden, Martin
Karlsson, Martin
Mandrioli, Claudio (from January)
Millnert, Victor
Morin, Martin
Nayak Seetanadi, Gautham
Nilsson, Gustav
Nylander, Tommi
Rosdahl, Christian
Ruuskanen, Johan
Sadeghi, Hamed
Thelander Andrén, Marcus
Troeng, Olof
Turesson, Gabriel (until June)
Vreman, Nils (from September)

Industrial PhD students
Martins, Alexandre; Axis
Skarin, Per; Ericsson

BOARD OF THE DEPARTMENT

Anders Rantzer
Martina Maggio
Giacomo Como
Karl-Erik Årzén
Anders Nilsson
Mattias Fält

Deputy members of the Board
Anton Cervin
Tore Hägglund
Bo Bernhardsson
Pontus Giselsson
Pontus Andersson
Olof Troeng

LONG-TERM VISITORS

González Cava, José Manuel; visiting MSc student, University of La Laguna, Spain (September–November).
Orlov, Yury; guest professor, CICESE, Mexico (until June).
Pazzaglia, Paolo; visiting PhD student, Scola Superiore Sant'Anna, Italy (from October)
Quesnel, Charlotte; visiting MSc student, ENSMM, France (March–June).
Shariari, Zahra; visiting PhD student, UBC, Canada (September–November).
Zhao, Di; visiting PhD student, HKUST, Hong Kong (from August).
Zhu, Li; visiting postdoc, Dalian University of Technology, China (until June).

STAFF ACTIVITIES

Ariu, Kaito
ME and BE in Aeronautics and Astronautics, PhD student at the department since 2017. At the end of 2018 he transfered to an equivalent position at KTH, Stockholm.

Andersson, Leif
MSc, Research Engineer since 1970. Leif started at the department with responsibility for the teaching and research laboratory. After some years he drifted to computer maintenance and became computer manager. He retired formally in 2012, but was immediately rehired on 30%.

A large part of his time the past year has been spent as an internal LaTeX consultant, helping the PhD students to make their theses beautiful, and also helping the staff with general LaTeX problems.

As previous years he has worked a lot with the publication database LUCRIS, and also assisting with transferring the department web pages to the LTH server.

Andersson, Pontus
MSc, Research Engineer at the department since 2012.

His main work involves development and design of student laboratory equipment. This includes mechanic and electronic design as well as implementation. He is also supporting student projects and is involved in various projects in the Robotics Lab.

Bergstedt, Jacob
MSc, PhD student at the department since August, 2013.

Together with researchers at the Pasteur Institute, Paris, he is investigating the human immune system in the Milieu Interieur project http://www.milieuinterieur.fr/en. He defended his thesis *Statistical Modeling and Learning of the Environmental and Genetic Drivers of Variation in Human Immunity* in December 2018 and is joining the Pasteur Institute as postdoc.

Årzén, Karl-Erik
Professor (2000), PhD (1987), joined the department in 1981.

His research interests are real-time and embedded control, real-time systems, cloud control, feedback computing, autonomous systems, and programming languages for control.

Coordinator for the Lund part of WASP (Wallenberg AI, Autonomous Systems and Software Program). Chair of the Program Management Group for WASP. During the year he has primarily been involved with WASP, the VINNOVA/ITEA3 AutoDC project, the Nordforsk University Network HI2OT and the the VR project Feedback Computing for Cyber-Physical Systems. He is partly or fully involved in the supervision of six PhD students.

Åström, Karl Johan
Professor in Automatic Control since 1965 and founder of the department, emeritus from 2000, senior professor since 2010.

A major activity was to work on the second edition of the book *Feedback Systems* co-authored by Richard Murray, Caltech.

In January he was invited to University of Valencia to give a short course on Model Based Systems Engineering.

In March he was invited to the University of Almeria to lecture about PID control. He also attended the retirement celebrations of Prof. Bo Egardt and gave a talk at the dinner.

In May he was an honorary guest in Ghent at the conference PID 18, the third of a successful series of conferences on PID control.

In June he participated in the CCS MBD Workshop in Charlotte, South Carolina.

In October he participatd in the LCCC Focus Period on *Learning and Adaptation for Sensorimotor Control*. He gave an improvised lecture about not forgetting the physics in a mini session on *learning* and a broad talk about *adaptive control* in the main conference.

In December he was invited to NTNU in Trondheim to be first opponent on the thesis by Chriss Grimholt, on that occasion he also gave a broad talk about *the development of the field of Automatic Control*.

Bagge Carlson, Fredrik
MSc and Lic. Tech., PhD student since 2014.

He is interested in machine learning and system identification, in particular within the field of control and applied to physical systems. He will defend his PhD thesis in Jan 2019, titled *Machine learning and system identification for estimation in physical systems*. Some of his recent endeavors include supervising the MSc thesis *Reinforcement Learning—Intelligent Weighting of Monte Carlo and Temporal Differences* by Martin Christiansson, and packaging and structuring software developed for my thesis as open-source repositories.

Bergeling, Carolina
Lic. Tech., MSc in Engineering Physics from Lund University. PhD student at the department since June 2013.

Her research interests include control of complex systems with focus on distributed control of energy systems.

In June 2016 she presented her licentiate thesis, *On Scalable H-infinity Control*. She was a visiting student at the Institute for Mathematics and its Applications, University of Minnesota, Minneapolis, USA, during October 2015 and May 2016.

She has developed and been a teaching assistant for the course Physiological Models and Computation and co-supervised Master's thesis projects.

Carolina is also part of two working groups on gender equality and diversity.

Carolina was on parental leave from June to December 2018.

Bernhardsson, Bo
Professor (1999), Docent (1998), PhD (1992). He has also worked at Ericsson during 2001–2010.

During 2018 he was a member of the LCCC board and one of the organizers of the graduate school in the WASP Autonomous Systems and

Software program.

During 2018 Bo Bernhardsson has also worked part time in a project for the European Spallation Source with the design of the RF system for the proton accelerator. His research interests are in control theory and its applications in communication systems and learning systems.

During 2018 he taught the basic course in Automatic Control and was elected best teacher of the year by the students. He also taught the PhD course in Robust Control (with Richard Pates) and two WASP PhD courses in Autonomous Systems (with Patric Jensfelt, KTH).

He is the main supervisor of 3 and co-supervisor of 7 PhD students.

Blomdell, Anders

Research Engineer at the department since 1988. Heavily involved in almost all aspects of Robotics research at the department, also responsible for the department network and lab computers for teaching and research.

Lots of work associated to planning for the big shuffle (renovation of the M-building).

Cervin, Anton

Docent (2008), PhD (2003), MSc (1998). Anton joined the department in 1998 and has been employed as an Associate Professor since 2007. His research interests include event-based and networked control, real-time systems, cloud control, and computer tools for analysis and simulation of controller timing.

He is the main supervisor of two PhD students and leads two research projects within event-based control and co-design of real-time control systems.

During 2018 he was responsible for the advanced-level courses Multivariable Control and Project in Automatic Control, and he also supervised or examined five master's theses. His administrative tasks included being deputy and assistant head of the department.

Como, Giacomo

Docent (2012), PhD (2008). He has been at the Department of Automatic Control since 2011 and was promoted Associate Professor (universitetslektor) in 2013. During 2018, he has partly been on leave at Politecnico di Torino.

His research interests are in Dynamics, Information, and Control in Networks, with applications to transport, infrastructure, as well as social and economic systems. He is PI of the VR Project "Resilient Control of Dynamical Flow Networks".

During 2018, he has served as main supervisor of Gustav Nilsson and as co-supervisor of Hamed Sadeghi and Martin Heyden. He has also been main supervisor of Laura Arditti, Leonardo Cianfanelli and Rosario Maggistro and co-supervisor of Luca Damonte, Leonardo Massai and Lorenzo Zino at Politecnico di Torino.

In Spring 2018, he taught the master level course Network Dynamics at Lund University.

In 2018, he supervised six masters' theses.

Edelborg, Cecilia

Financial Administrator at the department since 2017.

The responsibilities are primarily accounting regarding travel expenses, intermittent employments, reimbursements, invoices and projects. Also, administration of conferences and kick offs, committees and other administrative tasks.

She also is CPR trained as well as Fire protection trained and a member of the Equality group at the department and work with these questions.

Her background is from the Faculty of Law at Lund University.

Eker, Johan

Docent (2010), PhD (1999). Johan is an adjunct Professor and spends one day a week at the department and the remaining time at Ericsson Research.

His main interests are the area of resource management of large scale compute systems and datacenters using control theory and machine learning. In particular, he works with mission-

critical cloud applications such as distributed control systems and virtualized communication infrastructure.

Johan is the main supervisor for Victor Millnert and Albin Heimerson and the industrial supervisor for Per Skarin. All three are part of the WASP program.

Johan was co-authoring the WASP report on AI infrastructure for Sweden which was published late 2018 and is available for download on the WASP homepage.

Fält, Mattias
MSc, PhD student since August 2015.

His main research interest is methods for large-scale convex optimization. The focus has been on studying and improving convergence rates for first-order methods.

Giselsson, Pontus
Docent (2018), PhD (2012), MSc (2006). Pontus is currently Associate Professor at the Department of Automatic Control. His research interests are in optimization and its wide range of applications.

During 2018, Pontus was responsible for the undergraduate level courses Systems Engineering and Process Control and for the PhD level course Convex Optimization. He is supervising three PhD students and is director of doctoral studies at the Department of Automatic Control.

Greiff, Marcus
MSc, PhD student since March 2017.

His main research interest relates to topics of control and estimation of rigid-body dynamics generally, and unmanned aerial vehicles specifically.

The research is supervised by Anders Robertsson and part of an SSF project which is a collaboration with Chalmers.

During 2018, he has been a TA in Predictive control (FRTN15), Projects in automatic control (FRTF01) and the Automatic Control, basic course (FRTF05). Completed coursework includes Optimal control and Robust Control.

Hägglund, Tore
Professor, PhD (1984). Has been at the department since 1978 except for four years when he worked for ABB.

Responsible for two of the basic courses in Automatic Control in the engineering program.

Main research interests include process control, PID control, decentralized control, and monitoring and diagnosis.

Main research activities during the year have been automatic tuning of PID controllers, feedforward control and decentralized control structures.

Heimerson, Albin
MSc, PhD student since August 2018.

His supervisor is Johan Eker and his main project will be a collaboration with Ericsson about automated datacenters.

His research interests are towards ML, and he is very interested in how to control complex systems with a combination of ML and classic control.

He has been a teaching assistant in the basic control course in both Lund and China.

He has also been helping out with setting up a software stack for ML on the Ericsson cloud for one of the WASP courses that Bo Berhardsson was teaching.

Heyden, Martin
MSc, PhD student since October 2016.

His main research interest is the interaction between economics and traffic flows. The research is supervised by Anders Rantzer and part of the SSF-SoPhy project which is a collaboration with KTH.

During 2018, he has been a TA in *Multivariable Control* (FRTN10) and *Physiological Models and Computations* (FRTF01). Coursework completed includes *Robust Control* and *Functional Analysis in System Theory*.

Johansson, Rolf
Professor, MD, PhD. Active at the department since 1979.

Rolf Johansson's research interests are in system identification, robotics and nonlinear systems and automotive control.

He participates and leads the research projects KCFP Control and SARAFun. He is coordinating director for Robotics Laboratory with cooperation partners from Dept Computer Science and industrial partners. He has industrial cooperation with ABB Robotics, ABB Corporate Research, Scania and Volvo. He is responsible for the three following courses FRTN35 System Identification, FRTN15 Predictive Control and FRTF01 Physiological Models and Computation.

He has supervised 6 PhDs, out of which 2 of them have defended their thesis. Rolf has also supervised 7 Master's Thesis.

Johnsson, Charlotta
Professor (2018), Docent and ETP (2011), PhD (1999), MSc (1993).

Charlotta's main research interest covers Automation, Control and Operations. However, Charlotta is also involved in the research domains of Innovation and Entrepreneurship, Teaching and Learning in Higher Education, as well as Technology Management and Engineering Leadership.

She is the Chair of ISO TC184/SC5, hence actively working on standardisation activities for Smart Manufacturing and Industry 4.0.

Since 2017, Charlotta is also the Vice Dean of Engineering Faculty with focus on Collaborations and Innovations.

Karlsson, Martin
MSc, PhD student since April 2014.

His research interests are within state estimation, and robot learning and control.

In 2018, he has been working within the EU project SARAFun, with focus on robot learning for assembly tasks, and the VINNOVA project Surgeon's Perspective, considering robot-assisted surgery.

He has worked as a teaching assistant in the courses Applied Robotics and Nonlinear Control.

Maggio, Martina
Docent (2017), PhD (2012). Martina is an Associate Professor, and has been 7 years at the department.

Her research interests are Applications of Control Theory to Computing Systems and Embedded and Real-Time Systems. She is involved in WASP and VR projects.

She has been teaching during autumn the Project Course and Basic Control Course in China. During spring she was teaching in Real-Time Systems.

She has been Master Thesis advisor to Nils Vreman, *Minimizing Side-Channel Attack Vulnerability via Schedule Randomization* and David Rådberg, *Optimal Real Time Bidding in Online Advertising*.

She has been the examiner for Jonatan Ekelund *Balancing and Locomotion of a Hexapod Robot Traversing Uneven Terrain*.

She is supervising the following PhD students: Gautham Nayak Seetanadi, Claudio Mandrioli, Nils Vreman, Alexandre Martins, Tommi Nylander, Per Skarin, Haroui Peng@EIT, Lund and Stepan Shevtsov @KU Leuven and Linneus University, Vaxjo.

Mandrioli, Claudio
Claudio received Bachelor (2015) and Master degree (2017) from Politecnico di Milano in Automation and Control engineering. At the end of his master he was a visitor at the department to work on his thesis. He has then been employed as a PhD student at the department since January 2018.

He is part of and funded by the WASP research program. His research interests included so far modeling and control of computing systems - from a cloud system to small GPS devices. In the next future he will be working on developing methodologies for the testing of the adaptation layers in such systems.

In 2018 he was involved as Teaching Assistant in the basic course in automatic control given by the department.

Martins, Alexandre
Industrial PhD student at the department since April 2016, working in the Swedish network camera leader Axis Communications.

Reseach intrests are model predictive control, game theory, video compression.

He is part of the research project Autonomous Systems, WASP.

Millnert, Victor
MSc, PhD student since September 2014.

From September 2018 until March 2019 he has been a visiting researcher at University of California, Berkeley in the USA.

In order to enable smart manufacturing and smart collaborations in the coming industrial internet-of-things, or Industry 4.0, a key element is to be able to utilize smart services residing in the cloud. The challenge is that the applications require a very low and predictable end-to-end latency. With the coming 5G technology standard part of this puzzle will be solved since it will allow for a low-latency wireless connection to/from the cloud.

Victor have had teaching duties within Real-Time Systems.

Morin, Martin
MSc, PhD student since August 2017.

Research interests are large scale optimization with current work focusing on variance reduced stochastic first order methods applied of convex problems.

Teaching duties include supervision of lab and exercise sessions in the basic control course and multivariable control course.

Nayak Seetanadi, Gautham
PhD student at the department since January 2016 after 4 months as a research assistant.

His current research interests are bandwidth allocation schemes, applications of model checking and routing mechanisms for real-time communications. He is involved in teaching and supervision in real-time systems and systems engineering courses at the department.

He has also been involved at the PhD student union at LTH acting as the vice-president of the board for the year 2018.

Nilsson, Anders
PhD (2006), Research Engineer since 2010.

Spends most of the time looking after the department computers and their software.

With a past at the department of computer science developing compiler and runtime system for real-time Java, he also tries to squeeze in some time for research. Recently this has meant being involved in the EU H2020 SARAFun project.

Nilsson, Gustav
MSc in Engineering Physics (2013). Gustav is a PhD student at the department since 2013.

His research interests are in the field of control of networks with applications in transportation networks. Until mid-March 2018, Gustav was doing an internship at Mitsubishi Electric Research Laboratories (MERL) in Cambridge, MA. He has also been a visiting PhD student at Dipartimento di Scienze Matematiche *Giuseppe Luigi Lagrange*, Politecnico di Torino in July and October to November this year.

During the year, Gustav has supervised two masters' theses, both related to transportation networks. He has also served as a teaching assistant in the network dynamics course.

Nishimura, Mika
Born in Japan. Administrator at the department since 2014.

She handles the exam results in Ladok. She has contact with the printing office about doctoral thesis and other publications. She is responsible for purchase of office supplies, books and handles Lucat-catalogue system for the employees at the department. She reviews Lucris-research portal, updates LUP-student paper and parts of the web pages and keeps keys in order among other service-oriented tasks.

She also teaches Japanese at Folkuniversitetet in Lund since 2006.

Nylander, Tommi
MSc (2014), PhD student since January 2016.

He is part of the WASP Autonomous Clouds and Networks research cluster, focusing on control-based resource management.

During the year he has also taken some courses and been a teaching assistant in the Real-Time Systems course as well as in the System Identification course.

Olofsson, Björn
PhD (2015), MSc (2010). He is currently a researcher at the department, with wide research interests in robotics and control for autonomous vehicles.

During the year, he was involved in a research project within the eLLIIT Strategic Research Area, investigating optimal vehicle maneuvers and methods for autonomous driving in time-critical situations. He has also taken active part in the teaching at the department. He was involved in the development of study material and exercises for the module on motion planning in the WASP PhD student course on autonomous systems and was also acting as supervisor of a Master Thesis project.

Pates, Richard
Richard obtained the M.Eng and Ph.D degrees from the University of Cambridge in 2009 and 2014 respectively. He has been with the Department of Automatic Control in Lund since 2015, where he is currently a Researcher.

His research interests lie principally in the control of large scale systems, in particular electrical power systems.

This year his focus has been on performance limitations that are a consequence of system size, and their implications for decentralised control.

In addition he has taught a Ph.D. level course on Robust Control, supervised Rijad Alisic's masters thesis project, and is the co-supervisor for both Carolina Bergeling and Martin Heyden.

Pigot, Henry
Henry (Harry) joined the department in August 2018 as a Project Assistant. He graduated from the University of British Colombia in Vancouver with a BASc Electrical Engineering (Biomedical Option) in 2017. During his studies, Harry worked in Lund for nearly two years developing technology for heart and lung transplant surgery. In the year before joining the department, he started a hands-on programming and electronics club for children in Nepal.

Harry's main area of interest is medical technology development. In 2018 he worked with Kristian Soltesz on an improved ventilation method for patients undergoing cardiopulmonary resuscitation.

Rantzer, Anders
Professor of Automatic Control since 1999 and head of department.

He has been leading the Linnaeus center LCCC during 2008-2018 and serves as chairman for the RoboticsLab.

Anders Rantzer is the main supervisor for several PhD students and postdocs.

In 2018, he was teaching FRTN45 Mathematical Modelling, Advanced Course and FRTN05 Nonlinear Control and Servo Systems at the masters level.

He has broad interests in modeling, analysis and synthesis of control systems, with particular attention to uncertainty, optimization, scalability and adaptation.

Rasmusson, Monika
She joined the department in August 2011 and as from March 2017, she took over as finance officer and is now responsible for year-end closing, budget, forecast and reporting, both internally within the faculty and externally to sponsors.

As a part of the administrative team, her work includes backup function for her colleagues, editing the yearly Activity Report, among other administrative tasks.

She has a Bachelor's degree in Business administration, Lund University.

Robertsson, Anders
Professor (2012), Associate professor (2007), "Docent" (2005), Research Associate (May 2003), PhD (1999). Excellent Teaching Practitioner (ETP) in 2007.

His main interests are in nonlinear control, robotics and control of computing systems. Currently he is working on parallel kinematic robots, sensor-data integration and force control of industrial robots in collaboration with ABB Robotics/ABB CRC. The research has been conducted within the Robotics Lab, Linneaus Centre LCCC, eLLIIT network, and the projects SaraFUN (EU-H2020), Smart Systems (SSF), The Surgeons Perspective (Vinnova) and within a couple of recently started projects related to construction robotics (Vinnova and Boverket).

He has been teaching in the courses on Applied Robotics (MMKF15) and Basic course on Automatic Control (FRT090) at Beihang, China, and been supervisor for several project groups in mechatronics, electronics and participated in the teacher education at Vattenhallen, LTH.

He has acted as advisor/co-advisor for (2+5) PhD students and several Masters' Theses projects.

Rosdahl, Christian
MSc, PhD student since September 2017.

He is part of the Wallenberg AI, Autonomous Systems and Software Program (WASP) and works on a project with focus on efficient learning of dynamical systems with Bo Bernhardsson as supervisor.

During the year, Christian has been a teaching assistant in the Network Dynamics course and co-supervised a master's thesis project. He has also taken courses on autonomous systems, functional analysis in system theory as well as optimal and robust control.

Ruuskanen, Johan
MSc, PhD student since September 2017.

Johan is part of the WASP research program within the Autonomous Clouds and Networks cluster. He is supervised by Anton Cervin and co supervised by Karl-Erik Årzén. The main research topics include event-based estimation, cloud control.

During the year Johan has been a teaching assistant for the basic course both in Lund and in China, and a project supervisor in the course Physiological Models and Computations. In this time he has also participated in a number of PhD and master level courses.

Sadeghi, Hamed
MSc (2013) and BSc (2011) in Mechanical Engineering from Sharif University in Iran. He is a PhD student at the Automatic Control Department since August 2016.

His research interests are in Large-scale Optimization and its vast areas of applications. His research is a part of Large-scale Optimization and Control cluster within WASP-AS branch.

He was involved in teaching Systems Engineering/Process Control course during the spring and Multi-variable Control course during the fall.

Skarin, Per
MSc (2004), industrial PhD student since August 2016.

His research interests are Distributed Clouds, Autonomous Clouds, and Optimal Control.

He is part of the research project Autonomous Clouds, WASP.

Soltesz, Kristian
Docent (2018), PhD (2013). He has been employed as associate senior lecturer with the department since 2016.

His main line of research is the development of intensive care control systems. He is coordinating three interdisciplinary projects, financed by Vinnova and VR, aimed at achieving hemodynamic stabilization in organ donors, and in patients undergoing cardiopulmonary resuscitation. He is also part of a collaboration with the University of British Columbia (UBC), within which a system for closed-loop controlled intravenous anesthesia is developed. He has visited UBC annually within this collaboration.

Teaching-wise, he has been involved in MSc and BSc supervision and teaching of the depart-

ment's project course. He has also led a PhD study circle on teaching lab development.

Sun, Zhiyong
Zhiyong received his PhD at the Australian National University (2017). He joined the Department of Automatic Control as a postdoc researcher in June 2018.

His research interests include autonomous robotic systems, multi-agent coordination, formation control, and the general field of distributed control and optimization, and networked systems.

His recent research focus has been on feasible coordination of multi-vehicle systems under motion constraints, and event-based control for networked systems.

Thelander Andrén, Marcus
MSc, PhD student since August 2015.

His main research interests are stochastic event-based control and estimation.

During 2018 he has done research in event-based control for cloud- and server systems, and on numerical methods for computing optimal sampling policies for event-based control. He has been teaching in the real-time systems course, and supervising projects in the control project course.

Troeng, Olof
MSc (2012), PhD student since October 2014.

He works on control algorithms for the accelerating electromagnetic fields in the linear accelerator at the European Spallation Source.

In connection with the CDC conference, he made a rewarding research visit to Berkeley Lab to discuss cavity field control.

During the year, he supervised a MSc thesis on numerical issues in Q-design, and TA'd the nonlinear control course.

Turesson, Gabriel
PhD student since January 2013. He is working with Professor Rolf Johansson and Professor Per Tunestål in the KCFP PPC Control project, which is a cooperation with the Division of Combustion Engines.

Gabriel is studying control-related problems in partially premixed combustion (PPC) engines.

In June he defended his doctoral theses titled *Model-Based Optimization of Combustion-Engine Control*.

Vreman, Nils
MSc, PhD student since August 2018.

His research topics are within security for control systems, including (but not limited to) andomized scheduling and secure cloud-control.

During 2018 he has been teaching: Basic Automatic Control (FRTF05), Project in Automatic Control (FRTN40), and Nonlinear Control (FRTN05).

Westin, Eva
PhD in French linguistics.

Administrator at Automatic Control since 2008 and administrative manager from December 2017 for the administrators and research engineers at the department.

She handles the overall responsibility of human resources, guests and conferences. She also handles part of the process for research studies. Eva is the project administrator for the LCCC Linnaeus project. She is part of the workplace health and safety team at the department. She is also part of the Equality group at the Faculty of Engineering. Part of the Togetherness group in the M-building.

Yamamoto, Kaoru
PhD (2016). She joined the department as an LCCC postdoc in January 2017.

Her principal research interests are in analysis and synthesis of interconnected dynamical systems using complex analysis and control of signals beyond the Nyquist frequency in sampled-data systems.

She terminated her stay in July for a new position in Japan as associate professor.

PROMOTING GENDER EQUALITY AND DIVERSITY

The working group on gender equality and diversity was formed in early 2014. Since the start we have had some 15 seminars by invited speakers on subjects ranging from research communication and security at the university, to work ergonomics and how to implement diversity at one's workplace. We have also been visited by the LGBT network (HBTQ in Swedish), as well as the health care and staff units for employees at Lund University. The seminars have made issues on gender equality and diversity a natural talking point during our coffee breaks, which we believe is crucial for improving and tackling issues in these areas.

We have also a delegate from our department in the JäLM group at LTH, Eva Westin.

TOGETHERNESS

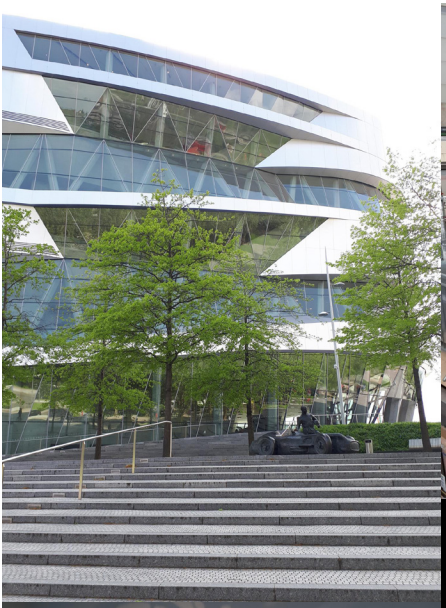
Togetherness - a cooperation over department and group boundaries - is an initiative to promote information and discussion on diversity and gender equality among the employees as well as the students of the M-building. The initiative was taken by Carolina Lidström and Eva Westin from the Department of Automatic Control in 2016 and has now grown to include members from all departments in the M-building. Since 2016 the group has arranged 10 seminars on the above topics.

ADMINISTRATIVE AND TECHNICAL STAFF VISITING STUTTGART UNIVERSITY

In April we finally went to visit Stuttgart University, were we met with different groups of people at SimTech, IPA Frauenhofer, Automatic Control, Vegas etc. The outcome of the visit was a lot of new impressions, exchange of ideas and motivation for our work.

We hope that we will see them next time here in Lund to present our University and it's surroundings.

When in Stuttgart, we also took the opportunity to visit the Mercedes-Benz Museum.

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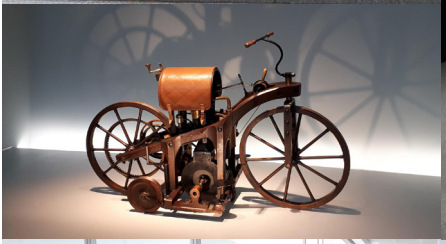
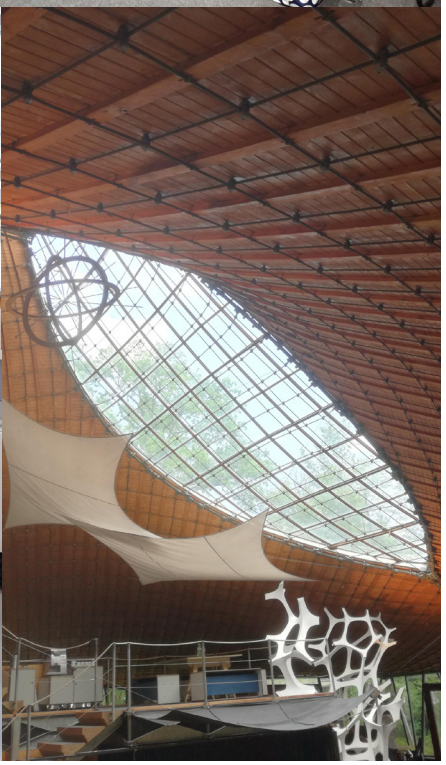





Room classification
• Determination of a room's function based on visual properties
• Used to assign object classes to room classes in semantic maps

AWARDS

GRANTS

Travel grant

Gustav Nilsson received a 1200 USD travel grant from Institute of Pure and Applied Mathematics to participate in a workshop.

Best Paper Award

Tommi Nylander, Marcus Thelander Andrén, Martina Maggio and Karl-Erik Årzen received a Best Paper Award for *Cloud Application Predictability though Integrated Load-Balancing and Service Time Control* at the 15th IEEE International Conference on Autonomic Control in September 2018, Trento, Italy.

Best Paper Award

Per Skarin, William Tärneberg, Karl-Erik Årzén and Maria Kihl received a Best Paper Reward for *Towards Mission-Critical Control at the Edge Over 5G* at the IEEE International Conference on Edge Computing in July, San Francisco, USA.

Master Thesis Award

Nils Vreman was awarded the ISACA Sweden Chapter MSc-scholarship for his Master Thesis.

Sparbanksstiftelsen Skåne Award

Karl Fredrik Erliksson and Richard Bai who did their Master's Thesis *Motion Planning using Positively Invariant Sets on a Small-Scale Autonomous Vehicle* in the Robotics Lab and with AB Berntec last semester have been awarded 'Sparbanksstiftelsen Skånes pris för särskilt framstående examensarbete' (award for particularly distinguished Master's Thesis).

New Professor at Automatic Control

Charlotta Johnsson was appointed Professor at Automatic Control in February 2018.

Honorary guests

Karl Johan Åström and Tore Hägglund were invited as honorary guests at the 3rd IFAC Conference on Advances in Proportional-Integral-Derivative Control, Ghent, Belgium.

ASSIGNMENTS

BOARD MEMBER

Årzén, Karl-Erik

Member of the Board for the eLLIIT strategic research area project.
Chair of the Program Management Group for the Wallenberg Autonomous Systems and Software Program (WASP).
Member of the Strategic Management Board for the EMSIG Special Interest Group on Embedded Systems.
Member of Research Board for the Faculty of Engineering, Lund University.

Como, Giacomo

Board member of the Lund Center for Control of Complex Engineering Systems (LCCC) and of the Excellence Project of the Department of Mathematical Sciences, Politecnico di Torino.

Eker, Johan

Advisory board member for Internet of Things and People Research Center at Malmo University.

Johnsson, Charlotta

Board Member at SESAM-Sverige, a network for industrial automation.
Board Member at PTW at Högskolan Väst, Trollhättan, Sweden.
Board Member of CIRCLE, Lund University, Sweden.
Board assignments in external companies.

Nayak Seetanadi, Gautham

Vice-president of the board for the PhD student union at LTH during 2018.

Rantzer, Anders

Member of the steering committee for the International Symposium on Mathematical Theory of Networks and Systems.
Member of Editorial Board for the Springer Journal Annual Reviews in Control.
Member of Editorial Board for Proceedings of the IEEE.

MEMBER OF INTERNATIONAL PROGRAM COMMITTEE (IPC)

Como, Giacomo

Member of the IPC of the 7th Conference on Complex Networks and their Applications, 2018.
Member of the IPC ot the 7th IFAC workshop on Distributed Estimation and Control in Networked Systems, 2018.
Member of the IPC of the 22nd International Conference on System Theory, Control and Computing, 2018.
Member of the IPC of the 2nd Symposium on Management of Future motorway and urban Traffic Systems, 2018.
Member of the IPC of the 15th IFAC Symposium on Control in Transportation Systems (CTS 2018).

Hägglund, Tore

IPC Member, 3rd IFAC Conference on Advances in Proportional-Integral-Derivative Control, Ghent, Belgium.

IPC Member, 23rd IEEE International Conference on Emerging Technologies and Factory Automation, ETFA'2018, Torino, Italy.
IPC Member, IEEE - ICSC 7th International Conference on Systems and Control, Valencia, Spain.

Johansson, Rolf
Member of Advisory Committee, IEEE BioRob 2018, IEEE International Conference on Biomedical Robotics and Biomechatronics (BioRob2016), 26 -29 August 2018, Enschede, The Netherlands; Sponsored by IEEE Robotics and Automation Society & IEEE Engineering in Medicine and Biology Society.
IPC Member, 2018 IEEE Conf. Control Technology and Applications (CCTA 2018), 21-24 Aug 2018, Copenhagen, Denmark.

Maggio, Martina
Program Chair for the Brief Presentations Session at Real-Time Systems Symposium, RTSS 2018.
Participated in Conference Program Committees for Real-Time Systems Symposium, RTSS 2018.
Participated in Conference Program Committees forInternational Conference on Embedded Software, EMSOFT 2018.
Participated in Conference Program Committees for Euromicro Conference on Real-Time Systems, ECRTS 2018.
Participated in Conference Program Committees for International Conference on Autonomic Computing, ICAC 2018.

Rantzer, Anders
Member of the IPC for 6th International Conference on Positive Systems (POSTA2018), Hangzhou, 2018.

Soltesz, Kristian
IPC member of MED19.

OPPONENT AND MEMBER OF EXAMINATION COMMITTEE

Bernhardsson, Bo
Deputy member of the examination committee for Eelco van Horssen, University of Eindhoven.
Deputy member of the examination committee for Yangxurui Liu, EIT, Lund University.
Deputy member of the examination committee for Hei Victor Cheng, Linköping University.

Como, Giacomo
Member of the PhD examination committee for Marius Schmitt, ETH (Switzerland), June 22, 2018 and Stephane Durand, Université de Grenoble (France), December 11, 2018.

Giselsson, Pontus
External Reviewer for Felix Rey, PhD Thesis, ETH, Zurich, Switzerland, Dec 7, 2018.
Member of examination committee for Erik Bylow, PhD Thesis, Lund University, Lund, Sweden, April 20, 2018.
External reviewer for Goran Banjac, PhD Thesis, Oxford University, Oxford, Great Britain, March 7, 2018.

Hägglund, Tore
Member of the evaluation committee for the PhD thesis by Ali Mohammed Hussein Kadhim, Luleå University of Technology, Luleå, Sweden.
Examiner for the PhD thesis by Dan Herman, Technical University of Denmark, Lyngby, Denmark.

Rantzer, Anders
Member of PhD Examination Committee for Viktor Larsson, Lund University, June 1, 2018.

ADVISORY COMMITTEES AND WORKING GROUPS

Årzén, Karl-Erik
Member of the Norwegian committee on assessment of competence for the title of full professor in IT.
Co-Chair for the Panel on Signals and Systems, Swedish Research Council.
Member of the Royal Swedish Academy of Engineering Sciences (IVA).

Como, Giacomo
Chair of the IEEE-CSS Technical Committee on Networks and Communications.
Organizer and Member of the Scientific Committee of the Workshop *Paths in Mathematical Control Theory*', Politecnico di Torino, February 2018.

Johansson, Rolf
Member of IEEE EMBS Technical Committee (TC) for Biomedical Robotics.
Member of Joint EMBS/RAS Advisory Committee on Biorobotics;
Member of International Advisory Board for the project consortium SFI Offshore Mechatronics, Norway Research Council & Norwegian Offshore and Drilling Engineering (NODE)**.**

Johnsson, Charlotta
Chair of ISO TC184/SC5 (Industrial Automation / Interoperability, integration and architectures for enterprise systems and automation applications).
Voting member in the standardization committee ISA95 and an information member in the standardization committees ISA88 and ISA99.
Member in SIS and SEK. She serves as the Swedish expert in the international IEC 62264, IEC 61512, ISO 22400 and ISO 15746 standards, as well as in the groups ISO SMCC, IEC AhG3, IEC TC65E AhG1, as well as in the joint committee IEC/TC65-ISO TC184 JWG21 (Reference Architecture for Smart Manufacturing).

Rantzer, Anders
Member of the IEEE Control Systems Award Committee.
Chairman of the IFAC Fellow Selection Committee.
Member of the Advisory Board for Lecture Notes in Control and Information Sciences at Springer Verlag Heidelberg.
Member of the IEEE Control System Society Technical Committee on Nonlinear Systems and Control.
Member of the IFAC Technical Committee on Nonlinear Systems.

Robertsson, Anders
Reviewer professorship/Assoc Professorship NTNU. January 3, 2018.
Co-chairing session on *Cloud versus in-network-processing for latency-critical industrial control operations* at 13th Cloud Control workshop, June 15, 2018 in Stockholm, Sweden.
Chair for Aerospace session at IEEE CCTA, August 21, 2018 in Copenhagen, Denmark.

OTHER ASSIGNMENTS

Årzén, Karl-Erik
Associate Editor for Real-Time Systems Journal.
Area Editor for the Leibniz Transactions on Embedded Systems (LITES).
Associate Editor for ACM Transactions on Cyber-Physical Systems.

Como, Giacomo
Associate Editor of the IEEE Transactions on Control of Network Systems and of the IEEE Transactions on Network Science and Engineering.

Johansson, Rolf
Editor, Mathematical Biosciences, (Elsevier).
Editor, Intelligent Service Robotics (ISR), (Springer).
Associate Editor, International Journal of Adaptive Control and Signal Processing, (Wiley).
Associate Editor, Chinese Journal of Scientific Instrument, (China Instrument and Control Society).
Member of Editorial Board, Robotics and Biomimetics, (Springer).

Johnsson, Charlotta
Serving as the IFAC Liaison with IEC 65A.

Maggio, Martina
Member of the Editorial Board of the ACM Transactions on Embedded Computing, Associate Editor in the domain specific area of Self-Adaptive Embedded Systems.

Martins, Alexandre
Member of the WASP student council, created in 2018.

Westin, Eva
Representative for Automatic Control in and member of the Equality group (JäLM) at the Faculty of Engineering.

LONGER VISITS ABROAD

Greiff, Marcus
December 2018, he was a teaching assistant in the basic control course given at Beihang University, China.

Heimerson, Albin
In November/December 2018 he was a teaching assistant in the basic control course given at Beihang University, China.

Johnsson, Charlotta
Spent two weeks teaching the basic control course at Beihang University, Beijing, China, December 8-20, 2018.

Maggio, Martina
Spent two weeks teaching the basic control course at Beihang University, Beijing, China, November/December, 2018.

Millnert, Victor
Visiting researcher at University of California, Berkeley in the USA, September 2018–March 2019.

Nilsson, Gustav
Internship at Mitsubishi Electric Research Laboratories (MERL) in Cambridge, USA, October 2017-March, 2018.

Robertsson, Anders
During November 2018, he was teaching the basic control course given at Beihang University, Beijing, China.

Ruuskanen, Johan
November 2018, he was a teaching assistant in the basic control course given at Beihang University, Beijing, China.

LECTURES BY STAFF OUTSIDE THE DEPARTMENT

Årzén, Karl-Erik

Jitter-Robust LQG Control and Real-Time Scheduling Co-Design, American Control Conference, Milwaukee, June 27, 2018.

Towards Mission-Critical Control at the Edge and Over 5G, High Tech Summit, DTU, Lyngby, Denmark Oct 11 2018.

Åström, Karl Johan

Mini course on Model Based Systeme Engineering; *Requirements, Modeling, Control Design, Architecture;* January 23-25, 2018, University of Valencia, Spain.

Advances in PID Control 2018. March 9, 2018, University of Almeria, Spain.

Dinner speech at Bo Egardt's retirement celebration in April 13, 2018.

Invited honorary guest at PID Conference in Ghent. May 8-12, 2018.

Participated at CCS MBD Workshop in Charlotte, North Carolina. June 18-21, 2018.

Don't forget the physics. Deep learning mini conference at LCCC Workshop on Learning and Adaptation for Sensorimotor Control. Oct 27, 2018 in Lund.

Adaptive Control - A Perspective. LCCC Workshop on Learning and Adaptation for Sensorimotor Control. Oct 26, 2018 in Lund.

Bernhardsson, Bo

The fascinating history and successes of feedback control. Dec 6, 2018 at NTNU Trondheim.

Invited seminar at University of Eindhoven*: Modeling and control of the LLRF system for ESS,* February 6, 2018.

Como, Giacomo

On network centrality, influence, and resilience, at the 20th European Conference on Mathematics for Industry (ECMI), Budapest, Hungary, June 18, 2018.

On efficiency and resilience of connected transportation networks, at the 2nd Symposium on Management of Future Motorway and Urban Traffic Systems (MFTS-2018), Ispra, Italy, June 11, 2018.

On scaling limits for multi-agent systems, 2nd kick-off meeting of the DISMA Excellence Project, Politecnico di Torino, Torino, Italy, March 5, 2018.

Resilient Control of Dynamical Flow Networks, at the 2nd SmartData@PoliTO Workshop on Big Data and Data Science, Camogli, Italy, March 2, 2018.

Eker, Johan

Invited talk at Nordic University *Hub on Industrial IoT,* August 2018.

External talk at Ericsson One, November 2018.

Invited talk at DTU High tech summit, October 2018.

Invited talk at Industri-Forsknings-Forum, May 2018.

Invited talk at the Halmstad University, April 2018.

Giselsson, Pontus

Plenary talk at GAMM ANLA workshop on Applied and Numerical Linear Algebra. Höör, Sweden October 10-12, 2018.

Invited talk at DIMACS Workshop on ADMM and Proximal Splitting Methods in Optimization. Single-track workshop. Simon's Institute, Rutgers University, New Brunswick, USA, June 11-13, 2018.
Invited talk at Automatic Control Laboratory (IfA), ETH, Zürich, Switzerland, December 6, 2018.
Invited talk at Department of Mathematics, UCLA, Los Angeles, USA, November 8, 2018.
Invited session: Recent Advances in Optimization Methods for Machine Learning Informs Annual Meeting, Phoenix, USA, November 6, 2018.
Invited session: Large-Scale and Distributed Optimization, SMP, Bordeaux, France, July 3, 2018.
Invited talk at Electrical and Computer Engineering NYU Campus Abu Dhabi, March 1, 2018.
Invited talk at Department of Microsystems Engineering Freiburg, Germany, February 8, 2018.

Hägglund, Tore

A new efficient ratio control structure. Nordic Process Control Workshop, Åbo, Finland, January 19, 2018.
En effektivare metod för kvotreglering (A more efficent method for ratio control), ITF Automationsdagar, Stockholm, February 1, 2018.
Research in the regulatory control layer. XVI Simposio de Ingeniería de Control, Almeria, Spain, March 8. Invited lecture.
Development of basic process control structures. 3rd IFAC Conference on Advances in Proportional-Integral-Derivative Control, Ghent, Belgium, May 11.
Control of Industrial Processes. Industrial course at SSAB - Luleå, November 11.

Johansson, Rolf

Industrial Robots, Skills and Work-Space Sensing, City University of Hong Kong, Dept. Mechanical and Biomedical Engineering, Hong Kong, July 20, 2018.
Robotikrevolutionen—Hur Stor Blir Skillnaden mellan Nuet och Framtiden?, Lunds Filosoficirkel, Folkuniversitetet, Lund, Sweden, September 11, 2018.
The Future of Drones—UAV/UAS System Autonomy, Ericsson Science & Innovation Talk, Ericsson, Lund, Sweden, November 30, 2018.

Johnsson, Charlotta

Berkeley method of Entrepreneurship – using games for practicing the entrepreneurial mindset. Invited together with Suoranta M to workshop at SPACE-EU network conference, Kolding Denmark, April 2018.
Industry 4.0 - ESS and MaxIV as drivers of Industrial IT Development. Invited presentation at Future Production System conference in Lund, August 2018.
Kirurgens perspektiv – Bildbehandling och robotic för 3D-grafik vid öppen hjärtkirurgi (Eng: Image processing and Robotics for 3D-image graphics used for open heart surgery). Keynote speaker at Medicinteknikdagarna, Umeå Sweden, October 2018.
Strategies and Standards for Smart Swedish Industry. Invited presentation at PiiA Summit, Västerås Sweden, October 2018.

Karlsson, Martin

Alexandros Kogkas, Katie Driggs-Campbell, and Martin Karlsson presented their work at the 2018 International Conference on Intelligent Robots and Systems (IROS) in Madrid, Spain.

Nilsson, Gustav

Generalized proportional allocation for traffic signals, DISMA Politecnico di Torino, Department of excellence 2018-2022, July 4, 2018.

Rantzer, Anders

Towards a Scalable Theory of Control, University of Southern California, Los Angeles, April 9, 2018.

Adaptive Control — What can we learn?, California Institute of Technology, April 12, 2018.

Adaptive Control — What can we learn?, University of Minnesota, Minneapolis, June 25, 2018.

Concentration bounds for single parameter adaptive control, American Control Conference, Milwaukee, June 27, 2018.

Direct Method to H-Infinity Optimal Control and Algorithm Improvements, 23rd International Symposium on the Mathematical Theory of Networks and Systems, July 17, 2018.

Anti-Windup Scheme for Networked Proportional-Integral Control, 23rd International Symposium on the Mathematical Theory of Networks and Systems, July 19, 2018.

H-Infinity Optimal Adaptive Control for First Order Systems, 23rd International Symposium on the Mathematical Theory of Networks and Systems, July 19, 2018.

When are optimal controllers scalable?, ERC Workshop on Modeling Estimation and Control of Large-scale networks, Grenoble, September 11, 2018.

Towards a Scalable Theory of Control, Harvard University, Cambridge, USA, December 14, 2018

Scalable synthesis for positive systems, Conference on Decision and Control, Miami Beach, December 18, 2018.

Robertsson, Anders

Two-Degree-of-Freedom Control for Trajectory Tracking and Perturbation Recovery during Execution of Dynamical Movement Primitives; Smart Cooperative Robots for Agile Assembly Workshop @ ERF2018, March 14, 2018 in Tampere, Finland.

Lecture on *robot force control and its applications* at NTNU, Norway, April 17, 2018.

Teacher Education at Vattenhallen Science Center, Lund University (Styr- och Reglerteknik), April 19, 2018.

WASP-cluster meeting in Norrköping. Presentation of SSF - Semantic Mapping and Visual Navigation-project *UAV motion planning, control and sensor fusion* by Marcus Greiff and Anders Robertsson, May 8, 2018.

Detection and Control of Contact Force Transients in Robotic Manipulation without a Force Sensor by Martin Karlsson, Anders Robertsson, Rolf Johansson, Presentation at Swedish Control meeting, June 19, 2018.

Presentation at Collaborative Robotic Systems session *From caged animals to collaborative robotics,* eLLIIT workshop, October 22, 2018.

Estimation, learning and control for robots in free space motion and during contact force interaction, Invited seminar at Beijing University, China, November 23, 2018.

Sun, Zhiyong

Invited seminars at several universities in China, including:

Conservation laws and invariance principles in networked control systems. Beijing Institute of Technology, Beijing, China, December 20, 2018

Event-based multi-agent consensus control via Lp signals. Peking University, Beijing, China, December 24, 2018.

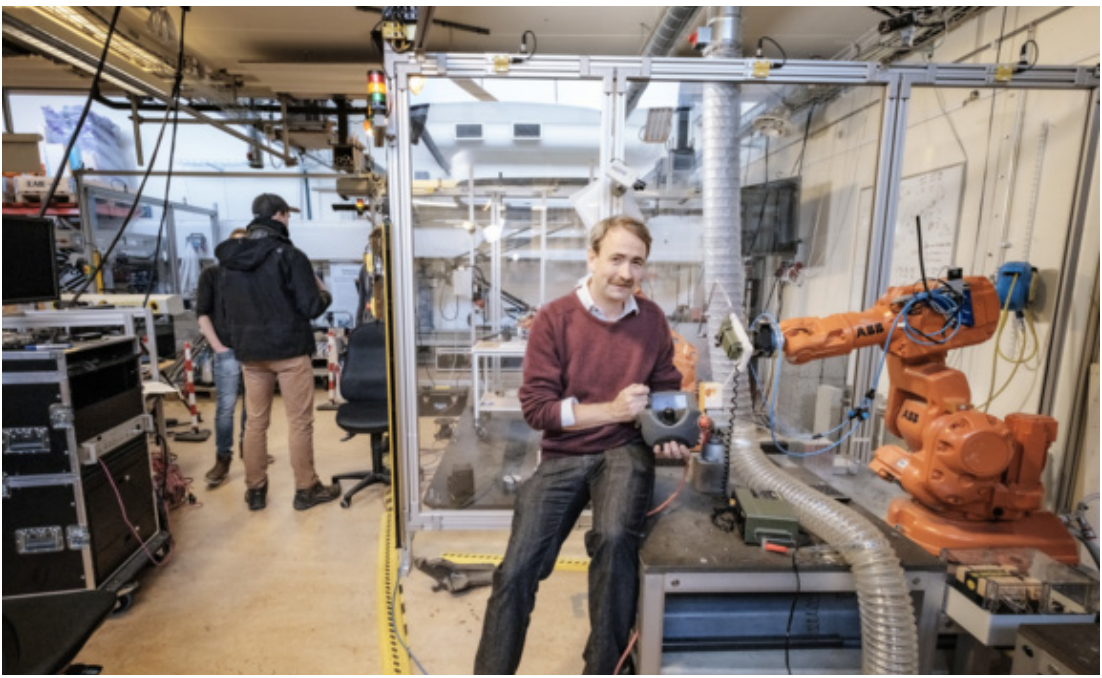
Troeng, Olof

Controlling the Acceleration of the ESS Proton Beam (Digit@LTH) October 18, 2018, Lund, Sweden.
RF Cavity Field Control at ESS, December 13, 2018 at Lawrence Berkeley National Laboratory, CA, USA.

POPULAR SCIENCE PRESENTATIONS

Robertsson, Anders

January 23, 2018, UIC-Syd presentation and demo in Robotlab around 15-20 visitors.
February 4, 2018, around 40 pupils including tutor student of technology. Swedish mastership in programming for upper comprehensive school and gymnasium.
February 6, 2018, RobotLab demo for Prof Kenjiro TAKEMURA, Keio University, Japan, Pascal Bernaud, Ecole Centrale i Paris and Christina Grossman, LTH.
March 6, 2018, RobotLab presentation and Masterprogramme evaluation IProd, 6 students.
March 23, 2018, visit of 40 students from technical high school Lars Kagg-gymnasiet, Kalmar. Demo by Anders Robertsson and Elin Topp.
March 12, 2018, Seminar and hands-on experience *Robotar, cyklar och andra svårstyrda saker*, around 100 high-school students visiting Lab and RobotLab; Natur-, Medicin- och Teknikdagarna at Lund University.
September 15, 2018, Kulturnatten, Dept of Automatic Control and guided tours to RobotLab, about 90 visitors.
October 5, 2018, Perstorp highschool having Education day in Automatic Control, LTH and RobotLab demo.
October 11, 2018, AlfaLaval Open Door-presentation at Navet, LTH, around 20 visitors in RobotLab
October 18, 2018, Visit in RobotLab from Vattenhallen Science Center, around 10 visitors.
November 27-29, 2018, EUrobotics week, the RobotLab had in total around 500 visitors.

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