Activity Report 2017

Automatic Control

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Activity Report 2017

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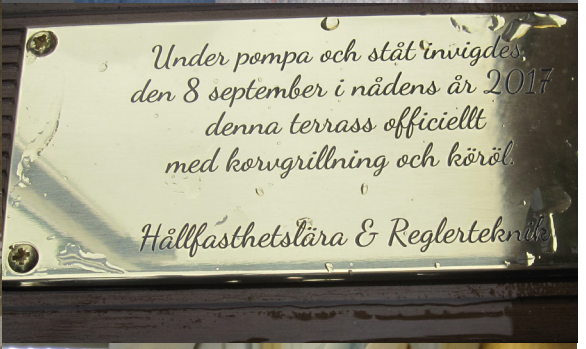
Content

Introduction

This report describes the main activities at the Department of Automatic Control at Lund University during the period January 1 to December 31, 2017


Under pompa och ståt invigdes,
den 8 september i nådens år 2017
denna terrass officiellt
med korvgrillning och köröl.
Hållfasthetslära & Reglerteknik

AUTOMATIC CONTROL 2017

The year 2017 was the year when the entire Lund University celebrated its 350th anniversary with seminars, focus weeks, exhibitions etc. In September a big party took place in Lundagård, where both personnel and students were invited and around 7 000 attended.

Beginning of March, we had a farewell dinner including a guided tour at Skissernas Museum for Ingrid Nilsson, our financial officer, as she retired from her position. Her successor Monika Rasmusson took over as per March 1st.

In April the administrative group was completed again as we welcomed Cecilia Edelborg as our new financial administrator.

The LCCC focus period on Large-Scale and Distributed Optimization took place in Lund in June 2017. It spanned over five weeks with a 3-day workshop in the middle. The highly cross-disciplinary research theme was chosen by the LCCC board to support the strategic vision of the Centre.

euRobotics week is now well established and took place at the end of November. During this week, 14 one-hour-long guided tours were arranged in the robotics lab at the department. The main audience consisted of about 350 school children and students of all ages from 14 different schools in the region who had booked a tour, but also about 50 adults from the public and the University during special sessions. Different demos were included in the tours, like: Robot doing free-form hot-wire cutting in styrofoam; Interaction and programming of a dual-arm robot by lead-through motions; Parallel kinematic manipulators; Simultaneous localization and mapping for mobile robots; Natural-language programming of an industrial robot; Tactile/haptic feedback for operator interface.

At the Automatic Control department, we can summarise the year in numbers as below;

The economy showed a turnover for 2017 of 51 MSEK, a slight decrease from last year and we are now 43 persons working at the department (guests not included). More about financial figures is found in the chapter *Economy.*

Today (2017) the department has 6 full time professors, 1 senior professor, 2 professors emeriti, 1 adjunct professor, 5 associate professors, 1 assistant professor, 4 research engineers, 4 administrators, 1 post-doc, 1 researcher, 20 PhD students and 3 industrial PhD students. Some of these numbers include part-time positions. During the year, 5 new PhD students were admitted to the department, 2 of them are now engaged in the WASP project. More will follow in the chapter *Staff* .

This year there were three licentiate theses presented by Fredrik Bagge Carlson, Olof Troeng and Martin Karlsson.

Three PhD theses by Christian Grussler, Josefin Berner and Yang Xu were completed during 2017. The total number of PhDs graduated from the department is now up to 119. Read more about it in chapter *Education.*

During 2017 the department gave 14 different courses to 1067 students at LTH and 30 students presented their master's thesis at the department. We also arranged 7 PhD courses. More about this in the chapter *Education.*

We look back on another successful year, where new colleagues, interesting guests and new projects have contributed to the department and are now looking forward to new challenges in the years to come.

Monika Rasmusson and Tore Hägglund

Education

Education on Undergraduate and Graduate Levels, Licentiate and Doctoral Dissertations

UNDERGRADUATE EDUCATION

The engineering education follows the central European systems with five year program leading up to the university degree "civilingenjör" (civ. ing.), with the international title MSc.

Automatic Control courses are thought 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).

The department has been involved in LTH's China Profile for several years and has taught Automatic Control, Basic Course at Zhejiang University in Hangzhou since 2009. Starting in 2017, the China Profile's new partner university is Beihang University in Beijing. This year 14 Swedish and 20 Chinese students took the basic control course at the new location. A total of six staff from the department spent some time at Beihang University during the fall.

This year, in total 1 067 students were registrered out of which 904 passed our courses. The number of registered students correspond to 140 fullyear equivalents during the year.

30 students completed their masters' theses projects, in total 23 theses were presented during 2017. A list of the masters' theses is given in the *Publications and seminars "Masters' Theses"*.

In the table on the next page, our courses are listed along with the number of students who passed each course. Each course in the engineering program has its own webpage, documentation, manuals, old exams, etc. We also have information sheets about the engineering courses, the master's thesis and the doctorate program.

You will find the links at www.control.lth.se/education.

Students from the project course at Automatic Control

TOTAL NUMBER OF STUDENTS WHO PASSED OUR COURSES 2017

Reglerteknik AK FRT010, FRTF05
(Automatic Control, Basic Course) 482
Realtidssystem FRTN01
(Real-Time Systems) 53
Olinjär reglering och servosystem FRTN05
(Nonlinear Control and Servo Systems) 44
Flervariabel reglering FRTN10
(Multivariable Control) 52
Prediktiv reglering FRTN15
(Predictive Control) 27
Processreglering FRTN25
(Process Control) 29
Nätverksdynamik FRTN30
(Network dynamics) 34
Systemidentifiering FRT041, FRTN35
(System identication) 7
Projekt i reglerteknik FRT090, FRTN40
(Projects in Automatic Control) 30
Systemteknik FRT110, FRTF10
(Systems Engineering) 43
Reglerteori FRT130, FRTF15
(Control Theory) 6
Matematisk modellering FRT095, FRTN45
(Mathematical Modeling) 36
Fysiologiska modeller och beräkningar FRTF01
(Physiological Models and Computations) 31
Examensarbete FRT820, FRTM01
(Master's Thesis Project) 30

GRADUATE EDUCATION

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”.

In 2017 the department adopted a new general syllabus for doctoral 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 2017 there were three licentiate theses presented by Fredrik Bagge Carlson, Olof Troeng and Martin Karlsson. Three doctoral theses were defended during the year by Christian Grussler, Josefin Berner and Yang Xu. We have admitted Marcus Greiff, Martin Morin, Christian Rosdahl, Johan Ruuskanen and Kaito Ariu as PhD students, out of which two PhD students are now funded by the WASP project.

The following PhD Courses were given in 2017

- *Feedback Control of Computing Systems*, Prof Alberto Leva
- *Motion Planning and Control*, Björn Olofsson, Karl Berntorp
- *Lab Development*, Kristian Soltesz
- *Research Innovation*, Anton Cervin, Görel Hedin, Martin Höst, Charlotta Johnsson
- *Nonlinear Control*, Anders Rantzer, Anders Robertsson, Bo Bernhardsson
- *Real-Time and Embedded Systems with Applications to Machine Learning*, Prof Zonghua Gu
- *Study Circle in Model Predictive Control*, Karl-Erik Årzén

LICENTIATE DISSERTATIONS

The licentiate theses, of which the abstracts are presented below, are available in their entirety at www.control.lth.se/publications


Fredrik Bagge Carlson


Martin Karlsson


Olof Troeng

MODELING AND ESTIMATION TOPICS IN ROBOTICS

Bagge Carlsson, Fredrik

The field of robotics offers a wide array of estimation problems, ranging from kinematic and dynamic calibration to pose estimation and computer vision. This thesis presents a set of methods to solve estimation problems encountered in robotics, with an emphasis on industrial robotics. The researched topics are all practically motivated and have found immediate use in applications.

Industrial robotics often require high accuracy in the control of the tool position, applied forces etc. This thesis presents a set of methods to solve commonly encountered estimation problems, including accurate friction estimation, spectral analysis of disturbances in electrical motors, kinematic calibration and pose estimation under the influence of high external forces.

Common themes among the articles, such as the linear least-squares procedure, are introduced in greater detail in the beginning of the thesis for the uninitiated reader.

ON MOTION CONTROL AND MACHINE LEARNING FOR ROBOTIC ASSEMBLY

Karlsson, Martin

Industrial robots typically require very structured and predictable working environments, and explicit programming, in order to perform well. Therefore, expensive and time-consuming engineering work is a major obstruction when mediating tasks to robots. This thesis presents methods that decrease the amount of engineering work required for robot programming, and increase the ability of robots to handle unforeseen events. This has two main benefits: Firstly, the programming can be done faster, and secondly, it becomes accessible to users without engineering experience. Even though these methods could be used for various types of robot applications, this thesis is focused on robotic assembly tasks.

Two main topics are explored: In the first part, we consider adjustment of robot trajectories generated by dynamical movement primitives (DMPs). The framework of DMPs as robot trajectory generators has been widely used in robotics research, because of their convergence properties and emphasis on easy modification. For instance, time scale and goal state can be adjusted by one

parameter each, commonly without further considerations. In this thesis, the DMP framework is extended with a method that allows a robot operator to adjust DMPs by demonstration, without any traditional computer programming or other engineering work required. Given a generated trajectory with a faulty last part, the operator can use lead-through programming to demonstrate a corrective trajectory. A modified DMP is formed, based on the first part of the faulty trajectory and the last part of the corrective one. Further, a method for handling perturbations during execution of DMPs on robots is considered. Two-degree-of-freedom control is used together with temporal coupling, to achieve practically realizable reference trajectory tracking and perturbation recovery. In the second part of the thesis, a method that enables robots to learn to recognize contact force/torque transients acting on the end-effector, without using a force/torque sensor, is presented. A recurrent neural network (RNN) is used for transient detection, with robot joint torques as input. A machine learning approach to determine the parameters of the RNN is presented.

Each of the methods presented in this thesis is implemented in a real-time application and verified experimentally on a robot.

CAVITY FIELD CONTROL FOR HIGH-INTENSITY LINEAR PROTON ACCELERATORS

Troeng, Olof

The European Spallation Source will, once fully operational in 2025, be the world's brightest neutron source. The neutrons will be generated by bombarding a tungsten target with protons accelerated to 96\% the speed of light by electromagnetic fields confined in 155 radio-frequency cavities along the world's most powerful linear accelerator.

This thesis has been motivated by the strict control specifications on the amplitudes and phases of the accelerating electromagnetic fields. By considering the field control problem from an automatic control perspective, the thesis aims at improving the understanding of the problem and to explain important aspects of the control design.

Throughout the thesis it has been helpful to model the cavity and RF system by complex-coefficient single-input single-output systems.

The complex-coefficient representation was particularly useful for discussing: (1) the control design for cavities with parasitic resonance modes; (2) the effect of loop phase variations on feedback stability; (3) the directionality of the disturbances and the objective function.

The thesis presents a non-standard parametrization and derivation of the cavity field dynamics that make it easier to relate the physical cavity process to the model, and simplifies the understanding of how the cavity parameters affect the achievable control performance.

The control performance of simple PI(D)-controllers and general linear time-invariant controller was compared using the Youla parametrization and convex optimization; it was found that PI(D)-controllers in many cases achieved performance similar to the more general linear time-invariant controller; this indicates that simple PI(D)-controllers in many cases are an excellent choice for cavity field control.

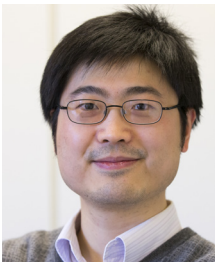
Lastly, the energy-optimal strategy to build up the electromagnetic cavity fields is derived, allowing the sustainability of the European Spallation Source to be further improved.

DOCTORAL DISSERTATIONS

The Doctoral theses, of which the abstracts are presented below, are available in their entirety at www.control.lth.se/publications

Christian Grussler

Josefin Berner



Yang Xu

RANK REDUCTION WITH CONVEX CONSTRAINTS

Grussler, Christian

This thesis addresses problems which require low-rank solutions under convex constraints. In particular, the focus lies on model reduction of positive systems, as well as finite dimensional optimization problems that are convex, apart from a low-rank constraint.

Traditional model reduction techniques try to minimize the error between the original and the reduced system. Typically, the resulting reduced models, however, no longer fulfill physically meaningful constraints. This thesis considers the problem of model reduction with internal and external positivity constraints. Both problems are solved by means of balanced truncation. While internal positivity is shown to be preserved by a symmetry property; external positivity preservation is accomplished by deriving a modified balancing approach based on ellipsoidal cone invariance.

In essence, positivity preserving model reduction attempts to find an infinite dimensional low-rank approximation that preserves nonnegativity, as well as Hankel structure. Due to the non-convexity of the low-rank constraint, this problem is even challenging in a finite dimensional setting. In addition to model reduction, the present work also considers such finite dimensional low-rank optimization problems with convex constraints. These problems frequently appear in applications such as image compression, multivariate linear regression, matrix completion and many more.

The main idea of this thesis is to derive the largest convex minorizers of rank-constrained unitarily invariant norms. These minorizers can be used to construct optimal convex relaxations for the original non-convex problem. Unlike other methods such as nuclear norm regularization, this approach benefits from having verifiable a posterior conditions for which a solution to the convex relaxation and the corresponding non-convex problem coincide. It is shown that this applies to various numerical examples of well-known low-rank optimization problems. In particular, the proposed convex relaxation performs significantly better than nuclear norm regularization. Moreover, it can be observed that a careful choice among the proposed convex relaxations may have a tremendous positive impact on matrix completion.

Computational tractability of the proposed approach is accomplished in two ways. First, the considered relaxations are shown to be representable by semi-definite programs. Second, it is shown

how to compute the proximal mappings, for both, the convex relaxations, as well as the non-convex problem. This makes it possible to apply first order method such as so-called Douglas-Rachford splitting. In addition to the convex case, where global convergence of this algorithm is guaranteed, conditions for local convergence in the non-convex setting are presented.

Finally, it is shown that the findings of this thesis also extend to the general class of so-called atomic norms that allow us to cover other non-convex constraints.

AUTOMATIC CONTROLLER TUNING USING RELAY-BASED MODEL IDENTIFICATION
Berner, Josefin

Proportional-integral-derivative (PID) controllers are very common in the process industry. In a regular factory there may be hundreds or thousands of them in use. Each of these controllers needs to be tuned, and even though the PID controller is simple, tuning the controllers still requires several hours of work and adequate knowledge in order to achieve a desired performance. Because of that, many of the operating PID controllers today are poorly tuned or even running in manual mode. Methods for tuning the controllers in an automated fashion are therefore highly beneficial, and the relay autotuner, that was introduced on the market in the 1980's, has been listed as one of the great success stories of control. The technology development since the 1980's, both concerning PID control and available computing power, gives opportunities for improvements of the autotuner. In this thesis three new autotuners are presented. They are all based on asymmetric relay feedback tests, providing process excitation at the frequency intervals relevant for PID control. One of the proposed autotuners is similar to the classic relay autotuner, but provides low-order models from which the controllers are tuned by simple formulas. The second autotuner uses the data from a very short relay test as input to an optimization method. This method provides more accurate model estimations, but to the cost of more omputing. The controller is then tuned by another optimization method, using the estimated model as input. The principle of the third autotuner is similar to the second one, but it is used to tune multivariable PID controllers for interacting processes. In this case a relay feedback experiment is performed on all loops simultaneously, and the data is used to identify the process transfer function matrix. All of the proposed autotuners strive to be user-friendly and practically applicable. Evaluation of the three autotuning strategies are done both through simulation examples and on experimental processes. The developed autotuners are also compared to commercially available ones, and the study shows that an upgrade of the industry standard to the newly available autotuners will yield a significant performance improvement.

LQG-BASED REAL-TIME SCHEDULING AND CONTROL CODESIGN
Xu, Yang

Having multiple control tasks concurrently running on a single computing platform increases the processor utilization but degrades the control performance due to delay and jitter. In scheduling and control codesign, the objective is to optimize the combined performance of all the controllers, subject to a schedulability constraint. The codesign procedure consists of selecting task parameters, e.g., periods and priorities, as well as designing the controllers so that the scheduling-induced delay and jitter are taken into account.

In the thesis, four linear-quadratic-Gaussian (LQG) codesign methods are proposed: stochastic, periodic, harmonic, and robust LQG codesign. In stochastic LQG codesign, the delay distributions are calculated at design-time. Then LQG controllers are designed assuming these delay distributions. The obtained task periods generally give rise to infinite hyperperiods. This can be avoided by perturbing the periods slightly in order to obtain a finite hyperperiod, yielding a periodic delay pattern for the control loops. The periodicity is then accounted for by using periodic LQG control design, resulting in a periodic sequence of feedback gains for each controller. In harmonic LQG codesign, again the task periods are perturbed, but this time to make the periods harmonic. The scheduling-induced delays will be constant and standard LQG design can be applied. Finally, a robust LQG codesign method is presented. The design is based on convex optimization and guarantees system robustness in the presence of delay and jitter. A new rule of thumb for initial sampling period assignment is proposed. We propose a jitter-aware priority and period assignment codesign method to optimize the overall system performance.

A large evaluation of the proposed four codesign methods is performed using the Jitterbug toolbox. All of the four methods lead to improved control performance compared to earlier work. The harmonic scheduling and control codesign shows the largest overall improvements.

Research

This chapter contains the different projects that were ongoing during 2017

EXCELLENCE CENTERS

LCCC - Linnaeus Center
eLLIIT - The Linköping - Lund Initiative on IT and mobile communication
PIC - Process Industrial Center
WASP - Wallenberg AI, Autonomous Systems and Software Program

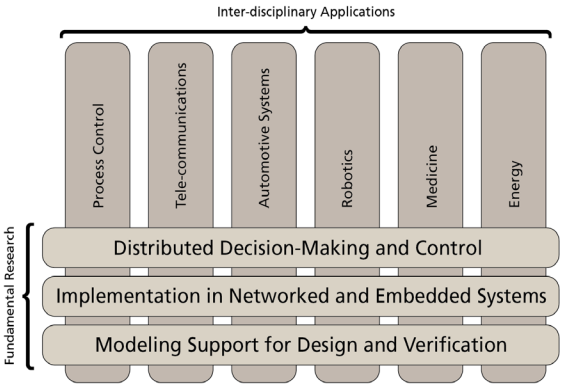
LCCC - LINNAEUS CENTER

Our society is dependent on flexible infrastructure for industrial production, energy supply and communication systems. This requires research and innovations on control of complex systems. Many challenges are common to a wide range of application areas and need to be adressed using a combination of competences from control, communications and computer science.

LCCC is developing theory, methods and tools for control of large-scale engineering systems. Positions for PhD students and postdocs in prioritized areas are combined with short term guest programs of a wider scope. This contributes to creating a highly creative and stimulating environment, that attracts strong applicants at all levels.

LCCC is mainly devoted to fundamental research. The research emphasizes the interaction between theory and applications. Questions addressed could be; How should control equipment across Scandinavia be coordinated to quickly find new routes for electrical power when a transmission line is broken? How should micro-processors in a vehicle gather measurements from several sources and combine engine force with brakes on different wheels to recover from a dangerous situation? How can multiple applications in a cell-phone be coordinated to make optimal use of battery, memory and processing power?

All these questions are examples of distributed control problems, where several actuators need to cooperate with access to different information and with bounds on the communication between them. The challenge for LCCC is to address such problems and at the same time extend theory and methodology of control beyond the traditional centralized viewpoint.Three directions of fundamental research have been defined to cover the span from mathematical theories to computer tools and implementation. Inspiration comes from application projects, usually with external funding from other sources. See the diagram:



Three horizontal blocks illustrate the main directions of fundamental research, and six vertical blocks illustrate the application areas. Research is pursued within the vertical and horizontal blocks as well as in the intersections. The research is led by LCCC faculty members, with competence including control, computer engineering and communications.

LCCC focus period on Large-Scale and Distributed Optimization

The LCCC focus period on Large-Scale and Distributed Optimization took place in Lund in June 2017. It spanned over five weeks with a 3-day workshop in the middle (June 14-16). The highly cross-disciplinary research theme was chosen by the LCCC board to support the strategic vision of the Centre.

The event was organized by the LCCC faculty members Pontus Giselsson and Anders Rantzer, and local practical arrangements were handled by Eva Westin. A scientific committee was formed, composed by Stephen Boyd (Stanford University), Asuman Ozdaglar (MIT), Angelia Nedich (Arizona State University), Wotao Yin (UCLA), Mikael Johansson (KTH), Amir Beck (Technion), Panagiotis Patrinos (KU Leuven), Heinz Bauscke (UBC Kelowna) and the organizers. The scientific committee selected other world-leading researchers in the field and invited them to give a seminar at the workshop, extend their stay during the focus period compatibly with their commitments, and nominate outstanding young researchers for an extended stay. Nineteen young researchers were selected by the scientific committee and invited to join the Center for periods of 3 to 5 weeks and to give a seminar during the focus period.

Scientific theme

Optimization is a core component in many fields such as machine learning, signal processing, control, statistical estimation, and bioinformatics. The underlying objective may be to extract information from large data sets, estimate signals from noisy measurements, predict a patient's inclination to be affected by a disease, or teach a machine to classify unseen data. These apparently different tasks can be modeled as, sometimes quite similar and often convex, optimization problems. Traditional applications of optimization typically gave rise to problems of small to medium size. Such problems can efficiently be solved by standard interior-point methods. With the arrival of the big data era and technologies and compute power to handle such data, the focus has over the last decade shifted towards large-scale problems. In this regime, previous standard methods are not applicable. Therefore, a plethora of new tailored algorithms have been developed. These methods have iterations costs that grow favorably with problem dimension and computations that can be parallelized or distributed. Many of these algorithms have been developed within the different application fields of optimization. The aim of this workshop was to bring together leading optimization experts from these different fields that all have contributed in pushing state-of-the-art in large-scale and distributed optimization.

List of speakers:
Francis Bach, École normale supérieure, France
Amir Beck, Technion, Israel
Stephen Boyd, Stanford University, USA
Volkan Cevher, EPFL, Switzerland
Venkat Chandrasekaran, Caltech, USA
Pontus Giselsson, Lund University, Sweden
Christian Grussler, Lund University, Sweden
Anders Hansson, Linköping University, Sweden
Mikael Johansson, KTH, Sweden
Mihailo Jovanovic, University of Southern California, USA
Laurent Lessard, University of Wisconsin–Madison, USA
Russell Luke, University of Goettingen, Germany
Julien Mairal, INRIA Grenoble, France
Angelia Nedich, Arizona State University, USA
Pablo Parrilo, MIT, USA
Panagiotis Patrinos, KU Leuven, Belgium
Anders Rantzer, Lund University, Sweden
Patrick Rebeschini, Yale University, USA
Madeleine Udell, Cornell University, USA
Lin Xiao, Microsoft Research, USA

Visiting scholars:
Arda Aytekin, KTH, Sweden
Ross Boczar, UC Berkeley, USA
Philipp Braun, University of Bayreuth, Germany
Aranya Chakrabortty, North Carolina State University, USA
Neil Dhingra, Univeristy of Minnesota, USA
Federica Garin, INRIA Rhône-Alpes, France
Alexander Gasnikov, Moscow Institute of Physics and Technology, Russia
Tryphon Georgiou, UC Irvine, USA
Anna von Heusinger, University of Würzburg
Mingyi Hong, Iowa State University
Soomin Lee, Georgia Tech, USA
Yong Sheng Soh, Caltech, USA
Zhou Su, TU Delft, The Netherlands
Adrien Taylor, UC Louvain, Belgium
Andreas Themelis, KU Leuven, Belgium
Cesar A. Uribe, University of Illinois, USA
Yang Zheng, University of Oxford, UK
René Schneider, EPFL, Switzerland
Ernest Ryu, UCLA, US

The LCCC focus period on Large-Scale and Distributed Optimization took place in Lund in June 2017.

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

Researchers: Karl-Erik Årzén, Bo Bernhardsson, Anton Cervin, Anders Rantzer, Martina Maggio, Anders Robertsson, Rolf Johansson, Yang Xu, Josefin Berner, Jacob Bergstedt, Mahdi Ghazaei, Björn Olofsson in collaboration with researchers at the Dept of Computer Science, Electrical and Information Technology, and Mathematics, Lund University, and Linköping University, Halmstad University and Blekinge University

Funding: Vinnova/VR

ELLIIT is a strategic research area for Information and Communication Technology (ICT) research at Linköping, Lund, Halmstad and Blekinge, which has been created to support and enhance an internationally acknowledged research environment in these areas. The objective is scientific excellence in combination with industrial relevance and impact. It is organized within the Swedish government's strategic research support initiative.

The Department of Automatic Control participate in eLLIIT in the following ways:

Karl-Erik Årzén is vice-director for the Lund part of eLLIIT. Bo Bernhardsson is an eLLIIT professor.

The Department participate in the following eLLIIT 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

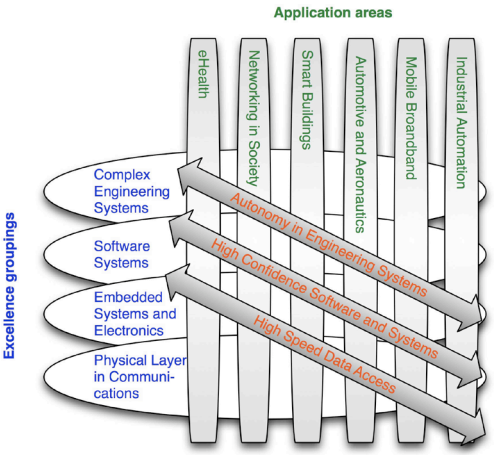


Illustration of the interaction between the themes, the application areas and the groupings (http://www.liu.se/elliit)

PIC - PROCESS INDUSTRIAL CENTER

Researchers: Josefin Berner, Tore Hägglund, Charlotta Johnsson, Kristian Soltesz

PICLU, short for Process Industry Centre at Lund University, is a joint venture by the Department of Chemical Engineering and the Department of Automatic Control at the Faculty of Engineering (LTH) at Lund University.

The mission of the Centre is to strengthen a leading research environment in process optimization and control through strong interaction between industry and academy, in order to facilitate innovation and competitiveness in the process industry at large. At the heart of PICLU lies a close collaboration with national and international companies, actors within the process industry and their suppliers.

A strong collaboration between the Department of Chemical Engineering and the Department of Automatic Control began in 1999, when the joint research centre CPDC (Chemical Process Design and Control) was founded, on the initiative from the Swedish Foundation of Strategic Research. After a brief period under the name of CEPROC (Centre for Process Optimization and Control) in 2007, PICLU was formally founded in 2008. The foundation process received vital funding from the Swedish Foundation of Strategic Research.

PICLU's philosophy

1. Close collaboration with industry to ensure relevant industrial problems, real multidisciplinary applications and to allocate in-kind resources;
2. Interesting scientific problem formulation that can be analyzed and generalized for use outside the specific application.

PICLU is currently conducting a number of interrelated research projects as part of Phase 3 (2014-2017), see below mentionned projetcs;

- *PiiA-bio* is a three-year project including three stages studying fed-batch steering, steering of cleansing steps, and automation of connected steps. PiiA-bio is financed by VINNOVA and industry partners are Novozymes, Novo Nordisk and Pfizer Health.
- *ProOpt* is a three-year project studying optimization of complex processes, optimization of dynamic processes, and development of

optimization tools. The project is financed by VINNOVA and industry partners are Perstorp AB, Novo Nordisk and Modelon.

- *PiiA-Metrics* is a two-year strategic PiiA project mapping key numbers within the process industry and giving implementation advice on their interchangability in software applications.
- *Automatic tuning* is a project where second generation automatic tuning procedures for PID controllers are developed. A pre-project was financed by PiiA/Vinnova.
- *Smart Mini Factories* is a two-year PiiA project, part of the Smart Industry strategy by the Ministry of Enterprise and Innovation. The project aims to show how industrial digitalization can enable advanced small-scale production of pharmaceuticals. The project is financed by VINNOVA and industry partners are Sobi, Novo Nordisk and Modelon.
- *Integrated DSP* is a three-year Biologics project at Vinnova. The work is focused on a new production paradigm in biopharmaceutical industry, where the purification steps are highly connected and integrated, some times intensified, to form efficient continuous production of pharmaceuticals. The industry partners are Sobi, Novo Nordisk and Modelon.
- *PiiA pre-projects* and PiiA pre-studies are shorter PiiA projects, less than a year in length, and used to start up research within new work areas. It is financed by VINNOVA. PICLU has performed a number of these shorter projects.

Funding: Knut and Alice Wallenberg Foundation (KAW)

Wallenberg AI, Autonomous Systems and Software Program (WASP) is Sweden's largest individual research program ever, and provides a platform for academic research and education, fostering interaction with Sweden's leading technology companies. The program addresses research on 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 autonomous systems, and is an integrated research theme of the program. WASP's key values are research excellence and industrial relevance.

The graduate school within WASP is dedicated to provide the skills needed to analyze, develop, and contribute to the interdisciplinary area of autonomous systems and software. The curriculum provides the foundations, perspectives, and state-of-the-art knowledge in the different disciplines taught by leading researchers in the field. Through an ambitious program with research visits, partner universities, and visiting lecturers, the graduate school actively supports forming a strong multi-disciplinary and international professional network between PhD-students, researchers and industry.

The graduate school provides added value on top of the existing PhD programs at the partner universities, providing unique opportunities for students who are dedicated to achieving international research excellence with industrial relevance.

WASP involves five Swedish universities: Chalmers, KTH, Linköping University, Lund University, and Umeå University together with numerous Swedish industries. At Lund University the following four departments participate: Department of Automatic Control, Department of Computer Science, Department of Electrical and Information Technology, and the Matematical Imaging Group at the Department of Matematics.

In November 2017 the Knut and Alice Wallenberg Foundation granted an additional billion Swedish kronor to extend WASP with a broad investment into artificial intelligence.

The initiative in artificial intelligence will follow two pathways. The larger of these involves an investment into machine learning, deep learning and the next generation of AI. The latter involves asking the system how it reached a particular answer, whereby the system can justify its answers and use them in a general situation. The second pathway deals with increasing our understanding of fundamental mathematical principles behind AI.

The two pathways have resources to recruit 14 senior researchers each, and in total 120 research students, where the research students will become members of graduate schools and take specialist courses in relevant fields. In addition to this there will be 30 industrial PhD students, with the total aim of 150 PhD students in WASP-AI. The two new graduate schools will coordinate with the existing WASP graduate school, where over 100 research students are currently studying.

The program director for WASP is Professor Lars Nielsen, Linköping University. The chairs of the three program management groups of WASP are

- Professor Karl-Erik Årzén, Lund University - WASP-AS (Autonomous Systems and Software)

- Professor Danica Kragic, Royal Institute of Technology - WASP-AI/MLX (Machine Leraning, Deep Learning and Explainable AI)
- Professor Johan Håstad, Royal Institute of Technology - WASP-AI/MATH (Matematical foundations of AI)

WASP is divided into 10 clusters

The autonomous systems and software part of WASP is divided into 10 clusters. Each cluster involves university, industrial, and affiliated PhD students. The clusters cover areas that are scientifically important, of high relevance, and which form a broad but well-connected research palette. On the software and computation side, one cluster will develop methodology for advanced industrial software development, one cluster focuses on software technology issues, one cluster concerns the security of autonomous systems, and one cluster concerns the rapidly emerging area of autonomy in cloud and communication network infrastructures. Two clusters consider the key aspect of cooperation between autonomous systems and humans, where one cluster tackles perception and robotics, and the other deals with new concepts in human-machine interaction such as cognitive digital companions. One cluster deals with the fundamental questions of localization, and one deals with scalability, both developing new techniques that are expected to be essential in many autonomous systems. The remaining clusters are aiming at the future automated transport systems and at fundamental questions related to artificial Intelligence and machine learning.

The 10 WASP clusters are described in more detail below.

The projects in summary:

- *Software Engineering for Smart Systems* - Smart and autonomous systems are dependent on software to realize their functionality, but the functionality of these systems must be able to evolve much more rapidly than is possible with classical software engineering approaches. This cluster will study data-driven methods for continuously evolving the functionality and performance of smart systems.
- *Autonomous Clouds and Networks* - This cluster will provide autonomy and predictability in the distributed cloud by developing dynamic, control-based resource management methods for deciding how much and what type of resources to allocate, and when and where to deploy them. The cluster also considers autonomy and analytics for communication networks including both the radio access network and the core network, with a special emphasis on 5G.
- *Perception and Learning in Interactive Autonomous Systems* - The cluster will study perception methods based on fusion of multi-modal sensory information in combination with learning for autonomous systems.
- *Interaction and Communication with Sensor-Rich Autonomous Agents* - This cluster will develop the next generation of decision support systems, so called cognitive companions, designed to adaptively reduce the cognitive load caused by the large and rapid information flows while ensuring mission-critical decision timescales.
- *Smart Localization Systems* - Accurate localization anywhere and anytime – of vehicles, robots, humans, and gadgets in both the absolute and relative sense – is a fundamental Component in achieving high level of autonomy. The research challenge is to provide scalable, available and reliable smart localization technology needed to enable future intelligent and autonomous systems.
- *Large Scale Optimization and Control* - The cluster will develop basic theory and methodology for distributed optimization, learning and decision-making in large scale dynamic systems. This is essential to efficiently and reliably operate infrastructure networks for transportation, communications, data, electricity, heat and water, as

well as smart cities and health care. The main research challenges are in the intersection between optimization, control, statistics, machine learning and economics.

- *Automated Transport Systems* - Automated transport systems will revolutionize the efficiency of transportation of people and goods, and at the same time dramatically reduce environmental impact. This cluster concerns optimization of the overall transport performance by taking advantage of new possibilities for efficient communication, accurate position estimation, and smart decision systems.
- *Security for Autonomous Systems.* Autonomous systems need to be designed with security and privacy in mind in order to be trustworthy. In this cluster, we investigate security and privacy research challenges that arise from advances in autonomous systems, and, conversely, how advances in security and privacy research can be used to make autonomous systems safer.
- *Software Technology for Autonomous Systems.* Autonomous software requires specific software analysis and construction methods. This cluster fosters research with WASP in this area .
- *AI and Machine Learning.* A heuristic definition of AI is the development of agents that perceive the world and use these observations to learn about the world, plan and reason. This is tightly connected to Machine Learning, where agents are given the ability to learn from data examples rather than being explicitly programmed. Common to the AI and Machine Learning WASP projects are that AI and Machine Learning are used in different ways to make autonomous systems smarter and more capable.

WASP winter conference took place in Lund

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 areas are:

MODELING AND CONTROL OF COMPLEX SYSTEMS	LARGE SCALE OPTIMIZATION AND CONTROL	CONTROL AND REAL-TIME COMPUTING
PROCESS CONTROL	TOOLS AND SOFTWARE	AUTOMOTIVE SYSTEMS
MEDICAL PROJECTS		ROBOTICS

We have applied for and received grants mainly from the below mentionned contributors;

- Swedish Research Council (VR)
- Vinnova
- Swedish Foundation for Strategic Research (SSF)
- Knut and Alice Wallenberg Foundation (KAW)

MODELING AND CONTROL OF COMPLEX SYSTEMS

Adaptive Control in Flying Vehicles
ICT platform for sustainable infrastructures
LISA 2 - Line Information System Architecture
Energy and Building Management
Collaboration with the European Spallation Source

ADAPTIVE CONTROL IN FLYING VEHICLES

Researchers: Anders Pettersson, Rolf Johansson, Anders Robertsson, Karl Johan Åström

The goal of this project is to address the question whether adaptive control can be used in products that SAAB are developing today or in the future.

There are two fundamentally different ways of controlling systems with dynamics that change over time: adaptive or robust control. The industrial baseline for flying applications today is to use robust control, which caters for the effect of parametric uncertainties, but this baseline comes with an associated loss of performance. On the other hand, with an adaptive controller it is possible to boost the performance of the closed-loop system, but then the inherent robustness may be insufficient.

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Questions to be addressed:

- Can better performance be achieved for a fully/partly adaptive controller compared to a robust controller, especially with uncertain dynamics in the plant and its subsystems?
- When in a product development cycle, can adaptive steering be used? In what applications can adaptive techniques be used? Subsystems such as actuators perhaps, as well as at the top level?

For the use of adaptive control in these systems, aspects such as product safety, control law clearance and certification should be taken into account.

ICT PLATFORM FOR SUSTAINABLE INFRASTRUCTURES

Researchers: Anders Rantzer, Bo Bernhardsson, Carolina Lidström, Richard Pates, and partners at IEA and KTH

Funding: SSF

Resource-efficient infrastructures are critical for sustainable societies that want to maintain and improve today's standard of living. National and international climate goals imply large increases in renewable electricity production. This variable generation together with the increasing international trading of electricity affects the power flows in the electricity networks, which needs to be managed by system operators on local, regional and national levels. This development is in addition to the continuously increasing demand on reliable electricity supply. Traditionally this double challenge would be met by the building of new power lines. This is a simple and effective solution, but due to public reluctance to new power lines and the lengthy permission process alternatives are sought for. One general alternative is the use of automation for optimizing the use of the available network capacity. This concept - currently referred to as Smart Grids - involves investment in and installation of ICT equipment rather than physical capacity. While having been applied locally before, the situation now calls for application on a system-wide scale. Similar trends can be observed in other infrastructures.

This project aims to design the decision-layer of an ICT platform for controlling large-scale infrastructures to operate reliably, economically, and with minimum resource waste. Special attention is given to functionality for detecting, clearing and recovering from critical operating conditions. A key component is the ARISTO real-time power system simulator, which will be used as demonstrator to illustrate the results.

DET NORDISKA ÖVERFÖRINGSNÄTET
The transmission grid in the Nordic countries

LISA2 - LINE INFORMATION SYSTEM ARCHITECTURE 2

Researcher: Charlotta Johnsson incl partners from KTH, Lund University, Chalmers, Scania and Volvo Cars

Funding: Vinnova

The project Line Information System Architecture 2 – Smart event-driven services (LISA2), will deliver industrial-ready services – enabling Swedish industry to understand and tune their factories. Producing the future vehicles in safe and environmentally sustainable way requires handling of an increasing number of data during manufacturing.

This project is a continuation of the VINNOVA-FFI-LISA project. LISA has delivered and validated a modern flexible and scalable event driven architecture able to implement collection and fusion of data from different automatic production sources with a granularity level that stretch down to the single sensor. This provides, in principle, the possibility to mine and parse data across the different layers of manufacturers' ICT infrastructure, independently from predefined control logic constraints. LISA also preliminary investigated the transformation of data in meaningful information and the relative visualization.

The main purpose of the LISA2 project, is to leverage on the LISA project, and realize a full industrial implementation. LISA2 will produce a set of demonstrators, both in industry and academia, to validate the practical embodiment of the services produced and the knowledge enhancement in the road towards production cyber physical system enabling fast integration, reconfigurability and scalability of automatic production resources. The results are expected to be of very large significance for OEM as well as suppliers in Sweden in respect of efficient as well as appropriate information handling.

ENERGY AND BUILDING MANAGEMENT

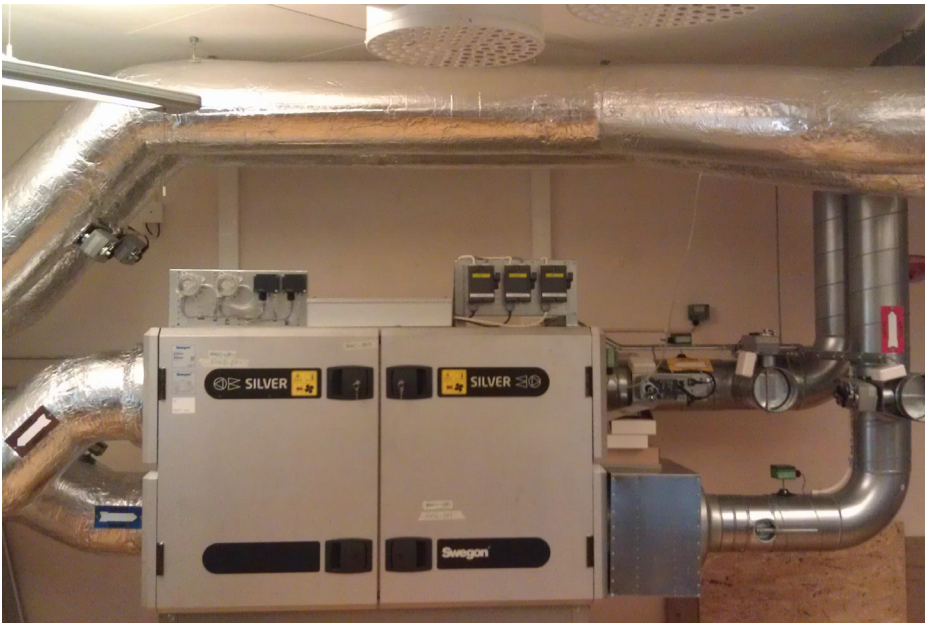
Researchers: Josefin Berner, Anders Rantzer

Funding: eLLIIT and LCCC

Buildings account for 40 % of total energy consumption in the European Union, in Sweden one third of the energy used is related to the building sector, and 60% of the energy used in buildings is for heating and ventilation. With a growing building sector, it is necessary to decrease the energy used by heating and ventilation in buildings, so the total energy used in the buildings sector is not increased. Improved control and management of heating and ventilation systems in buildings can help to decrease the energy usage.

This project aims at improving the temperature control in buildings, especially using PID control and Model Predictive Control (MPC). One approach involves automatic tuning of PID controllers (for more details on automatic tuning see Automatic Tuning). To perform well for temperature control, PID controllers must be tuned correctly, which is often not the case in practice. Automatic tuning can help to overcome this problem. The automatic tuning procedure developed in the project has been tested on an industrial air handling unit with good results.

Another approach is to investigate the temperature interaction between different rooms or zones in a building. Usually, each room would be controlled by a local controller (e.g. On/Off-control or PID). However, the temperature dynamics of adjacent rooms or zones have an influence on each other, which can be significant. To take this interaction into account, the local PID controllers are connected with a decoupling network in order to improve temperature control and occupant comfort.



COLLABORATION WITH THE EUROPEAN SPALLATION SOURCE

Researchers: Bo Bernhardsson, Anders J Johansson (Dept of Electrical and Information Technology), Rolf Johansson, Olof Troeng, Björn Olofsson

Funding: European Spallation Source, ESS

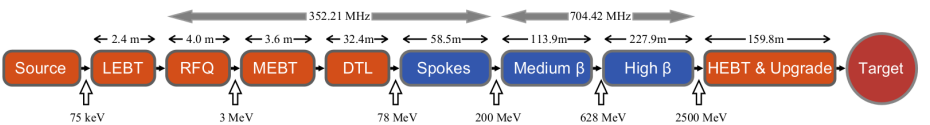
The European Spallation Source will be a major user facility at which researchers from academia and industry will investigate scientific questions using neutron beams.

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.

Control for the Radio-Frequency System

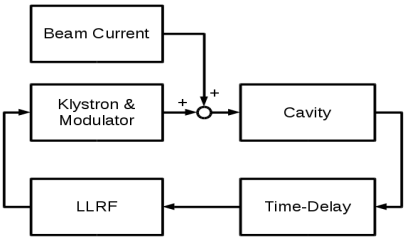
The neutrons are produced by colliding high-speed protons with a rotating tungsten target. The protons are accelerated by oscillating electro-magnetic fields in 155 radio-frequency cavities along the 482 meter long linear accelerator.

In order to avoid defocusing of the beam (which leads to activation of the accelerator structure), it is crucial that the amplitudes and phases of the cavities are kept close to their nominal values. This requires both high-performance feedback loops and a very stable phase reference.



Cavity Field Control

In order to achieve regulation of the cavity fields sufficiently close to the reference values, feedback loops with sampling frequencies of 10 MHz will be used. The Department of Automatic Control is involved in system modeling and controller design for the these loops as well as supporting the development of requirements on RF system components. The work is coordinated by this group at the Department of Electrical and Information Technology.



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.

The Dept. of Automatic Control at Lund University 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. The Department of Automatic Control 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.

LARGE SCALE OPTIMIZATION AND CONTROL

Distributed Control and Verification
Large-scale Convex Optimization
Low-rank approximation with convex contraints
Dynamic Exchange Economics in Transport Systems
Control Using Distributed Information
Dynamics, Information and Control in networks

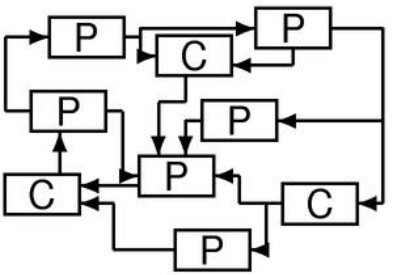
One of the greatest challenges of modern engineering is the sustainable and safe operation of large-scale technical systems. To address this challenge, we need to develop scalable methods for control and optimization.

DISTRIBUTED CONTROL AND VERIFICATION

Researchers: Carolina Lidström, Martin Heyden, Richard Pates, Hamed Sadeghi, Kaoru Yamamoto, Anders Rantzer

Funding: VR

Most of control theory has been developed in a centralized setting, where all measurements are processed together to compute the control signals. This paradigm has conceptual advantages, but also inherent limitations. In contrast, industrial practice often relies on distributed control structures. Hence, there is a strong need for theory and methodology supporting design and verification of distributed controllers. The purpose of this research project is to address this need along three main directions:



- **Structured H-infinity optimal control**. Non-uniqueness of H-infinity optimal controllers is exploited for derivation of distributed control structures.
- **Scale Free Performance**. Distributed and decentralised control architectures are inherently limited when compared to their centralised counterparts. This can result in the emergence of seemingly fundamental undesirable behaviours. We investigate both the types of behaviours that can be regulated in a scale free manner, and those that cannot.
- **Scalable Integral Quadratic Constraints**. We are exploring scalable versions of classical anlysis methods for feedback systems. Driving applications range from neuro-science to structural engineering and stochastic optimization.

LARGE SCALE CONVEX OPTIMIZATION

Researchers: Pontus Giselsson, Mattias Fält

Funding: SSF

Large-scale convex optimization problems appear naturally in many engineering fields such as machine learning, signal processing, image reconstruction, control, and bioinformatics. Many efficient algorithms exist that are specialized for a particular problem formulation. In this project, we are developing and analysing general purpose algorithms that can solve essentially any large-scale convex optimization problem. We are focusing on algorithm developement, theoretical algorithm analysis, as well as creation of software packages for user-friendly access to the developed methods.

LOW-RANK APPROXIMATION WITH CONVEX CONSTRAINTS

Researchers: Christian Grussler, Anders Rantzer, Pontus Giselsson, Andrey Ghulchak

Funding: LCCC Linnaeus center

Model Order Reduction of Postive Systems:
Transportation networks, biological systems as well as heat transfer model are only a few examples for systems with the fundemental property of operating with positively measured inputs and outputs only. Typically these systems are large-scale and one way of overcoming this issue in control and simulations is to approximate the systems with the help of so-called Model Order Reduction (MOR). Unfortunately, standard MOR-methods do not preserve positivity and by that may lead to false conclusions in simulations as well as controller design.

Research in Positivity Preserving Model Order Reduction has been conducted earlier, however with strong conservatism regarding dimensionality and errors. Our main goal is to supply new approximaton strategies with the incentive of weakening the current conservatism, e.g. by considering ellispoidal cone invariant systems.

Low-rank approximation with convex constraints
Model order reduction that is preserving external positivity is essentially equivalent to a low-rank approximation of an infinite-dimensional Hankel-matrix under the preservation of the Hankel-structure and the non-negativity. However, even for finite matrices it is unkown how to find an optimal low-rank approximation that preserves convex constraints. Instead heuristics, like the nuclear-norm regularization method are the state of the art.

Our main goal is to fill this gap and give deterministic solutions that do not depend on a regularization parameter.

DYNAMIC EXCHANGE ECONOMICS IN TRANSPORT SYSTEMS

Researchers: Martin Heyden, Anders Rantzer

Funding: SSF

We study the interplay between economics and traffic flows in transport networks. Such competitive interaction is essential in many applications, including logistics, electrical power flow and telecommunications. Our objective is to understand and exploit the interaction between node demands and network dynamics with focus on:

- Exchange equilibria in traffic networks.
- Network dynamics in presence human decision-makers

This is a subproject of SoPhy.

CONTROL USING DISTRIBUTED INFORMATION

Researchers: Hamed Sadeghi, Anders Rantzer

Funding: KAW through WASP

Motivated by applications in infrastructure networks (mainly traffic and transportation) we are studying how network flows can be optimized using distributed controllers. Existing results for linear systems with an H-infinity objective will be generalized to accommodate non-linear flow constraints and other convex objectives. Goals:

- Scalable methodology for control of network flow control
- Stable and robust systems optimal performance
- Apply methods to traffic/transportation systems

The project is a subproject of WASP.

DYNAMICS, INFORMATION, AND CONTROL IN NETWORKS

Researchers: Giacomo Como, Gustav Nilsson, Kaito Ariu

Funding: VR

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.

The group has hosted several master theses.

CONTROL AND REAL-TIME COMPUTING

Event-Based Estimation and Control
Event-Based Information Fusion for Self-Adaptive Cloud
Co-Design of Robust and Secure Networked Embedded Control Systems
LUCAS
Power and temperature control for large-scale computing infrastructures
Feedback Computing in Cyber-Physical Systems
Autonomous Cloud

In the Control and Real-Time Computing area we work in two main directions:

- Implementation of control systems on resource-constrained implementation platforms, e.g., small embedded processors or networked controllers with limited communication bandwidth. This also includes event-based control.
- Applications of control to computing and communication systems. This includes control of server systems and adaptive resource management of embedded systems.

EVENT-BASED ESTIMATION AND CONTROL

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

Funding: VR, KAW through WASP

The vast majority of all feedback controllers today are implemented using digital computers, relying on periodic sampling, computation, and actuation. For linear systems, sampled-data control theory provides powerful tools for direct digital design, while implementations of nonlinear control designs tend to rely on discretization combined with fast periodic sampling. In recent years, there has been a growing research interest in event-based control, in particular in connection to distributed and networked control systems. The basic idea is to communicate, compute, or control only when something significant has occurred in the system. The motivation for abandoning the time-triggered paradigm is to better cope with various constraints or bottlenecks in the system, such as sensors with limited resolution, limited communication or computation bandwidth, energy constraints, or constraints on the number of actuations.

During 2017 we have studied optimal event generation for reset control of linear stochastic systems. This is a fundamental event-based control problem whose solution can be applied in for instance H2-optimal networked control with communication costs. We have shown that optimization of the reset boundary is related to an elliptic convection-diffusion-type partial differential equation over a domain with free boundary, a so called Stefan problem.

EVENT-BASED INFORMATION FUSION FOR THE SELF-ADAPTIVE CLOUD

Researchers: Johan Ruuskanen, Anton Cervin

Funding: KAW through WASP

Successful self-adaptive resource provisioning in the cloud relies on accurate tracking of workload variations and timely detection of changes in the infrastructure. The project will develop novel, event-based estimation techniques for information fusion in cloud server systems using on Monte Carlo-based inference methods.

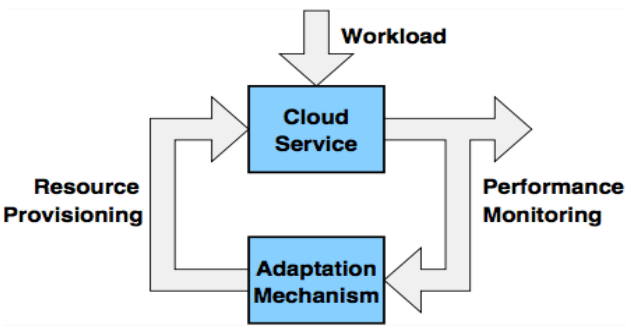
Self-Adaptive Cloud Systems

The idea of the self-adaptive cloud is to handle workload variations and structural changes by regulating the resources provided to the cloud service. The goal is to provide just the right amount of computing resources at all times, so that the cost is minimized while still maintaining good performance. This can be viewed as a classical feedback control loop (see the figure to the right), where the cloud service is the plant under control and the adaptation mechanism is the controller. Workload variations are viewed as disturbances that should be countered by adjustments in the resource provisioning. Performance can be measured for instance by average or Xth percentile response times, throughput, utilization, and power usage. Resource provisioning can be handled by, e.g., downscaling or upscaling the number of compute units allocated to the cloud service.

Event-Based Estimation and Control

The control loop depicted above looks fairly conventional, but if we zoom in, some interesting features can be noted. The arrows that connect the different blocks in the diagram do not represent continuous signals but rather discrete events. Measurement information is available only when something happens in the system, for instance when a new customer arrives or when a request is completed. Likewise, the resources are typically quantized and can only be set at fixed levels. To deal with these special features, new control techniques need to be developed that can handle events-based rather than continuous signals.

In recent years, new theory for event-based control has started to appear. The main idea is to act only when the magnitude of the control error is larger than a certain threshold, thereby saving resources and reducing tear and wear. In this project we will focus on event-based in-

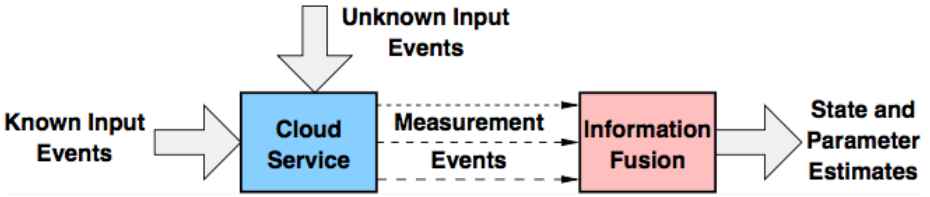


formation fusion. Similar to a Kalman filter, the general idea is to estimate states and parameters of the cloud system by using a model of the system together with various measurements. Some of the key challenges of estimation in cloud systems are:

- All primary measurements are event-based
- The amount of events – observable as well as unobservable – is massive
- Events of different types and on very different time scales need to be fused.

Information Fusion Using Particle Filters

The principle of event-based information fusion is illustrated in the figure below. Known inputs to the cloud service are for instance the commands from the Adaptation Mechanism, while the unknown inputs represent for instance customer arrivals that cannot be measured. Combining a-priori model knowledge with measurements, the Information Fusion system needs to take all types of events (and also the absense of events) into account when forming its estimates of key parameters and states.



The event-based information fusion problem is challenging because of the non-linear behavior of the cloud service and because new information is only available at discrete events. One promising approach to tackle the problem is to use particle filters, which is a family of Monte Carlo-based inference methods that have gained much attention in the last decades. Using particle filters for cloud systems is however not straightforward. New dynamical system models need to be developed, and the filters need to be adapted to handle event-based rather than time-based measurements. Another research challenge is how to weigh together the information from different types of events in an optimal way.

Experimental Evaluation

The novel information fusion schemes developed in this project will be evaluated both in simulations and in a server test-bed at the department. Starting from single-server systems, modeled as M/M/1 queueing systems, we will gradually scale the models and experiments to include more servers and concurrent cloud services. In the experiments we may also include various self-adaptive mechanisms that are being developed in parallel research projects at the department.

CO-DESIGN OF ROBUST AND SECURE NETWORKED EMBEDDED CONTROL SYSTEMS

Researchers: Yang Xu, Anton Cervin and Karl-Erik Årzén, in collaboration with the Embedded Systems Lab at Linköping University

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.

Working along two parallel research paths, we will explore both passive and active approaches to achieve robustness. In the passive approach, we aim for techniques that take parametric plant and platform uncertainty into account at design time, while the run-time system should provide predictable exception handling and provable performance bounds. In the active approach, the run-time system should be able to adapt to new and unexpected conditions via reconfiguration and self-optimization. Here a great research challenge is to devise adaptation schemes that do not consume too much resources in themselves. 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 2017, the research focused on jitter-robust LQG design. Adding a jitter margin constraint to a standard LQG formulation makes it possible to trade off performance and timing robustness for real-time controllers. On December 15, Yang Xu defended his PhD thesis with the title *LQG-Based Real-Time Scheduling and Control Codesign*.

LUCAS - LUND CENTER FOR APPLIED SOFTWARE RESEARCH

Researchers: Karl-Erik Årzén, Rolf Johansson, Anders Robertsson, Anton Cervin, Anders Nilsson and Anders Blomdell in collaboration with Dept of Computer Science, Lund University

The Center for Applied Software Research (LUCAS) is a collaboration between the software-oriented parts of the Departments of Automatic Control and Computer Science at LTH. In total around 15 faculty members and 20 PhD students are involved in LUCAS. The focus of LUCAS is industrially-oriented and motivated software research. This includes research on software engineering, software technology, and software applications. Special focus is put on real-time systems, in particular embedded systems, networked systems, and control systems.

LUCAS started in 1999 and its status has changed over the years. Currently its main role is to act as an umbrella organization. The main activity is the annual LUCAS workshop. The internal breakfast seminars goes from Fall 2017 under the name Digit@LTH and also involves digitalization-related activities at the Mathematics and the EIT departments.

POWER AND TEMPERATURE CONTROL FOR LARGE-SCALE COMPUTING INFRASTRUCTURES

Researcher: Martina Maggio

Funding: VR

Modern computing systems are constrained by dark silicon, the abundance of transistors enables processors to draw more power than they can safely sustain. For example, the Exynos 5 processor (in the Samsung Galaxy S4 phone) has a 5.5W peak power that is nearly twice the maximum sustainable heat dissipation, limiting peak speed to less than 1 second. At the other end of the spectrum, the next generation of exascale supercomputers is predicted to be constrained by an operating budget of approximately 20 MW. In addition, Microsoft was recently fined for not using enough power and violating an agreement with a utility company. Executing efficient code in these systems requires solving a constrained optimization problem: maintaining the power budget, while maximizing performance within the power constraint.

Many separate components contribute to total power consumption and various techniques have been proposed to manage individual components. For example, management systems exist for CPU allocation, dynamic voltage and frequency scaling, processor idling, cache, DRAM, and disk. However, the coordination of these many actuators is non-trivial and requires knowledge on all the potential nonlinearities that the hardware infrastructure may expose. The goal of this research is to develop a platform-independent resource manager to control the temperature and power consumption of large computing infrastructures like data centers. This management system should be general with respect to the running platform and must address three challenges:

- **Unknowns**: prior research approaches rely on rigorous models for either the specific machine under control or for a specific application and platform. A generalized power management system, however, must either construct its models on the fly or compensate for inaccuracies and unknowns in the model.
- **Interaction**: System components interact to produce a complex (often nonlinear) effect on power, temperature and performance. If individual components are controlled separately, their interaction can lead to suboptimal behavior, even when these separate controllers are individually optimal. Thus, a generalized power management system must coordinate all available components even if they are not known at design time or vary at runtime.
- **Optimization**: A power manager must not exceed the power budget, yet must also deliver the best possible performance for a given budget. A generalized approach must not sacrifice too much performance for generality.

This research addresses the above challenges, the result so far has been a machine-level power management system that is general with respect to the components it manages, and uses feedback control to ensure that the power and temperature budget are respected, while delivering the best possible performance to the running applications.

FEEDBACK COMPUTING IN CYBER-PHYSICAL SYSTEMS

Researchers: Karl-Erik Årzén (project leader), Johan Eker, Martina Maggio, Victor Millnert, Gautham Nayak Seetanadi in collaboration with Jorn Janneck and PhD students at Dept of Computer Science, LTH and with Enrico Bini at Scuola Superiore Sant'Anna in Pisa, Italy

Funding: VR

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 above.

The project is divide 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 (Jörn Janneck)

AUTONOMOUS CLOUD

Researchers: Karl-Erik Årzén, Martina Maggio, Johan Eker, Tommi Nylander, Per Skarin, Alexandre Martins, Viktor Millnert in collaboration with Maria Kihl at the Dept of Electrical and Information Technology, with Erik Elmroth, Cristian Klein, and Chanh Nguyen at Umeå University, and with Amir Roozbeh and Dejan Kostic at KTH.

Funding: KAW through WASP

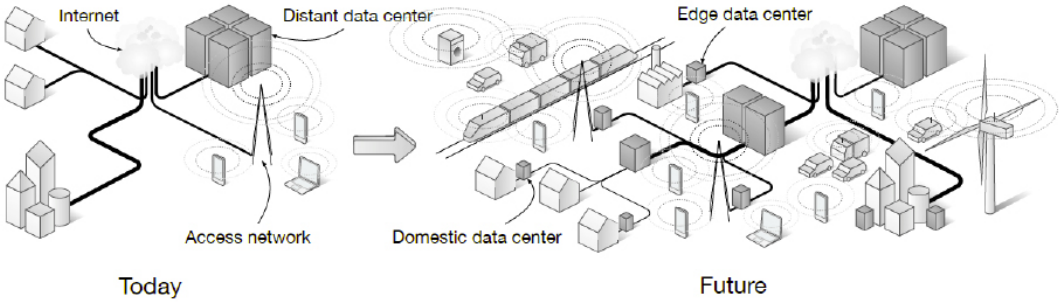
Background

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 heterogeneity 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.

Project Outline

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 techni-



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

ques 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.

Industrial PhD Projects

The project contains three industrial PhD student projects out of which two are at our department.

These are:

- *Mission-Critical Cloud* - PhD student: Per Skarin, Ericsson Research; Academic Supervisor: Karl-Erik Årzén; Industrial Supervisor: Johan Eker, Ericsson
- *Autonomous learning camera systems in resource constrained environments*; PhD student: Alexandre Martins, Axis; Academic Supervisor: Karl-Erik Årzén; Industrial Supervisor: Mikael Lindberg, Axis

PROCESS CONTROL

PID Control
Automatic Tuning
Decentralized Control Structures
Sysint4.x
Dig-Pi

The department has always had an active collaboration with the process industry as well as with the suppliers of process control instrumentation and systems. Most of the research projects are formed together with the process industry, and several of them are performed with active participation by staff from industry. Many of the research results are also transfered to instrument and system suppliers, and implemented and used in process industry.

PID CONTROL

Researchers: Karl Johan Åström, Josefin Berner, Tore Hägglund and Kristian Soltesz

This project has been in progress since the beginning of the eighties, and resulted in industrial products as well as several PhD theses. Three monographs on PID control that are based on experiences obtained in the project have also been published. The last is "Advanced PID Control", published in 2005. It is also translated to Spanish 2009: "Control PID avanzado". The research is currently focused on the following topics:

Automatic Tuning of PID Controllers

The PID controller is used almost everywhere in industry, but a lot of PID controllers work poorly due to bad tuning. To be able to automatically tune PID controllers is a useful feature that has been around since the beginning of the 80's. A lot has happened since then both regarding PID knowledge, but mainly in available computing power, and we are now developing new autotuners that can take advantage of that. More information about our current autotuner research is found on the page for Automatic Tuning.

Optimal Robust PID design

A Matlab-based software tool for optimal PID design has been developed at the department. The software finds the PI or PID controller that minimizes the Integrated Absolute Error (IAE) value during a step load disturbance on the process input, with respect to robustness constraints on the sensitivity and complementary sensitivity functions. This PID design method is called SoftWare-based Optimal Robust Design (SWORD).

Varying the time constant of the low-pass filter, it is possible to find optimal or near-optimal solutions to an optimization problem extended with a noise sensitivity constraint. As the time constant of the low-pass filter increases, the PID controller will gradually transform into a PI controller and then finally an I controller. This gives a natural set of I, PI and PID controllers to choose from. The final controller can be selected based on visual feedback of the control signal activity due to measurement noise.

PID design by convex optimization

Convex optimization has grown to become a

mature and powerful tool in a vast number of research fields. Design of PID controllers subject to robustness constraint is not a convex optimization problem, however, it fits well into the framework of the convex-concave procedure. Using that procedure, tuning algorithms for both SISO and MIMO PID controllers have been develpoed. Although globally optimal controllers cannot be guaranteed, the method produces robust controllers with good performance. The work is done in collaboration with Stephen Boyd, Stanford University.

Optimization-Based Robust PID Design in Matlab

Compact and relatively efficient implementations of software for solving the PID design problems introduced above under Optimal Robust PID Design and PID design by convex optimization are available through the Matlab code PIDopt. The software also allows for co-design of PID controllers and measurement filters.

Interactive learning modules for PID control

We are also developing interactive learning modules for PID control. The modules are designed to speed up learning and to enhance understanding of the behaviour of loops with PID controllers. The modules are implemented in SysQuake, and the work is done in collaboration with professor Sebastián Dormido at UNED, Madrid, and José Luis Guzmán at Universidad de Almería.

The tools can be downloaded from Universidad de Almería.

AUTOMATIC TUNING

Researchers: Josefin Berner, Kristian Soltesz, Tore Hägglund, Karl Johan Åström

Methods for automatic tuning of PID controllers were developed in the early eighties, and implemented in industrial single-station controllers and DCS systems. A main reason was the technology shift from analog to computer-based controllers and systems at that time, which made implementation of such tuning functions possible. These methods were limited by the computer power and the knowledge about PID design that were available at that time. Since then, the computational power and the knowledge about PID design has increased, which provides the possibility to develop new tuning functions with better performance.

Within process industry, a large number of processes can be accurately modeled using simple models, i.e. SISO FOTD or SOTD, and there are efficient tuning rules for PID controllers that are based on these model structures.

We aim at developing a methodology for automatic tuning of PID controllers, using nonlinear feedback for idenfication input generation and optimization based methods for both process parameter identification and controller synthesis.

The main components of the auto-tuning alogorithm are the following:

1. Generate identification input with little or none a priori system information
2. Transfer function parameter identification through optimization
3. Model verification
4. PID synthesis
5. Performance evaluation

As a case study, a modified version of the method has been applied in closed-loop controlled anesthesia.

Developed autotuners

In the PhD Thesis by J. Berner, three different versions of the autotuner are developed and described.

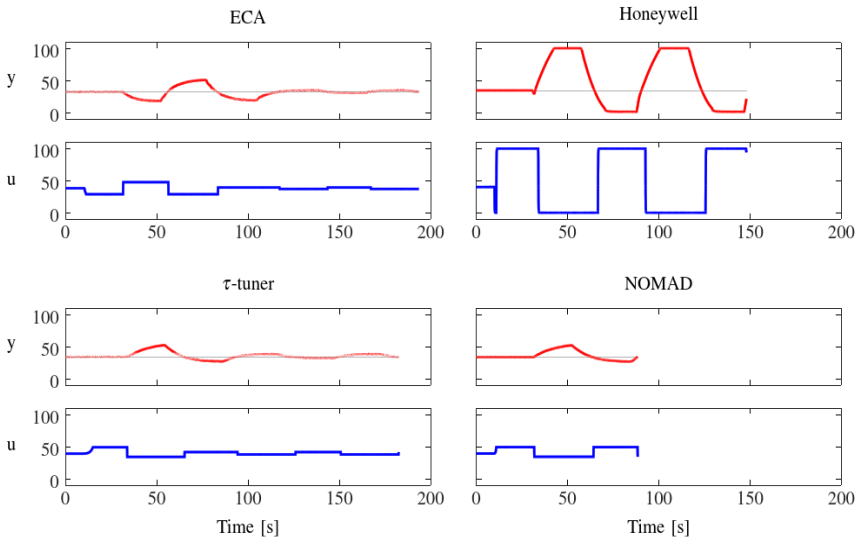
One version is called the Tau-tuner and conducts a simple experiment, using an asymmetric relay function as feedback. From the experiment the static gain and the normalized time delay

of the system can be estimated, and from this a FOTD model can be achieved from analytical formulas. From the achieved model the parameters of a PI or PID controller is tuned by existing tuning rules.

The second version is called the NOMAD-tuner and it uses a similar but even shorter experiment, and then uses the experiment data to find a first or second order model with time delay using numerical parameter estimation methods. The PID controller parameters are then obtained by optimization methods. This version requires more calculations, but is more robust to disturbances, gives more accurate models and can be started without waiting for steady-state.

The third version is called the multi-NOMAD and is an extension of the NOMAD-autotuner to multivariable (two-input two-output) systems.

All versions have been evaluated in simulations and on physical processes. The Tau-tuner has also been tried on an industrial air handling unit. Matlab/Simulink implementations of all three autotuners are available in this git-repo, and the Tau-tuner has also been implemented and tested in Modelica and JGrafchart.



DECENTRALIZED CONTROL STRUCTURES

Researcher: Tore Hägglund

This project aims to revise, improve, and develop new basic control structures 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.

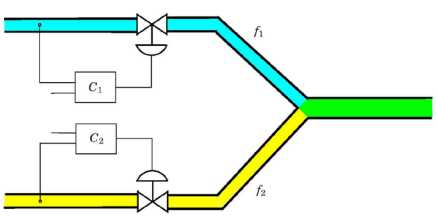
PID controllers is often implemented with set-point weighting to improve the response to changes in the reference. By using convex optimization techniques the parameters for the set-point weights can be found efficiently, fast as well as be guaranteed to be globally optimal. By solving an optimization 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 disturbances. 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.



SYSINT4.X

Researchers: Charlotta Johnsson and Jacob Mejvik in collaboration with Fredrik Heinz, Linköping University and Klas Nilsson, Sven G Robertz, Jacek Malec, Mattias Haage, Elin Topp, Dept of Computer Science, Lund University.

Funding: Vinnova

Increased digitization creates opportunities for increased productivity, but also several risks such as:

- Flexibility limited to overall (partly already digital) systems, while faults on the factory floor can be difficult to manage.
- Physical performance decreases if know ledge and practices of the staff is not taken care of.
- Proposed systems within Industry 4.x might not sufficiently consider business models and responsibilities of technology providers on a system level.
- Existing (well working) subsystems och equipment cannot be used efficiently.

The proposed project w ill together with industrial technology providers end users, and system integrators, investigate these and other productivity-related problems, and propose a new initiative including appropriate stakeholders from both industry and academia. There w ill be an emphasis on manufacturing systems that include robots since those systems impose special demands on the combination of flexibility and motion performance.

During the formation of Industry 4.0 the applicants were involved in several relevant EU-projects together with German partners. This has resulted in several solution, patents and new business, but benefits for Swedish industry has been deficient. The proposed planning project combines via a Lund-Linköping collaboration the industrial experiences with related relevant research within academia and upcoming within WASP. Several other stakeholders at different locations w ill be part of a bigger initiative, which w ill be formed such that it is complementary to other projects.

DIG-PI

Researchers: Charlotta Johnsson in collaboration with Carsten Nokleby from Sesam-Sverige, and representatives from Perstorp Specialty Chemicals AB, Tetra Pak Processing Systems, Södra Cell AB, Arla Foods, ÅF industry AB, Prevas AB, Hild, FPA Konsult AB, Rockwell Automation AB, Schneider-Electric AB, Siemens AB and B&R Industriautomation AB.

Funding: Vinnova- PiiA

This is a visionary project with the focus on "Digitalized Process Industry (DigPI)" and its possibilities to create benefits for the Process Industries in Sweden. The aim of this pre-study project (DigPI-1) is to specify visions, and goals for future Digitalized Process Industries, and in a future full-sized research project (DigPI-2) set up a physical demonstration platform (testbed) where these visions and goals can be demonstrated. The pre-study is divided in four work-packages (WP):

- WP1: Identify a suitable process for the demonstration platform
- WP2: Define innovative concepts to be visualised in the demonstration platform
- WP3: Benchmark within the process industry.
- WP4: Understanding of business benefits

For the most successful future regarding the development and direction of a Digitalised Process Industry, collaboration between the stakeholders (solution-providers, end-users, integrators, network-organizations and academia) is key. The project partners in this pre-study (DigPI-1) consists of; one academic partner, one network-organisation, and 13 industry partners. Further, the industry partners includes 4 solution-providers, 5 end-users 2 integrators och 2 consultant companies.

ROBOTICS

Robotics Research
Robotics Lab
SARAFun
Semantic mapping and visual navigation for smart robots

ROBOTICS RESEARCH

Researchers: Rolf Johansson, Anders Robertsson, Björn Olofsson, Karl-Erik Årzén, Mahdi Ghazaei, Fredrik Bagge Carlson, Anders Blomdell, Anders Nilsson, Martin Karlsson and Pål Johan From in close cooperation with colleagues from neighbor departments at the Robotics Lab at LTH, Lund University, and ABB Robotics/CRC, Västerås, Sweden.

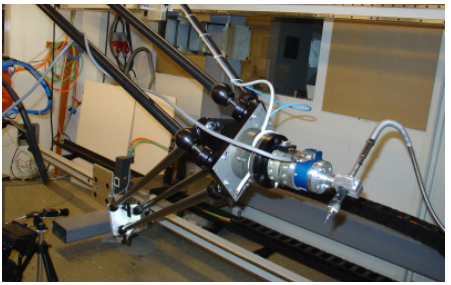
Robotics offer both theoretical and practical challenges. Robotics is a multi-disciplinary topic and we collaborate with both national and international robotics colleagues regarding different aspects of robotics and we also have a close cooperation with industrial partners. Our main research are in motion and compliance control, control system architectures and different sensor fusion problems with application mainly to industrial manipulators. We use mainly modified and extended ABB robot control systems as experimental platforms.

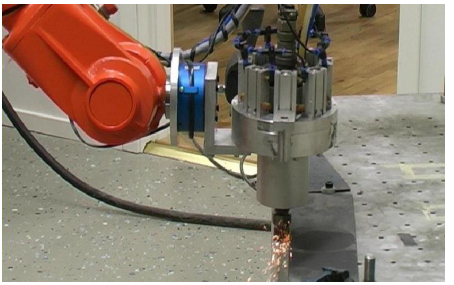
The laboratory for robotics and real-time systems is centered around industrial manipulators with open control system architectures. In the lab we have several generations of robots from an elderly ABB IRB6 robot, an ABB IRB2000 robot, an ABB Irb2400 (S4CPlus) to the more modern ABB IRB140 (IRC5), Gantry-Tau robot (IRC5), ABB IRB120 (IRC5) and the latest dual-arm concept robot Frida (ABB IRC5). Hardware interfaces have been developed to create an open system suitable for control experiments (Orca/Orcinus). The computer hardware is either PCI-based with both microprocessors and signal processors integrated into an embedded system for hard realtime control in one of the labs and integrated with an additional PCI-based G4 PowerPC for the new Open Control system

based on S4CPlus and the newly developed networked architecture running on Linux/Xenomai-platforms.

The systems are connected to a network with workstations, which are used for program development and control design. A purpose of the current project is to show how to organize open robot control systems and to verify these ideas by means of experiments.

One goal is to permit efficient specification and generation of fast robot motions along a geometric path which requires coordinated adjustment of the individual joint motions. Another aspect of robot motion control is how to integrate simultaneous control of force and position according to ideas of impedance control in which stability is an important theoretical is-





sue. A major topic in this project is to integrate aspects of control, sensor fusion and application demands using robot vision and force sensing. Another project is on the structure and programming of control systems for industrial robots. The problem addressed is how the software architecture and the realtime structure of a robot control system should be designed to allow easy and flexible incorporation of additional sensors and new control algorithms.

A software layer between a supervisory sequence control layer and the basic control level has been proposed. Case studies and prototype experiments show promising results and further implementation is going on. The project Autofett aimed towards use of force control in manufacturing operations such as robotized fettling and is now continued in the SMErobot and FlexAA-projects. 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 ICRA Best Automation paper.

Several research interests are represented in Robotics Lab:

- Open Control Software Architectures
- Exteroceptive Robots
- Force Control
- Robot Vision
- Sensor Fusion
- Adaptive and Iterative Learning Control
- Task-level Programming
- Productive Robotics & Work-space Sensing

ROBOTICS LAB

Robot control systems and other manufacturing equipment are traditionally closed. This circumstance has hampered system integration of manipulators, sensors and other equipment. As a result, such system integration has often been made at an unsuitably high hierarchical level.

The purpose of past and present 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.

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 – under grant agreement No 644938 – SARAFun.

The 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.

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.

SEMANTIC MAPPING AND VISUAL NAVIGATION FOR SMART ROBOTS

Researchers: Marcus Greiff, Bo Bernhardsson, Anders Robertsson with colleagues from the Dept of Mathematics, Lund, and Chalmers University of Technology.

Funding: SSF

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.

AUTOMOTIVE SYSTEMS

KCFP, Closed-Loop Combustion Control

KCFP, CLOSED-LOOP COMBUSTION CONTROL

Researchers: Rolf Johansson and Gabriel Turesson in cooperation with Lianhao Yin and Prof. Per Tunestål, Div. Combustion Engines, Lund University

Competence Center Combustion Processes (KCFP) at Lund University 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 pre-mixed 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 rate 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

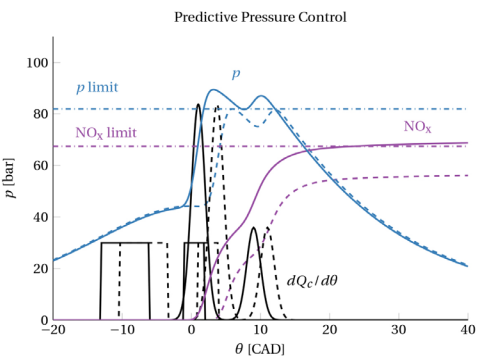


Fig. 1 Model predictive control has been utilized to efficiently fulfill constraints on cylinder pressure and NOx emissions with the use of multiple injections. This figure illustrates how the controller predicts a deviation in pressure, NOx formation and heat release rate (dashed) from the previous cycle data (solid).

MEDICAL PROJECTS

Hemodynamic Stabilization
Ventilator for Improved Cardiopulmonary Resuscitation
Surgeon's perspective
Milieu Intérieur

HEMODYNAMIC STABILIZATION

Researchers: Kristian Soltesz, Rolf Johansson, Anders Robertsson in collaboration with Igelösa Life Science AB.

Funding: Vinnova through the MedTech4Health strategic innovation program

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 variables, 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 och medical treatment scenaraios, 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 stabilizatioin 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.

VENTILATOR FOR IMPROVED CARDIOPULMONARY RESUSCITATION

Researchers: Kristian Soltesz, Trygve Sjöberg and Audrius Paskevicius in collaboration with Igelösa Life Science AB.

Funding: Vinnova

Description
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.

SURGEONS PERSPECTIVE

Researchers: Charlotta Johnsson, in collaboration with Kiet Tran, Skåne University Hospital Lund, Jonas Unger, Linköping University and Christer Mårtensson, Business Region Skåne

Funding: Vinnova - UDI

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 w ill 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 robotic surgery.

MILIEU INTERIEUR

Researchers: Jacob Bergstedt supervised by Bo Bernhardsson, and Etienne Patin from the Pasteur Institute, together with Magnus Fontes from Genentech, USA.

Funding: eLLIIT

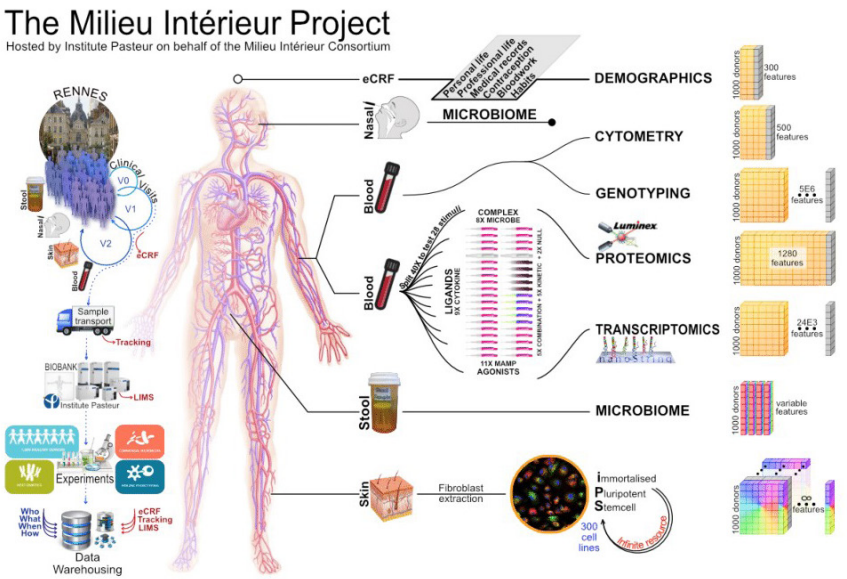


Figure 1. Summary of the Milieu Intérieur project

The Automatic Control department collaborates with the Pasteur institute in Paris in the Milieu Intérieur project, summarized in figure 1. This data intensive biomedical project aims at paving the way toward precision medicine in Europe. A very fine grained set of data has been collected for 1000 French subjects. This includes, among other things, immunophenotyping, proteomics, transcriptomics, methylation, microbiota, as well as clinical and demographical information. Taken together, the hope is that the project will be able to offer an unprecedented view into the complexity of the relationship between genes and physical characteristics in humans.

The role of the Automatic Control department in the project is for example to develop a broad framework for investigating multivariate relationships between processes at various levels of the chain between genes and their biological outcome, so called phenotypes, and for building statistical models customized to answer particular biomedical research questions. For instance, 15 point mutations in the genome, shown in figure 2, that affect the immune system in humans has been found from our analysis and were recently published in Nature immunology.

The contributor to the project from the Automatic Control department is Jacob Bergstedt. Supervisors are Bo Bernhardsson, also from the Automatic Control department, and Etienne Patin from the Pasteur institute, together with Magnus Fontes from Genentech, USA. The project is led by Lluis Quintana-Murci and Matthew Albert.

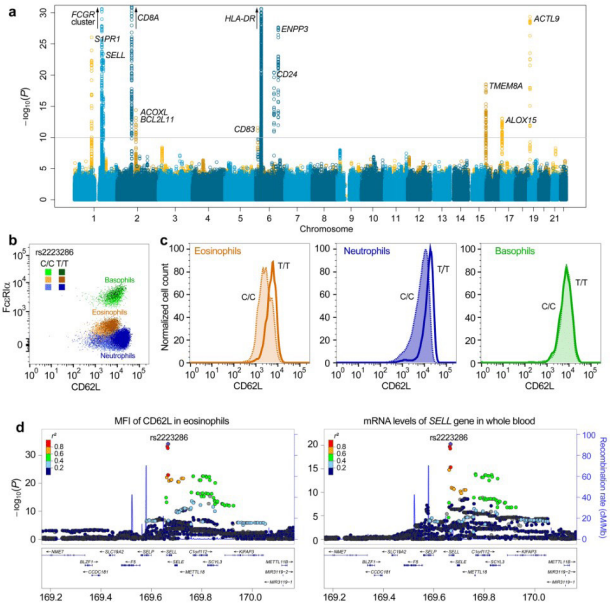


Figure 2: Point mutations that affect the immune system, found in the project.
Copyright: Nature Immunology

TOOLS AND SOFTWARE

JGRAFCHART
Jitterbug: A Matlab toolbox for real-time control performance analysis
JMODELICA.ORG
MPCtools
TrueTime: Simulation of Networked and Embedded Control Systems

Downloadable software developed at the department

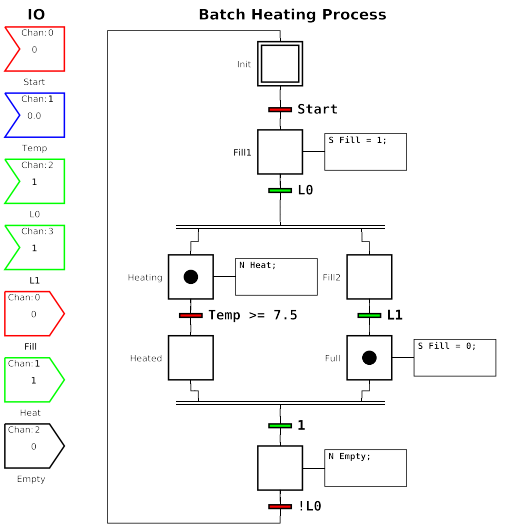
JGRAFCHART

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, for example, Grafchart for Industrial Automation and PRACE. It has also been used within the EU/GROWTH project CHEM for control in process industry, the EU FR7 project ROSETTA for robotic assembly, and several master's theses for example for modeling or code generation. DFKI has used it to implement the coordination of several demonstrators with real industrial equipment. Finally, there are a few cases where it is used for live industrial control, for example, myvision MANUFACTO.

JGrafchart is available for download as freeware.



Control of a Batch Heating Process implemented in JGrafchart.

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.

JMODELICA.ORG

JModelica.org is an extensible Modelica-based open source platform for optimization, simulation and analysis of complex dynamic systems. The main objective of the project is to create an industrially viable open source platform for optimization of Modelica models, while offering a flexible platform serving as a virtual lab for algorithm development and research. As such, JModelica.org provides a platform for technology transfer where industrially relevant problems can inspire new research and where state of the art algorithms can be propagated from academia into industrial use. JModelica.org is a result of research at the Department of Automatic Control, Lund University, and is now maintained and developed by Modelon AB in collaboration with academia.

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

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.

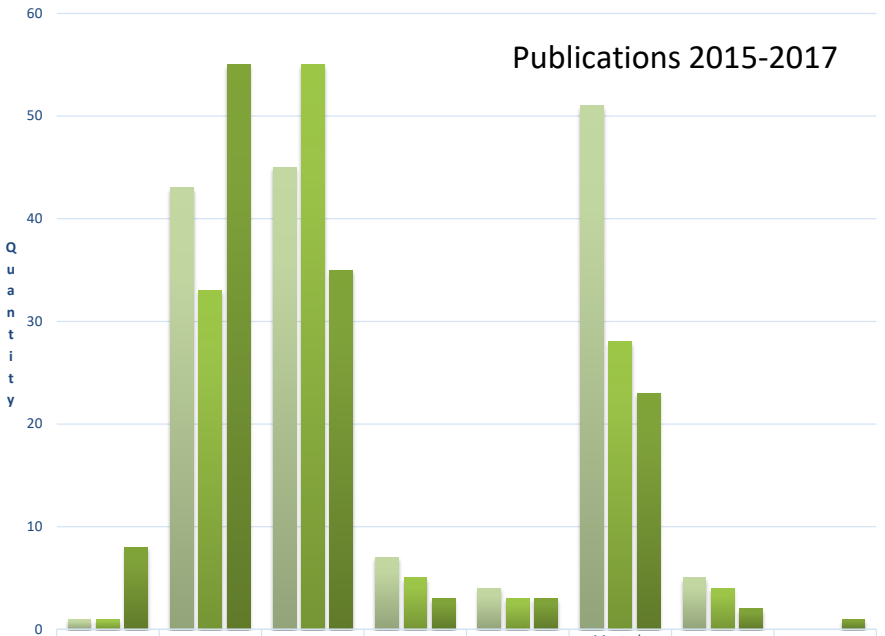
Publications and seminars

This chapter contains a list of publications and seminars during 2017

PUBLICATIONS 2017

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



	Book contr	Articles	Conf contr	PhD theses	Lic theses	Master's theses	Techn reports	Miscellaneous
2015	1	43	45	7	4	51	5	0
2016	1	33	55	5	3	28	4	0
2017	8	55	35	3	3	23	2	1

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Blanchini, Franco; Fenu, Gianfranco; Giordano, Giulia; Pellegrino, Felice Andrea; *Model-free tuning of plants with parasitic dynamics*; In 56th IEEE Conference on Decision and Control, CDC, 2017.

Blanchini, Franco; Fenu, Gianfranco; Giordano, Giulia; Pellegrino, Felice Andrea; *Discrete-time plant tuning without a model*; In 20th IFAC World Congress, 2017.

Capurso, Martino; Ghazaei, Mahdi; Johansson, Rolf; Robertsson, Anders; Rocco, Paolo; *Sensorless Kinesthetic Teaching of Robotic Manipulators Assisted by Observer-Based Force Control*; In IEEE International Conference on Robotics and Automation (ICRA 2017), Singapore, May 29-June 3, 2017.

Fält, Mattias; Giselsson, Pontus; *Line search for generalized alternating projections*; In 2017 American Control Conference, ACC 2017.

Fält, Mattias; Giselsson, Pontus; *Optimal convergence rates for generalized alternating projections*; In 56th IEEE Conference on Decision and Control, CDC, 2017.

Giordano, Giulia; Altafini, Claudio; Interaction sign patterns in biological networks: from qualitative to quantitative criteria; In 56th IEEE Conference on Decision and Control, CDC, 2017.

Hu, Bin; Seiler, Peter; Rantzer, Anders; *A Unified Analysis of Stochastic Optimization Methods Using Jump System Theory and Quadratic Constraints*; In Conference on Learning Theory, 2017.

Ingesson,Gabriel; Yin, Lianhao; Johansson, Rolf; Tunestål, Per; Efficiency Optimal, Maximum Pressure Control in Compression Ignition Engines; In 2017 American Control Conference, 2017, Seattle, WA, May 24-26, 2017.

Jiang, Yan; Pates, Richard; Mallada, Enrique; *Performance tradeoffs of dynamically controlled grid-connected inverters in low inertia power systems*; In 56th IEEE Conference on Decision and Control, CDC, 2017, Seattle WA, May 24-26, 2017.

Karlsson, Martin; Karlsson; Fredrik; *Cooperative Indoor Positioning by Exchange of Bluetooth Signals and State Estimates Between Users*; In European Control Conference, 2016.

Karlsson, Martin; Robertsson, Anders; Johansson, Rolf; *Autonomous Interpretation of Demonstrations for Modification of Dynamical Movement Primitives*; In IEEE International Conference on Robotics and Automation (ICRA), 2017, Singapore, May 29-June 3, 2017.

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

Maggio, Martina; Papadopoulos, Alessandro Vittorio; Filieri, Antonio; Hoffmann, Henry; *Automated Control of Multiple Software Goals using Multiple Actuators*; In 11th Joint Meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering, 2017.

Maggio, Martina; Papadopoulos, Alessandro Vittorio; Filieri, Antonio; Hoffmann, Henry; *Self-Adaptive Video Encoder : Comparison of Multiple Adaptation Strategies Made Simple*; In 12th IEEE/ACM International Symposium on Software Engineering for Adaptive and Self-Managing Systems, SEAMS 2017.

Malec, Jacek; Haage, Mathias; Nilsson, Anders; Stenmark, Maj; Topp, Elin Anna; *Semantic modelling of hybrid controllers for robotic cells*; In International Conference on Flexible Automation and Intelligent Manufacturing, 2017.

Millnert, Victor; Eker, Johan; Bini, Enrico; *Dynamic control of NFV forwarding graphs with end-to-end deadline constraints*; In IEEE International Conference on Communications 2017.

Nayak Seetanadi, Gautham; Maggio, Martina; Årzén, Karl-Erik; Almeida, Luis; Camara, Javier; *Event-Driven Bandwidth Allocation with Formal Guarantees for Camera Networks*; In IEEE Real-Time Systems Symposium (RTSS), 2017.

Nayak Seetanadi, Gautham; Maggio, Martina; Årzén, Karl-Erik; Almeida, Luis; Oliveira, Luis; *Game-Theoretic Network Bandwidth Distribution for Self-Adaptive Cameras*; In The 15th International Workshop on Real-Time Networks, 2017.

Olofsson, Björn; Bernhardsson, Bo; Zeng, Rihua; Andersson, Pontus; *Temperature Control of the ESS Phase Reference Line*; In 8th International Particle Accelerator Conference, IPAC 2017.

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

Shevtsov, Stepan; Weyns, Danny; Maggio, Martina; *Handling New and Changing Requirements with Guarantees in Self-Adaptive Systems using SimCA*; In The 12th International Symposium on Software Engineering for Adaptive and Self-Managing Systems, 2017.

Tärneberg, William; Karaca, Mehmet; Robertsson, Anders; Kihl, Maria; Cross layer control for bounded shared state inconsistency in wireless IoT devices; In 56th IEEE Conference on Decision and Control, CDC, 2017.

Tärneberg, William; Karaca, Mehmet; Robertsson, Anders; Tufvesson, Fredrik; Kihl, Maria; *Utilizing Massive MIMO for the Tactile Internet: Advantages and Trade-offs*; In IEEE SECON Workshops - Robotic Wireless Networks, 2017.

Thelander Andrén, Marcus; Bernhardsson, Bo; Cervin, Anton; Soltesz, Kristian; *On Event-Based Sampling for LQG-Optimal Control*; In 56th IEEE Conference on Decision and Control, CDC, 2017.

Troeng, Olof; Bernhardsson, Bo; Rivetta, Claudio; *Complex-coefficient systems in control*; In American Control Conference 2017.

Wadenbäck, Mårten; Karlsson, Martin; Heyden, Anders; Robertsson, Anders; Johansson, Rolf; *Visual Odometry from Two Point Correspondences and Initial Automatic Tilt Calibration*; In 12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2017), pp.340-346.

Yamamoto, Kaoru; Nagahara, Masaaki; Yamamoto, Yutaka; *Signal reconstruction with generalized sampling*; In 56th IEEE Conference on Decision and Control, CDC, 2017.

Yamamoto, Kaoru; Yamamoto, Yutaka; Nagahara, Masaaki; *Simultaneous rejection of signals below and above the Nyquist frequency*; In 2017 IEEE Conference on Control Technology and Applications (CCTA), 2017.

Yang, Tianhao; Yin, Lianhao; Ingesson, Gabriel; Tunestål, Per; Johansson, Rolf; Long, Wu-Qiang; *Simultaneous control of soot emissions and pressure rise rate in gasoline PPC engine*; In Proceedings of the 2017 IEEE Conference on Control Technology and Applications (CCTA), Aug 27-30, 2017, Kohala Coast, Hawaii.

Yin, Lianhao; Ingesson, Gabriel; Johansson, Rolf; Tunestal, Per; Hedrick, J.Karl; *Nonlinear air-path control of a heavy-duty diesel engine - A Receding Horizon Sliding Control approach*; In 2017 American Control Conference, ACC 2017, Seattle, WA, May 24-26, 2017, pp. 3619-3624.

PHD THESES

Berner, Josefin; *Automatic Controller Tuning using Relay-based Model Identification;* PhD Thesis TFRT-1118 Department of Automatic Control, Lund University, Sweden, October 2017.

Grussler, Christian; *Rank Reduction with Convex Constraints;* PhD Thesis TFRT-1117, Department of Automatic Control, Lund University, Sweden, January 2017.

Xu, Yang; *LQG-Based Real-Time Scheduling and Control Codesign*; PhD Thesis TFRT-1119, Department of Automatic Control, Lund University, Sweden, November 2017.

LICENTIATE THESES

Bagge Carlson, Fredrik; *Modeling and Estimation Topics in Robotics*; Licentiate Thesis TFRT-3272,Department of Automatic Control, Lund University, Sweden, March 2017.

Karlsson, Martin; *On Motion Control and Machine Learning for Robotic Assembly*; Licentiate Thesis TFRT-3274, Department of Automatic Control, Lund University, Sweden, July 2017.

Troeng, Olof; *Cavity Field Control for High-Intensity Linear Proton Accelerators*; Licentiate Thesis TFRT-3273, Department of Automatic Control, Lund University, Sweden, November 2017.

TECHNICAL REPORTS

Bagge Carlson, Fredrik; Haage, Mathias; *YuMi low-level motion guidance using the Julia programming language and Externally Guided Motion Research Interface*; Technical Report TFRT-7651, Department of Automatic Control, Lund University, Sweden, December 2017.

Giselsson, Pontus; Rasmusson, Monika (Eds); *Activity Report 2016*; Annual Report TFRT-4044,Department of Automatic Control, Lund University, Sweden, May 2017.

MASTERS THESES

Alijani, Farid; *Autonomous Vision-based Docking of a Mobile Robot with Four Omnidirectional Wheels*; Master's Thesis TFRT-6018, Department of Automatic Control, Lund University, Sweden, January 2017.

Assarsson, Joel; Thoulouis, Simon; Physical network modeling of a reverse osmosis purification unit; Master's Thesis TFRT-6027, Department of Automatic Control, Lund University, Sweden, May 2017.

Bergkvist, Ivar; *A high-accuracy wide-angle acoustic system for distance measurements and robot positioning*; Master's Thesis TFRT-6040, Department of Automatic Control, Lund University, Sweden, September 2017.

Björk, Markus; Levenhammar, Robin; Relay Auto-tuners in Modelica; Master's Thesis TFRT-6032, Department of Automatic Control, Lund University, Sweden, June 2017**.**

Bredberg, Carl; Stjernrup, John; *Driver Modeling, Velocity and Energy Consumption Prediction of Electric Vehicles*; Master's Thesis TFRT-6035, Department of Automatic Control, Lund University, Sweden, August 2017.

Dagbro, Magnus; *Adaptive Control of an Integrator with Unknown Dead-Time*; Master's Thesis TFRT-6030, Department of Automatic Control, Lund University, Sweden, September 2017.

Demeter, Zsolt; *RT-Bench, Improved Understanding of Application Performance with Memory Storage*; Master's Thesis TFRT-6043, Department of Automatic Control, Lund University, Sweden, October 2017.

Gomez-Trenor Sobrino, Alvaro; *Real-Time control of the Flexpicker ABB Robot*; Master's Thesis TFRT-6034, Department of Automatic Control, Lund University, Sweden, August 2017.

Greiff, Marcus; *Modelling and Control of the Crazyflie Quadrotor for Aggressive and Autonomous Flight by Optical Flow Driven State Estimation*; Master's Thesis TFRT-6026, Department of Automatic Control, Lund University, Sweden, March 2017.

Gustavi, Magnus; Andersson, Louis; *Implementation of control algorithm for mechanical image stabilization*; Master's Thesis TFRT-6042, Department of Automatic Control, Lund University, Sweden, September 2017.

Guth, Joakim; *On Distributed Maximization of Influence in Social Networks*; Master's Thesis TFRT-6045, Department of Automatic Control, Lund University, Sweden, October 2017.

Hedberg, Tobias; *Intellectual property rights in purchasing and sourcing - Overview of current best practices*; Master's Thesis TFRT-6044, Department of Automatic Control, Lund University, Sweden, October 2017.

Jaenson, David; Nguyen, Tuan; *Automatic Scaling of Web Services using an Adaptive Distributed System*; Master's Thesis TFRT-6037, Department of Automatic Control, Lund University, Sweden, August 2017.

Jankovic, Daniel; *Metrics for Integrated Modular Avionics Architecture*; Master's Thesis TFRT-6036, Department of Automatic Control, Lund University, Sweden, August 2017.

Kellerth Fredlund, Johan; Sadik Sulejmanovic, Kenan; *Autonomous driving using Model Predictive Control methods*; Master's Thesis TFRT-6029, Department of Automatic Control, Lund University, Sweden, April 2017.

Normann, Henrik; *Traceability of continuous processes*; Master's Thesis TFRT-6028, Department of Automatic Control, Lund University, Sweden, April 2017.

Olsson, Johannes; Sikström, Pontus; *Declarative Models for Self-Calibrating Robots*; Master's Thesis TFRT-6025, Department of Automatic Control, Lund University, Sweden, August 2017.

Ottosson, Erik; *Identification and Estimation of DC-Motor Dynamics for the Crazyflie Quadcopter;* Master's Thesis TFRT-6041, Department of Automatic Control, Lund University, Sweden, November 2017.

Palm, Oliver; *Development and implementation of autonomous features of a hexapod robot*; Master's Thesis TFRT-6033, Department of Automatic Control, Lund University, Sweden, August 2017.

Paulsson, Märta; *High-Level Control of UAV Swarms with RSSI Based Position Estimation;* Master's Thesis TFRT-6046, Department of Automatic Control, Lund University, Sweden, December 2017.

Rosdahl, Christian; *Distributed Control of Dynamic Flows in Traffic Networks*; Master's Thesis TFRT-6039, Department of Automatic Control, Lund University, Sweden, August 2017.

Strömbeck, Carl; *Modeling, Control and Optimal Trajectory Determination for an Autonomous Sailboat*; Master's Thesis TFRT-6038, Department of Automatic Control, Lund University, Sweden, August 2017.

Vikström Morin, Martin; *Optimal Control under Quantised Measurements - A Particle Filter and Reduced Horizon Approach*; Master's Thesis TFRT-6031, Department of Automatic Control, Lund University, Sweden, June 2017.

MISCELLANEOUS

Berner, Josefin; *Kontroll-Kalle styr fabriken (utökad version)*; Technical Report TFRT-7650, Department of Automatic Control, Lund Institute of Technology, Lund University 2017.

SEMINARS AT THE DEPARTMENT

February

02 *Excitable behaviors;* Rodolphe Sepulchre, Cambridge University.
03 *Sub-moments of linear Time-Delay-Systems: Model order reduction;* Luc N. Muhirwa, TU Kaiserslautern.
03 Defence of Doctoral Dissertation; *Rank Reduction with Convex Constraints;* Christian Grussler.
06 *Image completion using Deep Convolutional Generative Adversarial Networks and Tensorflow;* Mikael Lindberg, Axis Communications.

March

10 Licentiate seminar; *Modeling and Estimation Topics in Robotics;* Fredrik Bagge Carlson.
10 *Learning flexible models of nonlinear dynamical systems;* Thomas Schön, Uppsala University.

April

27 *Asymptotic optimality of finite models in stochastic control;* Professor Serdar Yüksel, Queen's University.

May

30 *Learning Regularizers from Data*; Yong Sheng Soh, Caltech.

June

01 *Unified view on accelerated randomized methods*; Alexander Gasnikov, Moscow Institute of Physics and Technology.
01 *Multi-Level Scenario-based Model Predictive Control for Optimal Maintenance Planning of Railway Networks*; Zhou Su, TU Delft.
02 *Active Measurement for Neuroscience*; Ross Boczar, UC Berkeley.
05 *Distributed Learning for Cooperative Inference*; Cesar A. Uribe, University of Illinois.
05 *Communication-Efficient Decentralized and Stochastic Optimization*; Soomin Lee, Georgia Tech.
07 Licentiate seminar; *Cavity Field Control for High-Intensity Linear Proton Accelerators*; Olof Troeng.
07 *Analysis and Implementation of an Asynchronous Optimization Algorithm for the Parameter Server*; Arda Aytekin, KTH Stockholm.
07 *Input-and-state observability of structured network systems*; Federica Garin, INRIA Rhône-Alpes.
08 Licentiate seminar; *On Motion Control and Machine Learning for Robotic Assembly*; Martin Karlsson.
08 *Learning for improved control performance*; Mikael Norrlöf, ABB.
08 *Performance Bounds for Remote Estimation under Energy Harvesting Constraints*; Ayca Ozcelikkale, Chalmers.
09 *Decentralized control and optimization*; Franco Blanchini, University of Udine.
09 *Distributed nonsmooth composite optimization via the proximal augmented Lagrangian*; Neil Dhingra, Univeristy of Minnesota.
13 *Analysis and Design of First-order Optimization Methods using the Performance Estimation Framework*; Adrien Taylor, UC Louvain.
13 *Density flows and optimal mass transport*; Tryphon Georgiou, UC Irvine.

14 *Accelerated Min-Sum for consensus*; Patrick Rebeschini, Yale University.
14 *Accelerated Douglas-Rachford splitting and ADMM for structured nonconvex optimization*; Panos Patrinos, KU Leuven.
14 *A Smooth Primal-Dual Optimization Framework for Nonsmooth Composite Convex Minimization*; Volkan Cevher, EPFL.
15 *Convex Optimization with Abstract Linear Operators*; Stephen Boyd, Stanford University.
15 *Sketchy Decisions: Convex Low-Rank Matrix Optimization with Optimal Storage*; Madeleine Udell, Cornell University.
15 *Primal and Dual Predicted Decrease Approximation Methods*; Amir Beck, Technion.
15 *A Globally Linearly Convergent Method for Large-Scale Pointwise Quadratically Supportable Convex-Concave Saddle Point Problems*; Russell Luke, University of Göttingen.
15 *Exciting unfashionable topics in process control*; Krister Forsman, Perstorp AB and NTNU.
15 Robust control for the analysis and design of large-scale optimization algorithms; Laurent Lessard, University of Wisconsin - Madison.
15 *Optimal and Long-Step Feasibility Algorithms*; Pontus Giselsson, Lund University.
15 *Low-Rank Inducing Norms with Optimality Interpretations*; Christian Grussler, Lund University.
16 *Optimal algorithms for smooth and strongly convex distributed optimization in networks*; Francis Bach, École normale supérieure.
16 *A Generic Quasi-Newton Algorithm for Faster Gradient-Based Optimization*; Julien Mairal, INRIA - Grenoble.
16 *Distributed Robustness Analysis*; Anders Hansson, Linköping University.
16 *Sparsity and asynchrony in distributed optimization: models and convergence results*; Mikael Johansson, Royal Institute of Technology, Stockholm.
16 *The proximal augmented Lagrangian method for nonsmooth composite optimization*; Mihailo Jovanovic, University of Southern California.
16 *Randomized Primal-Dual Algorithms for Distributed Empirical Risk Minimization*; Lin Xiao, Microsoft Research, Redmond.
16 *A Unified Analysis of Stochastic Optimization Methods Using Jump System Theory and Quadratic Constraints*; Anders Rantzer, Lund University.
20 *(Nonsmooth) Control Lyapunov Functions*; Philipp Braun, University of Bayreuth.
20 *The "Butterfly" robot: challenges for motion planning and control*; Anton Shiriaev, NTNU, Trondheim, Norway.
22 *Proximal-Proximal-Gradient Method*; Ernest Ryu, UCLA.
22 *Newton-type proximal algorithms for nonconvex optimization*; Andreas Themelis, KU Leuven.
27 *Computational Co-Designs for Controlling Very Large-Dimensional Power Systems*; Aranya Chakrabortty, North Carolina State University.
27 *Real-time optimization under uncertainty: Accelerated and distributed modifier-adaptation schemes*; René Schneider, EPFL Lausanne.
29 *Fast ADMM for Semidefinite Programs with Chordal Sparsity*; Yang Zheng, University of Oxford.
29 *A decentralized descent method for the numerical solution of the Nash equilibrum problem*; Anna von Heusinger, University of Würzburg.

August

18 *Robustness of distributed frequency control in future power systems: Time delays & dynamic communication topology*; Johannes Schiffer, University of Leeds.

21 *From Bode to Shannon: Fundamental Limitations and Limits of Feedback Revisited in an Information Age*; Professor Jie Chen, City University of Hong Kong, Hong Kong.

September

07 *Adaptivity, Internet or Other Things (AIoT)*; Gunnar Bengtsson, First Control Systems AB.

18 *Thermodynamics of information and control: the twin legacies of James Clerk Maxwell*; John Bechhoefer, Dept. of Physics, Simon Fraser University, Burnaby, British Columbia, Canada.

26 *Analysis tools of sliding mode systems*; Yury Orlov, CICESE, Ensenada, Mexico.

October

12 *Learning Disjunctions of Predicates*; Dana Drachsler Cohen.

17 *Nonsmooth H-infinity control*; Yury Orlov, CICESE, Ensenada, Mexico.

November

03 Defence of Doctoral Dissertation; *Automatic Controller Tuning using Relay-based Model Identification*; Josefin Berner.

08 *Research Challenges of the Future Electric Power System*; Göran Andersson, ETH Zürich, Switzerland.

27 *Hypertracking for signals beyond the Nyquist frequency*; Yutaka Yamamoto, Kyoto University.

December

15 Defence of Doctoral Dissertation; *LQG-Based Real-Time Scheduling and Control Codesign*; Yang Xu.

External Contacts

External contacts during 2017, both academic and industrial

EXTERNAL CONTACTS

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. There is naturally a strong symbiosis with teaching in this activity. A good mechanism is thus to introduce new research material into existing and new courses. A related form of technology transfer is to write books and monographs and to develop software. Exchange of personnel between industry and university is another very effective vehicle for technology transfer.

ACADEMIC CONTACTS

We have very good and fruitful relations and cooperations with a number of universities and academic institutions throughout the world. This year we have had important contacts with;

Aston University, School of Engineering and Applied Science, Birmingham, UK
Beihang University, BUA, Beijing, China
California Institute of Technology, USA
Carnegie Mellon University, School of Computer Science, USA
Carnegie Mellon University, Silicon Valley Campus, USA
CentraleSupélec-CNRS-U. Paris-Sud, U. Paris-Saclay, Laboratory of Signals and Systems, France.
City University of London, Dept of Computer Science, England
College of William and Mary, Computer Science Dept, England
Czech Technical University, Faculty of Information Technology, Czech Republic
DFKI, SmartFactory, Kaiserslautern, Germany
DTU, Denmark
ETH Zurich, Automatic Control Laboratory, Switzerland
European Innovation Academy, EU
Freie Universität Berlin, Dept of Computer Science, Germany
Grenoble Institute of Technology, France
Hanyang University, Seoul, Korea
Hasso Plattner Institute for Software Systems Engineering, Software Competence Center Hagenberg, Germany
Hasso-Plattner-Institut für Digital Engineering, Potsdam, Germany
Humboldt-Universität zu Berlin, Germany
Imperial College, London, Dept of Computing, England
INSA Lyon, Department of Computer Science, France
Jyväskylä University, Finland.
Karlsruhe Institute of Technology, Germany
Katholieke Universiteit Leuven, Dept of Computer Science, Belgium
Linköping University, ISY and IDA, Sweden
Linneaus University, Dept of Computer Science, Sweden
Lund University, Dept Clinical Sciences Lund, Biomedical Engineering, Lund, Sweden

Lund University, Centre for Mathematical Sciences, Sweden
Lund University, Dept of Chemical Engineering, Sweden
Lund University, Dept of Computer Science, Sweden
Lund University, Dept of Mathematics, LTH, Sweden
Lund University, Dept of Electrical and Information Technology, Lund, Sweden
Lund University, Div. Combustion Engines, Dept of Heat and Power Engineering, Lund, Sweden
Lund Unversity, Machine Design, LTH, Sweden
Lund University and Skåne University Hopital, Dept. Cardiothoracic Surgery, Lund, Sweden
Mälardalen University, MDH, Sweden
Max Planck Institute for Software Systems, Germany
Mines-Telecom Institute, Paris-Saclay University, Paris, France
Norwegian University of Science and Technology (NTNU), Dept of Chemical Engineering, Trondheim, Norway
Norwegian University of Science and Technology, Dept of Engineering Cybernetics, Norway
ParisTech, France
Politecnico di Torino, Italy.
Politecnico di Milano, Italy
Scuola Superiore Sant'Anna, Dipartimento di Informatica, Italy
Skåne University Hospital, Medical Services, Lund, Sweden
Technische Universität München, Institut für Informatik, Germany
Tsinghua University, Dept Precision Instruments and Mechanology, Beijing, China
TU Delft, Dept of Computer Science
TU Kaiserslautern, Germany
Umeå University, Dept of Computing Science, Sweden
UNED, Spain
Universidad de Almeria, Spain
Universidad de Buenos Aires, Departamento de Computación, Ciencias Exactas y Naturales, Chile
Universität Duisburg-Essen, Dept of Informatics, Germany
Universität Stuttgart, Dept of Computer Science, Germany
University of Brescia, Italy
University of Brighton, England
University of British Columbia (UBC), Electrical and Computer Engineering in Medicine (ECEM), Vancouver, Canada
University of California, Berkeley, Sutardja Center for Entrepreneurship and Technology, USA.
University of California at Riverside, Dept of Mechanical Engineering, USA.
University of Chicago, Dept of Computer Science, USA
University of Cyprus, KIOS Research and Innovation Center of Excellence, Cyprus.
University of Ghent, Belgium
University of Illinois at Urbana-Champaign, Dept of Computer Science, USA
University of Oxford, Dept of Computer Science, UK
University of Porto, Portugal
University of Udine, Dipartimento di Scienze Matematiche, Informatiche e Fisiche, Italy.
University of Udine, Dipartimento Politecnico di Ingegneria e Architettura, Italy.
University of Trieste, Dipartimento di Ingegneria e Architettura, Italy.
University of Torino, Dept of Computer Science, Italy
University of Twente, Netherlands
University of Würzburg, Dept of Computer Science, Germany
Watson Research Center, Hawthorne, NY, USA

INDUSTRIAL CONTACTS

We have very good working relations with many companies and organizations. The interactions are at different levels and of different intensities, from visits and discussions to joint projects. Master's theses and education are also important ingredients. During the year we have had major projects with;

AAK, Sweden
ABB Corporate Research, Västerås, Sweden
ABB Robotics, Sweden
Arla, Sweden
Axis Communications AB, Lund, Sweden
B&R Automation, Sweden
Business Region Skåne, Sweden
Cognibotics, Sweden
Corebon, Sweden
Ericsson, Lund, Sweden
European Spallation Source (ESS), Lund Sweden
EU Commission
FPA, Trollhättan, Sweden
Fraunhofer IPA, Stuttgart, Germany
Google, USA
Hild, Denmark
IBM Research
Igelösa Life Science AB, Igelösa, Sweden
Institut Pasteur, Paris, France
KCFP (Competence Center Cumbustion Processes)
MAXIV, Lund, Sweden
Mitsubishi Electric Research Laboratories, Massachusetts
Modelon AB, Sweden
Novozymes AS, Denmark
Perstorp AB, Sweden
Prevas, Sweden
Rockwell Automation, Sweden
RedHat, Manchester, UK
SAAB Bofors Dynamics, Linköping, Sweden
SAAB AB, Linköping, Sweden
Scania, Södertälje, Sweden
Schneider-Electric, Sweden
Siemens, Sweden
Skåne University Hospital, Pediatric Heart Surgery, Sweden
Södra, Sweden
Swedish Energy Agency
Tetrapak, Sweden
TWI Ltd, UK
Volco Cars, Gothenburg, Sweden
ÅF Consulting, Sweden

Economy

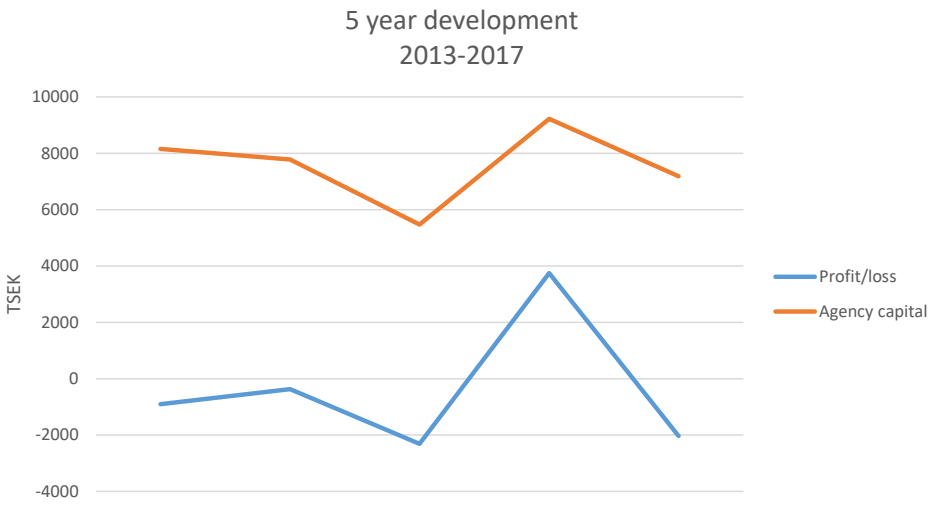
This chapter contains an overall view of the economy and funding

ECONOMY

The turnover for 2017 was 51 MSEK, a decrease by 5 MSEK since 2016. About half of the income, 52%, comes from Lund University, and the rest, 48%, from external grants.

The activities and the number of employees seems to have stabilized during the last years, the number of employees has slightly decreased and is now around 40 people. The department participated in one project funded by the European Union, in Horizon 2020, during 2017. 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 2017 we had the following grants:

VR – Linnaeus grant Lund Center for Control of Complex Engineering Systems LCCC
VR – Information Dynamics over large-scale networks
VR – Feedback Based Resource Management for Embedded Multicore Platforms
VR – Simultaneous Movement Tracking and Radio Channel Estimation
VR – Active Control of Compressor Systems Based on New Methods of Nonlinear Dynamic Feedback Stabilization
VR – Scalable and Resource-Constrained Control Systems
VR – Power and temperature control for large-scale computing infrastructures
VR – Methods for control of large-scale dynamical systems
VR – Feedback Computing in Cyber-Physical Systems
VR – Resilient control of dynamical network flows
VR - Reglering av montona system och diffusioner
VR - Large scale Convex Optimization
Vinnova – Line Information System Architecture 2, LISA2
Vinnova – Hemodynamic Stabilization
Vinnova – Den digitaliserade process industrin
Vinnova – Aktiv kvotreglering
Vinnova – Mot en trådlös intensivvård
Vinnova - Surgeon's perspective
Vinnova - Bloqqi - ett öppet modulärt automationsspråk
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
SSF – ICT platform for sustainable infrastructure, ICT-PSI
SSF /ICA – Algorithms for solving large-scale convex optimization problems
SSF – Dynamic exchange economics in Transport Systems
SSF - Semantic mapping and visual navigation for smart robots
EU – Horizon 2020, GA 644938, Smart Assembly Robot with Advanced FUNctionalities – SARAFun
KAW – Wallenberg AI, Autonomous Systems and Software Program – WASP
ESS – Temperature Control of Phase Reference Line
eLLIIT - The Linköping–Lund Initiative on IT and Mobile Communication
SKB - Control of Stirwelding Process for Sealing
Emissions Control for Low Climate Impact, KCFP3

Staff

During 2017 the staff situation at Automatic Control remains solid. Five new PhD students have been employed. We have also had the pleasure of hosting international guests.

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

Picture taken at the kick-off in August 2017

STAFF

PERSONNEL AND VISITORS

Professors

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

Associate Professors

Cervin, Anton, director of graduate studies
Como, Giacomo
Giselsson, Pontus
Johnsson, Charlotta
Maggio, Martina

Assistant Professor

Soltesz, Kristian (from June)

Research Engineers

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

Administrators

Edelborg, Cecilia (from April)
Nilsson, Ingrid (until February)
Nishimura, Mika
Rasmusson, Monika (70%)
Westin, Eva

Postdocs

Chong, Michelle (until December)
Giordano, Giulia (until August)
Pates, Richard (until September)
Soltesz, Kristian (until May)
Yamamoto, Kaoru

Researchers

Olofsson, Björn
Pates, Richard (from October)

PhD Students

Ariu, Kaito (from October)
Bagge Carlson, Fredrik
Bergstedt, Jacob
Berner, Josefin (until December)
Dellkrantz, Manfred (until July)
Fält, Mattias
Ghazaei, Mahdi (until June)
Greiff, Marcus (from February)
Grussler, Christian (until December)
Heyden, Martin
Karlsson, Martin
Lidström, Carolina
Mejvik, Jacob (until December)
Millnert, Victor
Morin, Martin (from August)
Nayak Seetanadi, Gautham
Nilsson, Gustav
Nylander, Tommi
Rosdahl, Christian (from September)
Ruuskanen, Johan (from September)
Sadeghi, Hamed
Thelander Andrén, Marcus
Troeng, Olof
Turesson (Ingesson), Gabriel
Xu, Yang (until December)

Industrial PhD Students

Martins, Alexandre, Axis
Petersson, Anders, SAAB
Skarin, Per, Ericsson

Shorter and longer stays

Hagdrup, Morten; visiting PhD student, Technical University of Denmark (September – November)

Kouhkouh, Hicham;visiting PhD student, ENSTA ParisTech, France (March – July)

Maggistro, Rosario; visiting PhD student, Politecnico di Torino, Italy (May – July)

Mandrioli, Claudio; visiting MSc student, Politecnico di Milano, Italy (March – June)

Orlov, Yury; guest professor, CICESE, Mexico (from September)

Varisco, Martina; visiting PhD student, University of Rome Tor Vergata, Italy (January – March)

Zhu, Li; visiting postdoc, Dalian University of Technology, China

Zorzan, Irene; visiting PhD student, University of Padova, Italy (until June)

STAFF ACTIVITIES

STAFF

Ariu, Kaito

Kaito is a Ph.D. student at the Department of Automatic Control since 2017. ME and BE in Aeronautics and Astronautics.

During 2017 he has been a teaching ssistant in the course: Nonlinear Control and Servo Systems.

He has been also attending several pure/ applied mathematics lectures.

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 also worked a lot with the publication database LUCRIS.

Andersson, Pontus

MSc, Research Engineer at the department since 2012.

Tasks include maintenance and development of student laboratory equipment, mechanic and electronic design and implementation. Involved in various projects in the Robotics Lab. Managed building of new lunch room terrace. Chairing weekly robot lab meeting.

Bergstedt, Jacob

Jacob Bergstedt has been a 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. This is a highly

multidisciplinary project, involving researchers in immunology, genetics, and bioinformatics, in which Jacob is developing a lot of the statistical methods. The methods employed range from new developments in causal inference, to regularized estimators from convex optimization.

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). During the year he has primarily been involved with WASP 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.

Co-supervised Josefin Berner on PID control and automatic tuning.

From March 10 to April 1 he visited Singapore National University, Nanyang Technological University and the Cambridge Centre for Advanced Research and Education in Singapore (CARES). In July he participated in the symposium on Perspective on System Identification and Control in Como. He also visted China from July 22to July 28 to lecture at the Department of Mathematics, Chinese Academy of Sciences Beijing and he delivered a plenary lecture at the Chinese Control

Conference in Dahlian. In November he visited Stocholm to participate in a symposium dedicated to Anders Lindquist.

Bagge Carlson, Fredrik
M.Sc., Ph.D. Student. He has been with the department since 2013.

My research interests include machine learning and system identification within robotics. I'm active within the project SARAFun.

Other teaching responsibilities include the courses System identification, predictive control and deep learning.

Berner, Josefin
Ph.D., Tech. Lic., MSc in Engineering Physics. PhD student since August 2012. Defended her PhD thesis *Automatic Controller Tuning using Relay-based Model Identification* in November 2017. She also wrote a new chapter to the story about her fictive control engineer *Kontroll-Kalle*.

During the year she attended a number of conferences presenting her work, and finalized the writing of her thesis.

She supervised a Master Thesis project in collaboration with Modelon during the spring.

She was a member of the research education council at LTH from January to June.

She was responsible for the department's lab session on Flickor på Teknis in March.

Bernhardsson, Bo
PhD 1992, Professor since 1999, has also worked at Ericsson for 9 year.

During 2017 he was vice head of the department and a member of the LCCC board. He is also one of the organizers of the WASP research school.

During 2017 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 linear systems, applications of control theory and the connection between communication theory and control theory.

During 2017 he taught one of the basic courses in Automatic Control.

He is the supervisor or cosupervisor of 11 PhD students.Control Department.

Blomdell, Anders
Research Engineer at the department since 1988. Heavily involved in almost all aspects of Robotics research at the department, also re-

sponsible 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
PhD (2003), Associate Professor (2007), Docent (2008), Director of PhD Studies.

Anton's research interests include real-time systems, event-based and networked control, and computer tools for analysis and simulation of controller timing.

He is currently supervising two PhD students.

During 2017 he was lecturer in the advanced-level courses Project in Automatic Control and Multivariable Control, and he was supervisor or examiner for three Master's theses.

Chong, Michelle
PhD (2013). She joined the department as a postdoctoral researcher in August 2015. Her research interest includes state and parameter estimation for nonlinear systems with applications in security for cyber-physical systems and neuroscience. Late 2017 she ended her postdoctoral at the department. As from January she has a new position as postdoctoral researcher at KTH, Stockholm.

Como, Giacomo
PhD (2008), Docent (2012). He has been with the faculty at the Department of Automatic Control since 2011 and was promoted Associate Professor (universitetslektor) in 2013.

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 currently a board member of LCCC and of the Department of Automatic Control. He has served as main supervisor of Kaito Ariu and Gustav Nilsson and as co-supervisor of Hamed Sadeghi and Martin Heyden.

In Spring 2017, he taught the master level course Network Dynamics at Lund University.

Edelborg, Cecilia
Financial Administrator at the department since 2017. The responsibilities are primarily economics, conferences, committees and other administrative tasks.

She is also a member of the Equality group at the Department of Automatic Control and work with these questions.

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

Eker, Johan
Johan Eker has been adjunct Professor (20%) at the department since 2014 and is working in the intersection of cloud computing, real-time systems and control systems. Research topics include automation applications that run on top of the cloud, as well as design and implementation of predictable and low latency cloud services.

He is the main supervisor for Victor Millnert and an industrial supervisor for Per Skarin, and also supervised the master's thesis project "Resource management for cloud applications" by David Jaenson and Tuan Nguyen.

He has been teaching graduate courses on cloud technologies and cloud resource management.

He is also a Principal Research at Ericsson Research and the driver for the Ericsson Research Data Center in Lund, working on large scale system with a focus on automation. He holds 56 granted patents.

Fält, Mattias
Mattias is a PhD student at the Department of Automatic Control since 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.

He was a teaching assistant in the the control theory and multivariable control courses as well as the basic control course at Beihang University, Beijing. He has also been involved in the development of new lab infrastructure at the department.

Ghazaei Ardakani, M Mahdi
Since the beginning of 2012, he is with the Automatic Control Department as a PhD student. His research interests include robotics, systems and control theory, machine learning, and dynamic simulation.

He defended his thesis in December 2016, named *On Trajectory Generation for Robots*.

Giordano, Giulia
Giulia was at the Department as a Postdoctoral Researcher from June 2016 to August 2017, and she is now an Assistant Professor at the Delft Center for Systems and Control, TU Delft.

She received her B.Sc. (2010) and M.Sc. (2012) degrees in Electrical Engineering and her Ph.D. (2016) from the University of Udine.

Her research interests are mainly focused on the analysis and the control of dynamical networks. In particular, she is interested in the structural analysis of dynamical systems endowed with a network topology, aimed at assessing parameter-free properties that exclusively depend on the interconnection structure, and in the design of network-decentralised strategies that govern the global system behaviour in spite of local action and local information constraints.

In the spring 2017 she taught the master level course "Network Dynamics" at Lund University, together with Giacomo Como.

In July 2017 she received the EECI PhD Award 2016 for her PhD thesis *Structural Analysis and Control of Dynamical Networks* and the NAHS Best Paper Award 2017 for her journal paper *A switched system approach to dynamic race modelling*, published on Nonlinear Analysis: Hybrid Systems in 2016.

Giselsson, Pontus
Pontus is currently Associate Professor at the Department of Automatic control. He received his MSc from Lund University in 2006 and his PhD from the Department of Automatic Control in at Lund University 2012.

His research interests are in convex optimization and its wide range of applications.

During 2017, Pontus was responsible for the undergraduate level courses in Systems Engineering and Process Control.

He is co-supervising four PhD students.

Greiff, Marcus
My name is Marcus Greiff and I have a PhD student at the Department of Automatic Control since early March 2017. I am supervised is Anders Robertsson, and co-supervised by Bo Bernhardsson. However, I am also working closely with Karl Bentorp, Björn Olofsson and the company Bitcraze AB.

My research interests are wide and many, but mainly concern control and estimation of nonlinear systems utilizing special mathematical structures (Lie algebra, linear substructures, etc). Specifically, I'm working on Bayesian state estimation and Lyapunov-based control in cascaded systems, geared towards quad-rotor control. With that said, I also have a great interest in motion planning by convex optimization.

I have been teaching systems engineering and process control (FRT110) as well as predictive control (FRTN15). In addition, I have mentored four master-level student projects. Two in the real-time systems course (FRTN01) and two larger projects in the project course in automatic control (FRTN40).

In addition, I was responsible for both lectures and demonstrations during the robotics week. I have also been involved in the development of lab equipment during the fall of 2017.

Grussler, Christian
Since 2012, he is a PhD-student at Lund University. His research interests are Model reduction, Cone invariant systems, Low-rank approximations and Optimization.

In February 2017 he defended his thesis named *Rank Reduction with Convex Contraints*.

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, adaptive control, control loop monitoring and diagnosis.

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

Tore Hägglund has also been head of the department and deputy centre director of "Centre for Research and Competence Development for the Process Industry", PIC-LU.

Heyden, Martin

MSc in Engineering Physics (2016) and 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 2016, he has been a TA in "Real-Time Systems" (FRTN01) and "Physiological Models And Computations" (FRTF01). Coursework completed includes "Introduction to Teaching and Learning in Higher Education".

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 is participates and leads the research projects ESS cooperation, 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 courses FRT041 System Identification, FRTN15 Predictive Control, and FRTF01 Physiological Models and Computation.

Johnsson, Charlotta

Professor, PhD (1999). Charlotta has been at the department since 1993 except for 4 years (2000-2004) when she worked in industry.

Charlotta is involved in research, education and innovation-outreach activities as well as in various external activities. 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 related to 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

He has worked as a Ph.D. student since April 2014.

His research interests are within state estimation, and robot learning and control. In 2017, he has been working within the EU project SARAFun, with focus on robot learning for assembly tasks.

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

Lidström, Carolina

Lic. Tech., MSc in Engineering Physics. PhD student since June 2013.

Her research interests include scalable and distributed control, with applications to buffer networks, water irrigation systems and temperature control.

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 of 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.

Maggio, Martina

Martina is an Associate Professor, and has been 6 years at the department.

Her research interests are Real-Time Systems, Application of Control Theory to Software Engineering and Computing Systems Problems.

She has been project leader for: *Power and temperature control for large-scale computing infrastructures*. She has also been an investigator in the project *Feedback Computing in Cyber-Physical Systems* and in the WASP Cluster *Autonomous Clouds and Networks*.

During 2017 she has had course co-responsibility for Real-Time Systems (FRTN01) and System Identification (FRT041/FRT145F) and was co-responsible for the invited course *Feedback Control of Computing Systems* given by Alberto Leva.

She is co-supervisor for 4 PhD students and was supervising the thesis *RT-Bench, Improved Understanding of Application Performance with Memory Storage* by Demeter, Zsolt. She has also been examiner for 2 Master's thesis i e *Development and implementation of autonomous features of a hexapod robot* by Olover Palm and *Balancing and Locomotion of a Hexapod Robot Traversing Uneven Terrain* by Jonatan Ekelund.

Millnert, Victor

PhD student at the department since September 2014 with research focus on autonomous cloud and networks, with emphasis on how to control virtualized network functions in a forwarding graph. This work involves a collaboration with Enrico Bini at the University of Turin. During the year of 2017 the research amounted in 3 publications.

Teaching duties included Applied Robotics, Real-Time Systems, and the Automatic Control Basic Course.

Morin, Martin

MSc in Engineering Physics. PhD student since August 2017.

Research interests are in large scale optimization, currently focusing on stochastic and asynchronous first order methods.

Teaching assistant: Basic course and Multivariable Control.

Nayak Seetanadi, Gautham

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

His current research interests are on feedback control for cyber-physical systems. His current project focuses on intelligent bandwidth allocation to a network of self adaptive cameras. He is also working on model checking and formal verification of complex systems.

His teaching responsibilities at the department involve supervision of exercise and lab sessions in the basic control course and system engineering course. He is also involved in the short project in the process control course.

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

M.Sc. in Engineering Physics (2013). Gustav Nilsson is a Ph.D. student at the department since 2013.

His research interests are in the field of control of networks with applications in traffic control, mainly traffic light control.

During the year he has been a teaching assistant in the basic course and co-supervised two Master's thesis.

Since mid-October, Gustav has been doing an internship at Mitsubishi Electric Research Laboratories (MERL) in Cambridge, MA.

Nilsson, Ingrid
Financial officer at the department since 2009. Ingrid is mainly responsible for the financial transactions at the department such as bookkeeping, budget managing and balancing of the books. Another big task is administration of research projects and reporting to the sponsors.

She retired end February 2017.

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

She handles student registration and 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 in Engineering Physics. 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 project course.

Olofsson, Björn
Ph.D. in Automatic Control, employed at the department since August 2010.

During the year, he has been involved in a research project within the ELLIIT Excellence Center 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 organized a Ph.D. course on Motion Planning and Control during the fall semester and was also acting as supervisor of Master's Thesis projects.

Pates, Richard
Richard has been a postdoctoral researcher at the department since 2015, having completed the Ph.D degree at the University of Cambridge.

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.

Rantzer, Anders
Professor of Automatic Control since 1999 and coordinator of the Linnaeus center LCCC since the start 2008. He has broad interests in modeling, analysis and synthesis of control systems, with particular attention to uncertainty, optimization, scalability and adaptation.

Anders Rantzer is the main supervisor for several PhD students and postdocs. In 2017, he was teaching "FRTN45 Mathematical Modelling, Advanced Course" and "FRTN05 Nonlinear Control and Servo Systems" at the masters level and "FRT025F Nonlinear Control Theory" at the PhD level. He gave lectures at the IFAC World Congress in Touluose and the Conference On Learning Theory (COLT) in Amsterdam.

Rasmusson, Monika
She joined the department as financial administrator in August 2011. As from March, she succeeded Ingrid Nilsson as financial officer and took over the responsabilities for budget, forecast, year-end closing and reporting, both internallly within the faculty and externally to sponsors.

As a part of the administrative team, her work includes backup function for her colleagues, editing the Activity Report as from 2012, among other administrative tasks.

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) and Smart Systems (SSF).

He has also been doing research on admission control in network nodes and control of server systems in cooperation with the Department of Electrical and Information Technology, LTH, Lund University and within the VR-funded CloudControl-project together with Umeå University.

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 Master's Thesis projects.

Rosdahl, Christian

MSc in Engineering Physics (2017) and PhD student at the department since September 2017.

He will work on a project about efficient learning of dynamical systems, where methods from machine learning and statistics are combined with control theory. The project is within the Wallenberg Autonomous Systems and Software Program (WASP) and Bo Bernhardsson is supervisor.

During the autumn, Christian has been a teaching assistant in the basic course and co-supervised a master's thesis project. He has also taken courses himself.

Ruuskanen, Johan

M.Sc. in Engineering Mathematics, PhD student since September 2017.

Johan is part of the WASP research program and is supervised by Anton Cervin.

The main research topics of Johan include autonomous cloud control and event-based estimation.

During the fall Johan has been a teaching assistant in the basic course and a lab assistant in the System Identification course.

He has also read a couple of courses during this time.

Sadeghi, Hamed

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

His research interests are in distributed control and optimization, as well as application of control theory to traffic and transportation systems. His research is a part of the WASP project.

He was involved in teaching Systems Engineering course and Basic course during the spring and Multivariable control during the fall.

Soltesz, Kristian

Kristian 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 two interdisciplinary projects aimed at achieving hemodynamic stabilization in organ donors, and in patients undergoing cardiopulmonary resuscitation.

During 2017 Kristian has also been involved as doctoral co-supervisor in research on automatic tuning of PID controllers, and event-based control, respectively. He has been course responsible for the project course and for the department's basic course, held at Beihang University in Beijing, China.

He has also coordinated a PhD course in lab development, and supervised bachelor and master projects.

Thelander Andrén, Marcus
MSc in Engineering Physics (2015) and a PhD student at the department since August 2015.

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

During 2017 he has done research on event-based sampling for LQG-optimal control, and has given seminars on this work at Technion, Israel, and at CDC 2017 in Melbourne, Australia.

In the fall of 2017 he was a teaching assistant in the basic control course given at Beihang University, China.

He has also been supervising projects in the mathematical modeling advanced course.

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

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

In June, he presented his licentiate thesis on this topic.

During the fall he was a teaching assistant in the course on Multivariable Control, and supervised two student groups in the projects course.

Turesson (Ingesson), 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.

During 2017, Gabriel contributed to the American control conference (ACC) in Seattle, US for which he received a scholarship from Kungliga Fysiografiska Sällskapet i Lund. The presented work covered optimal pressure control with with fuels of higher octane number.

Articles were also published in International Journal of Powertrains and Journal of Dynamic Systems, Measurement, and Control.

Gabriel has during the year taught the course on predictive control (FRTN15).

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 has 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 Engineeringas well as of the Togetherness group in the M-building.

Xu, Yang
MSc in Automatic Control. PhD student since June 2012.

Yang's main research interests involve integrated scheduling and synthesis of networked embedded event-based control systems. He is involved in the ELLIIT project.

He defended his thesis called *LQG-Based Real-Time Scheduling and Control Codesign* in December 2017.

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.

Since October 2017, she has been supervising the master's thesis of Emil Vladu.

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 7 seminars on the above topics.

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. Besides the seminar series, we have organized a lunch for master's thesis students and their supervisors, with the purpose of creating a platform for companies and students interested in control to meet, as well as for us to introduce the work we do at the department. In 2017 we welcomed Cecilia Edelborg to the group, to replace the outgoing member Eva Westin. Together with Carolina Lidström, Victor Millnert and Martina Maggio, she will help to continue to make the JäLM-group a success in 2018.

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

Below shows the delegates in the JäLM group Automatic Control.

AWARDS

GRANTS

Travel grant

Gustav Nilsson received a 1 000 USD travel grant from Institute for Pure and Applied Mathematics (IPAM), UCLA, CA, for participating in a workshop.

The Nakajima Foundation Scholarship

Kaito Ariu has received a five year study funding to support his PhD studies.

Iizuka Takeshi Scholarship Foundation

Kaito Ariu has received a one year research funding to support his research.

Associate member of Masayoshi Son Foundation

Kaito Ariu has been designated as an associate member as one of the 96 selected students from all over Japan under age 26**.**

EECI PhD Award

Giulia Giordano received the EECI PhD Award 2016, for the best PhD thesis in Europe in the field of Control for Complex and Heterogeneous Systems. The prize was awarded by the European Embedded Control Institute and presented at the IFAC World Congress, Toulouse, France, in July 2017.

Journal Best Paper Award

Giulia Giordano received the NAHS Best Paper Award 2017, for the best paper published on the journal Nonlinear Analysis: Hybrid Systems in the triennium 2014-2016. The prize was awarded for the paper *A switched system approach to dynamic race modelling* and presented at the IFAC World Congress, Toulouse, France, in July 2017.

Best Artifact Award

Martina Maggio received the Best Artifact Award at SEAMS17 for the artifact *Self-Adaptive Video Encoder: Comparison of Multiple Adaptation Strategies Made Simple*.

Travel grant

Olof Troeng received a travel grant from Ericsson Research Foundation for attending ACC in Seattle and present his conference contribution, *Complex-Coefficient Systems in Control*.

Best Paper Award

Johan Eker, Victor Millnert and Enrico Bini received a Best Paper Award for *Dynamic control of NFV forwarding graphs with end-to-end deadline constraints*, published in IEEE International Conference on Communications (ICC) - the largest conference in the communication society.

ASSIGNMENTS

BOARD MEMBER

Årzén, Karl-Erik

Member of the Board for the ELLIIT strategic research area project.
Member 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.

Eker, Johan

Expert evaluator for computer science education at Swedish Higher Education Authority (UKÄ).
Member of the leadership team of the Cloud Systems and Platform Research group at Ericsson.
Advisory board member for Internet of Things and People Research Center at Malmo University.

Johnsson, Charlotta

Board Member at PTW at Högskolan Väst, Trollhättan, Sweden.
Board member at SESAM-Sverige, a network for industrial automation.

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)

Årzén, Karl-Erik

Member of the Program Committee for the 2017 IEEE International Conference on Cloud and Autonomic Computing (ICCAC), Tucso, AZ, USA.
Member of the Program Committee for the 29th EUROMICRO Conference on Real-Time Systems (ECRTS'17), Dubrovnik, Croatia, June 27-30, 2017.
Finance Chair for the Real-Time Systems Symposium (RTSS), Paris, France, Dec 5 - 8, 2017.

Eker, Johan

Program committee member for DCC ACM SIGMETRICS Workshop Distributed Cloud Computing 2017.
Program committee member for ECRTS 2017.
Program committee member for Swedish Multicore Conference 2017**.**

Hägglund, Tore

Member of Committee for the 22nd IEEE International Conference on Emerging Technologies and Factory Automation, ETFA'2017, Limassol, Cyprus.

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, 2017 IEEE Int. Conf. Cybernetics and Intelligent Systems (CIS) and Robotics, Automation and Mechatronics (RAM), 19-21 Nov 2017, Ningbo, China.

Maggio, Martina

IPC member for the Embedded Systems Design for Real-Time Applications Track of the 23nd IEEE Real-Time Embedded Technology and Applications Symposium (RTAS 2017).

IPC member for the RTSS@work 2017.

IPC member for the 12th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS 2017).

IPC member for the 3rd International Workshop on Software Engineering for Smart Cyber-Physical Systems (SEsCPS 2017).

IPC member for the 8th International Workshop on Analysis Tools and Methodologies for Embedded and Real-time Systems (WATERS 2017).

IPC member for the Workshop on Mixed-Criticality (WMC 2017).

Rantzer, Anders

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

Member of the IPC for 2nd IEEE Conference on Control Technology and Applications (CCTA 2018), Copenhagen, 2018.

OPPONENT AND MEMBER OF EXAMINATION COMMITTEE

Bernhardsson, Bo

Deputy member of the examination committee for Rakesh Gangarajaiah PhD thesis *Adaptive Baseband Processing and Configurable Hardware for Wireless Communication* at EIT.

Examiner for Isabella Reinhold's licentiate thesis *High resolution time-frequency representations* in Mathematical Statistics, both at Lund University**.**

Cervin, Anton

External reviewer of licentiate thesis by Diana Yamalova, Dept. of Information Technology, Uppsala University, March 3.

Como, Giacomo

He served as a PhD committee member at the University of Groningen, the Netherlands, October, 2017.

Eker, Johan

Member of PhD thesis examination committee at Lund University for Hemanth Srinivas Prabhu.

Member of PhD thesis examination committee at Halmstad University for Essayas Gebrewahid.

Member of PhD thesis examination committee (extra) at Lund University for Nicolae Paladi.

External PhD thesis evaluator (opponent) at University of Porto for Hazam Ali.

Giselsson, Pontus

Member of examination committee of PhD thesis by Isak Nielsen, Linköping University, Sweden, May 2017.

External reviewer of PhD Thesis by Lorenzo Stella, , IMT Lucca, Italy, July 2017.

Hägglund, Tore

Member of the evaluation committee for the PhD thesis by Olle Trollberg, Royal Institute of Technology, Stockholm, Sweden, *On Real Time Optimization using Extremum Seeking Control and Economic Model Predictive Control*, September 15, 2017.

Johnsson, Charlotta

Committee Member of examination committee for Maj Stenmark, Computer Science, LTH, Lund University *Intuitive instruction of Industrial Robots: A knowledge based approach*, May, 2017.

Maggio, Martina

Opponent for Mojtaba Varmazyar, University of Luxembourg (first year examination).

Examiner of Sara Afshar, PhD defended in December 2017.

Examiner for Matthias Becker, PhD defended in December 2017.

Examiner for Inacio Sanudo Olmedo, PhD completed in December 2017, to be defended.

Examiner for Meng Liu, PhD defended in June 2017.

Rantzer, Anders

Member of Examination Committee for Sofie Haesaert, TU Eindhoven, PhD dissertation, February 16, 2017.

Faculty opponent for Per Rutquist, PhD dissertation, Chalmers, September 29, 2017.

Robertsson, Anders

Opponent for Robert Rogne, PhD thesis, NTNU, Trondheim, Norway in March 30, 2017.

Deputy member for Tom Evans PhD thesis, *Across landscapes and seascapes,* Dept of Biology, CANMove, Lund University, Sweden April 7, 2017.

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).

Chairman of IVA South - the Southern Sweden branch of the Royal Swedish Academy of Engineering Sciences.

Como, Giacomo

Invited member of the IEEE-CSS Technical Committee on Networks and Communication, within which he leads the Activity Group on Dynamics, Learning, and Behaviors in Social Systems.

Member in the International Program Committee of the 6th Conference on Complex Networks and their Applications.

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
Expert evaluator for KTH in matter of Promotion.
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.

OTHER ASSIGNMENTS

Årzén, Karl-Erik
Member of Research Board for the Faculty of Engineering, Lund University.
Treasurer and Member of the Executive Committee for the IEEE Computer System's Technical Committee on Real-Time Systems (TCRTS).
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.

Eker, Johan
Responsible for Cloud Architecture and Datacenter Resources, WASP Autonomous Research Arenas.
Moderated the panel discussion at the 11th Cloud Control Workshop, June 2017.

Como, Giacomo
During 2017, he has organised an invited open track at the 20th IFAC World Congress in Toulouse, France, and invited sessions at the 2nd Workshop on Control of Network Systems in Boston, MA, USA, and at the 56th Control Decision Conference in Melbourne, Australia.
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).
Editor, Intelligent Service Robotics (ISR), (Springer).

Johnsson, Charlotta
Serving as the IFAC Liaison with IEC 65A.
Nominated Chair for ISO TC184/SC5 (SC5: Interoperability, integration, and architectures for enterprise systems and automation applications).

Maggio, Martina
General chair of the 29th Euromicro Conference on Real-Time Systems (ECRTS), Dubrovnik, Croatia, 2017.
Co-Program chair of the ACM Student Competition, at the International Conference on Software Engineering (ICSE 2017).

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

LONGER VISITS ABROAD

Fält, Mattias
In the fall of 2017 he was a teaching assistant in the basic control course given at Beihang University, China.

Robertsson, Anders
During November 2017, he was teaching the basic control course given at Beihang University, China.

Soltesz, Kristian
Research visit at University of British Colombia, Electrical and Computer Engineering in Medicine; supervision of students, February 2017.

Thelander Andrén, Marcus
In the fall of 2017 he was a teaching assistant in the basic control course given at Beihang University, China.

LECTURES BY STAFF OUTSIDE THE DEPARTMENT

Årzén, Karl-Erik
Controlling the Cloud, NTU, Singapore, March 6, 2017.
Controlling the Cloud, Berkeley, CA, USA, March 24, 2017.

Åström, Karl Johan
Perspective on the field of control, CARES Singapore, March 22, 2017.
Event based control, CARES Singapore, March 22, 2017.
Modeling and Simulation - A Perspective. Invited lecture Volvo Cars, Göteborg, May 10, 2017.
Harry Nyquist - A Great Swedish Control Engineer. Invited lecture at Perspectives on System Identification and Control - Symposium in the honor of Sergio Bittanti, Como Italy, July 17-18, 2017.
Event Based Control, Academy of Mathematics and Systems Science, hinese Academy of Sciences, Beijing, July 24, 2017.
Automatic Control - A Perspective. Invited plenary lecture on Chinese Control Conference Dahlian, China, July 26, 2017.
Stochastic Control with Atomic Resolution. The Lindquist Symposium in Systems Theory; a workshop dedicated to his 75th birthday Anders Lindquist, Stockolm, November 25, 2017.

Como, Giacomo
Invited speaker at the SICE International Symposium on Control Systems 2017, in Okayama, Japan, March 2017.
During 2017, he also gave invited lectures and seminars at Osaka University, Japan, Tokyo Institute of Technology, Japan, Politecnico di Torino, Italy, and Boston University, MA, USA.

Giordano, Giulia
Invited Seminar, *Structural analysis of biological systems*, Department of Electrical Engineering, Linköping University, 20 April 2017.

Giselsson, Pontus
Invited talk at single track five-day workshop, *Splitting Algorithms, Modern Operator Theory, and Applications,* Oaxaca, Mexico, Sept. 18–22, 2017.
Invited talk at MPC scientific network meeting, *Regulation of Mobile Robots using MPC: Beyond Set Point Stabilization,* Gothenburg, Sept. 4–6, 2017.
Talk at the three-day workshop, *Distributed and Large-Scale Optimization,* LCCC workshop, Lund University, June 14–16, 2017.
Invited talk at the Automatic Control Laboratory, ETH, Zürich, Switzerland. Feb. 20, 2017.
Invited talk at the Institute for Systems Theory and Automatic Control, Stuttgart University, Germany. Feb. 7, 2017.

Hägglund, Tore
Control of Industrial Processes; Industrial course at Boliden - Skellefteå, March 16-17, 2017.

Johansson, Rolf

Robotars Rörelsestyrning och Läraktighet; KFS-Symposium Roboten-Människans Vän eller Fiende, Kungl. Fysiografiska Sällskapet, Lund, 28 Mars 2017 (Motion Control and Learning Skills of Robots, Royal Physiographic Society, Lund, Sweden, 28 March 2017).

Industrial Robots, Skills and Work-Space Sensing; CalTech, Dept Mechanical Engineering, Pasadena, CA, July 14, 2017.

Autonomous Interpretation of Demonstrations for Modification of Dynamical Movement Primitives; Int. Conf. Robotics and Automation (ICRA 2017). Singapore, May 31, 2017.

Johnsson, Charlotta

Smart Manufacturing: Definitions and Examples, presentation given at Embassy of Sweden, Dhaka, Bangladesh, March 2017.

Standarder för digitaliserig och smart industri, presentation given at industrimässorna, Malmö, March, 2017.

Berkeley Method of Entrepreneurship, Keynote speaker at SPACE-conference, Porto, Portugal, April, 2017.

Maggio, Martina

SEAMS 2017 (conference presentation), Buenos Aires, Argentina: *Self-Adaptive Video Encoder: Comparison of Multiple Adaptation Strategies Made Simple*.

FSE 2017 (conference presentation), Paderborn, Germany: *Automated Control of Multiple Software Goals using Multiple Actuators*.

Invited Talk, University of Modena and Reggio Emilia, Modena, Italy: *Predictable Cloud Computing: capacity shortages made affordable.*

Millnert, Victor

Dynamic control of NFV forwarding graphs with end-to-end deadline constraints; research presentations at IEEE ICC, UC Berkeley, Netflix, Google in September, and two Cloud Control Workshops in February and June.

Rantzer, Anders

H-infinity optimal control on networks, Invited lecture at BIRS worshop on Optimization and Inference for Physical Flows on Networks, Banff (Canada), March 7, 2017.

Adaptive Control — What can we learn?, WASP workshop at UC Berkeley, March 24, 2017.

Scalable System Analysis Using Integral Quadratic Constraints, Lecture at Mitsubishi Electric Research Laboratories (MERL), Boston, March 27, 2017.

H-infinity optimal control on networks, Lecture within LIDS Seminar Series, MIT, March 28, 2017.

Adaptive Control — What Can We Learn?, Workshop celebrating Malcolm Smith's 60th birthday, University of Cambridge, July 5, 2017.

Analysis of Stochastic Optimization via Jump Systems and Quadratic Constraints, Conference On Learning Theory (COLT 2017), Amsterdam, July 8, 2017.

Structure Preserving H-infinity Optimal PI Control, IFAC World Congress, Toulouse, July 10, 2017.

Can we make control theory scalable?, WASP Annual Meeting, Lidingö, September 6, 2017.

Towards a Scalable Theory of Control, ETH Control Seminar Series, Zürich, October 9, 2017.

Towards a Scalable Theory of Control, Invited workshop at the University of Sydney, Coogee Beach (Australia), December 9, 2017.

Robertsson, Anders

Overview of Robotics Research at Lund ; SSF-project workshop Båstad, Sweden, February 6-7, 2017.

Roboten – människans vän eller fiende artificiell intelligens och robotar i vardagen, Kungliga Fysiografiska sällskapets symposium, March 28, 2017.

Robotars rörelsestyrning och läraktighet; Kungliga Fysiografiska sällskapets symposium, March 28, 2017.

From caged animals to collaborative robotics; ELLIIT-workshop, föredrag hos P Doherty.

Estimation and Control for Robots in Free-Space Motion and during Contact Force Interaction, University of Science and Technology, Beijing, China, November 20, 2017.

Soltesz, Kristian

Hemodynamisk stabilisering. Invited talk at session organized by Medteck 4Health, January 31, 2017.

Hemodynamic Stabilization. Invited talk at Electrical and Control Engineering in Medicince (ECEM), University of Bristish Colombia, Vancouver, Cananda, January 10, 2017.

Thelander Andrén, Marcus

On Event-Based Sampling for LQG-Optimal Control, Control and System Theory Seminar at the Technion, Haifa, Israel, November 20, 2017.

Troeng, Olof

Towards a Better Understanding of Cavity Field Control; Low-Level RF Workshop in Barcelona, October, 16-19, 2017.

POPULAR SCIENCE PRESENTATIONS

Robertsson, Anders

March 13, 2017; 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.

March 13, 2017; Presentations and demo of Robotics Lab, around 30 visitors from Lund Soroptimister.

April 19, 2017; Teacher Education at Vattenhallen Science Center, Lund University ("Styr- och Reglerteknik")

April 20, 2017; Seminar for Rotary@Idon science Park, Lund *Produktiv robotik -´från djur i bur' till samverkande robotar.*

April 29, 2017; Guided tours in Robotlab, LTH/LU, Lund University 350-year anniversary, around 50 visitors.

May 15, 2017; Visit to Dept of Automatic Control and Robotlab, LTH/LU from Tunaskolan, Lund, 13 visitors.

June 1, 2017; Robot exhibition at Ideon Science park Innovation week at Ideon Science Park, Lund.

June 20, 2017; Guided tour in RobotLab Summer school, Trelleborg, 35 students+teacher (summer course for girls).

June 28, 2017; Guided tour in RobotLab, Summer school, Vattenhallen Science Center, Lund, 15 students +2 supervisors.

August 11, 2017 am; Visit Dept of automatic Control + RobotLab, summer course from Vattenhallen Science Center, Lund, 16 students+2 supervisors.

August 11, 2017 pm; Visit Dept of automatic Control + RobotLab, summer course from Vattenhallen Science Center, Lund, 16 students+2 supervisors.

September 16, 2017; Kulturnatten, Dept of Automatic Control and guided tours to RobotLab, about 140 visitors.

November 27-29, 2017; EU-robotics week, the RobotLab had in total about 400 visitors.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