Activity Report: Automatic Control 2015

Rasmusson, Monika; Maggio, Martina

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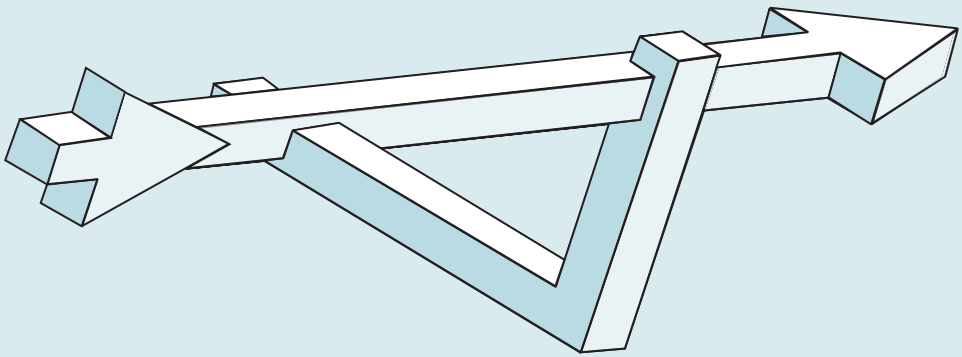
Activity Report 2015

50 YEAR ANNIVERSARY | AUTOMATIC CONTROL | LUND UNIVERSITY



Activity Report 2015

50 YEAR ANNIVERSARY | AUTOMATIC CONTROL | LUND UNIVERSITY

LUND
UNIVERSITY

Department of Automatic Control

MAILING ADDRESS
Department of Automatic Control
Lund University
P O Box 118
SE-221 00 LUND, Sweden

VISITING ADDRESS
Institutionen för Reglerteknik
Ole Römers väg 1
223 63 LUND

TELEPHONE
+46 46 222 87 87

WWW AND GENERIC E-MAIL ADDRESS
www.control.lth.se
control@control.lth.se

Edited by Martina Maggio and Monika Rasmusson

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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, 2015


REGLERTEKNIK
50 år
Ready


2000-tal

AUTOMATIC CONTROL 2015

The year 2015 was an interesting year in many ways. The economy showed a turnover for 2015 (2014) of 53 MSEK (58 MSEK) and we are 54 (57) persons working at the department (guests not included). More about financial figures is found in the chapter *Economy*.

Today (2015) the department has 6 full time professors, 1 senior professor, 2 professors emeriti, 1 adjoint professor, 3 associate professors, 2 assistant professor, 4 research engineers, 4 administrators, 6 post-docs and 25 PhD students including one industrial PhD student. Some of these numbers include part-time positions. During the year, 3 new PhD students were admitted to the department. More will follow in the chapter *Staff* .

Seven PhD theses by Olof Garpinger, Martin Hast, Jerker Nordh, Björn Olofsson, Andreas Stolt, Olof Sörnmo, Fredrik Ståhl, were completed during 2015. The total number of PhDs graduated from the department is now up to 111. Read more about it in chapter *Education*.

This year there were four licentiate theses presented by Madhi Ghazaei, Josefin Berner, Alina Andersson and Gabriel Ingesson.

During 2015 we gave 20 courses to 1 205 students at LTH and 43 students presented their master's theses at the department. We also arranged 7 PhD courses. More about this in the chapter *Education.*

euRobotics week is now established and took place at the end of November. During this week, about 20 one-hour-long guided tours were arranged in the robotics lab at Lund University. The main audience consisted of about 670 school children and students of all ages from 20 different school classes in the region who had booked a tour, but also about 30 adults from the public (including some from within Lund University) during special sessions. Different demos were included in the tours like: Ball-catching robot using stereo vision; 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 end of year 2014, a 5-year evaluation hearing took place in one of our projects, eLLIIT. The result of the evaluation was given in May, a summary is to be read in chapter *Research*.

The department celebrated 50 years in May 2015. A one-day conference event was organized to celebrate this and a majority of all previous employees showed up for the occasion. Several talks were given, illustrating the interesting past, present and future of the department and the field of automatic control. For the occasion a special control flag had been prepared which was hoisted for the first time under ceremoniously forms. A collage of pictures from this event is shown in chapter *Staff.*

There always seem to be an occasion to celebrate, what will be next year's celebration?

Martina Maggio and Monika Rasmusson

Education

Education on basic level, PhD studies, Licentiate and Doctoral dissertations

BASIC LEVEL

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).

During 2015 the department has been involved in courses given together with Lund University School of Economics and Management. 20 future engineers have completed a master's thesis in pair with a future economist, which equals 17 theses presented.

This year, in total 1 205 students were registrered out of which 997 passed our courses. 43 students completed their masters' theses projects, in total 34 theses were presented during 2015. We are now getting closer to pass 1000 Master's Thesis at Automatic Control.

A list of the masters' theses is given in the *Appendix "Masters' Theses".* The number of registered students correspond to 175 fullyear equivalents during the year.

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.

As from this autumn the students will do their exams under an anonymous code.

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

TOTAL NUMBER OF STUDENTS WHO PASSED OUR COURSES 2015

Reglerteknik FRT010
(Automatic Control, Basic Course) 499
Realtidssystem FRTN01
(Real-Time Systems) 91
Olinjär reglering och servosystem FRTN05
(Nonlinear Control and Servo Systems) 41
Flervariabel reglering FRTN10
(Multivariable Control) 60
Prediktiv reglering FRTN15
(Predictive Control) 25
Marknadsstyrda system FRTN20
(Market Driven Systems) 14
Processreglering FRTN25
(Process Control) 20
Nätverksdynamik FRTN30
(Network dynamics) 9
Systemteknik FRT110
(Systems Engineering) 57
Reglerteori FRT130
(Control Theory) 11
Systemidentifiering FRT041
(System Identification) 15
Projekt i reglerteknik FRT090
(Projects in Automatic Control) 50
Matematisk modellering FRT095
(Mathematical Modeling, Advanced Course) 35
Fysiologiska modeller och beräkningar FRTF01
(Physiological Models and Computations) 25
Kandidatarbete FRTL01
(Bachelor's Thesis) 2
Examensarbete FRT820
(Master's Thesis Project) 43
Examensarbete TMA820
(Master's Thesis Project within Technology Management) 20

PHD STUDIES

The PhD education consists of four years of studies: 120 hp of courses and 120 hp of thesis work. 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 2015 there were 4 licentiate theses presented by Mahdi Ghazaei, Josefin Berner, Alina Andersson and Gabriel Ingesson.

Seven doctoral theses were defended during the year by Olof Garpinger, Martin Hast, Jerker Nordh, Björn Olofsson, Andreas Stolt, Olof Sörnmo and Fredrik Ståhl.

We have admitted Gautham Nayak Seentanadi, Marcus Thelander Andrén and Mattias Fält as PhD students during 2015.

The following PhD Courses were given in 2015

- *Convex Optimization*, Pontus Giselsson
- *Cloud Control,* Johan Eker
- *Robust Control,* Anders Rantzer
- *Julia Course,* Kristian Soltesz
- *Hybrid Systems,* Maria Prandini
- *Numerical Optimization,* Andrey Ghulchak & Fredrik Magnusson
- *Large-Scale Convex Optimization,* Pontus Giselsson

LICENTIATE DISSERTATIONS

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


Mahdi Ghazaei


Josefin Berner


Alina Andersson


Gabriel Ingesson

TOPICS IN TRAJECTORY GENERATION FOR ROBOTS

Ghazaei, Mahdi

A fundamental problem in robotics is generating the motion for a task. How to translate a task to motion or a series of movements is a non-trivial problem. The complexity of the task, the structure of the robot, and the desired performance determine the sequence of movements, the path, and the course of motion as a function of time, namely the trajectory. As we discuss in this thesis, a trajectory can be acquired from a human demonstration or generated by carefully designing an objective function. In the first approach, we examine a number of robotic setups which are suitable for human demonstration. More notably, admittance control as a new dimension to the robot-assisted teleoperation is investigated. We also describe a free-floating behavior which makes robust lead-through programming possible. As a way to utilize these setups, we present some ideas for developing a high-level language for an event-based programming common to assembly tasks.

Since immediate reaction to variations in the target state and/or robot state is desirable, we reformulate the trajectory generation problem as a controller design problem. Using the Hamilton-Jacobi-Bellman equation, we derive a closed-loop solution to the fixed-time trajectory-generation problem with a minimum-jerk cost functional. We show that the resulting trajectory coincides with a fifth-order polynomial function of time that instantaneously updates due to changes in the reference signal and/or the robot states.

A short comparison is made between kinematic and dynamic models for generating optimal trajectories. The conclusion is that given conservative kinematic constraints, both models behave in a similar way. Having this in mind, we derive an analytic solution to the problem of fixed-time trajectory generation with a quadratic cost function under velocity and acceleration constraints. The advantage of the analytic solution compared to an on-line optimization approach lies in the efficiency of the computation.

To extend the idea of closed-loop trajectory generation, we adapt the Model Predictive Control (MPC) framework. MPC is traditionally applied to tracking problems, i.e., when there is an explicit reference signal. Thus, it is a common practice to have a separate layer that generates the reference signal. We propose an integrated approach by introducing a final state constraint in the formulation. Additionally, we give the interpretation that the difference between tracking and point-to-point trajectory-planning problems is in the density of the specified desired reference signal. We utilize a

strategy to reduce the discretization time successively. This way, we respect the real-time constraints for computation time while the accuracy of the solution is gradually improved as the deadline approaches. We have verified our proposed MPC approach to trajectory generation in a ball-catching experiment.

AUTOMATIC TUNING OF PID CONTROLLERS BASED ON ASYMMETRIC RELAY FEEDBACK
Berner, Josefin

This thesis presents an improved version of the classic relay autotuner. The proposed autotuner uses an asymmetric relay function to better excite the process in the experiment phase. The improved excitation provides the possibility to obtain better models and hence better tuning, without making the autotuner more complicated or time consuming.

Some processes demand more accurate modeling and tuning to obtain controllers of sufficient performance. The proposed autotuner can classify these processes from the experiment. In an advanced version of the autotuner an additional experiment could be designed for these processes, in order to further increase the possibilities in modeling and tuning. The experiment design would then rely on information from the relay experiment. A simple version of the autotuner could instead make a somewhat better model estimation immediately, or suggest that some extra effort may be put in modeling if the control performance of the loop is crucial. The main focus in this thesis is on the simple version of the autotuner.

The proposed autotuner uses the process classification for model and controller selection also in the simple version. The processes are classified according to their normalized time delays. In this thesis a simple method of finding the normalized time delay from the asymmetric relay experiment is presented and evaluated.

Research presented on different versions of the relay autotuner is often based solely on simulations. In large simulation environments, the ability to automatically tune the large amount of PID controllers is practical and time-saving. However, the ability to use the autotuner in an industrial setting, requires considerations not always present in a simulation environment. This thesis investigates many of these issues, regarding parameter settings and possible error sources. The proposed autotuner is implemented, tested and evaluated both in a simulation environment and by industrial experiments. The simple version of the autotuner gives satisfactory results, both in simulations and on the industrial processes. Still, there is a possibility to further increase the performance by an advanced version of the autotuner.

ANALYTIC PARAMETERIZATION OF STABILIZING CONTROLLERS FOR THE MOORE-GREITZER COMPRESSOR MODEL
Andersson, Alina

This work presents an extension, simplification and application of a design procedure for dynamic output feedback design for systems with nonlinearities satisfying quadratic constraints (QC). Our method was motivated by the challenges of output feedback control design for the three-state Moore-Greitzer (MG) compressor model. The classical three-state MG model is a nonlinear dynamical system that is widely used in stall/surge analysis and control design.

First, we find the parameter set of the stabilizing dynamic output feedback controllers for the surge subsystem by using conditions for stability of a transformed system and the associated matching conditions.

Second, we choose the optimal control parameters from the stabilizing set with respect to different desired criteria.

We show the set of parameters of the stabilizing controllers for the surge subsystem and the set of parameters of the stabilizing controllers with extended integral part for MG compressor.

We present simplified sufficient conditions for stabilization, new constraints for the corresponding parameters and examples of optimal problem for the surge subsystem of the Moore-Greitzer compressor model.

We discuss the degree of robustness and clarify an alternative proof of stability of the closed-loop system with the surge subsystem and the stabilizing dynamic output feedback controller without an integral state. In addition, we show the derivation of a quadratic function by using CVX.

MODEL-BASED CONTROL OF GASOLINE PARTIALLY PREMIXED COMBUSTION

Ingesson, Gabriel

Partially Premixed Combustion (PPC) is an internal combustion engine concept that aims to yield low NOx and soot emission levels together with high engine efficiency. PPC belongs to the class of low temperature combustion concepts where the ignition delay is prolonged in order to promote the air-fuel-mixture homogeneity in the combustion chamber at the start of combustion. A more homogeneous combustion process in combination with high exhaust-gas recirculation (EGR) ratios gives lower combustion temperatures and thus decreased NOx and soot formation. The ignition delay is mainly controlled by temperature, gas-mixture composition, fuel type and fuel-injection timing.

It has been shown that PPC run on gasoline fuel can provide sufficient ignition delays in conventional compression-ignition engines. The PPC concept differs from conventional direct-injection diesel combustion because of its increased sensitivity to intake conditions, its decreased combustion-phasing controllability and its high pressure-rise rates related to premixed combustion, this puts higher demands on the engine control system. This thesis investigates model predictive control (MPC) of PPC with the use of in-cylinder pressure sensors. Online heat-release analysis is used for the detection of the combustion phasing and the ignition delay that function as combustion-feedback signals. It is shown that the heat-release analysis could be automatically calibrated using nonlinear estimation methods, the heat-release analysis is also a central part of a presented online pressure-prediction method which can be used for combustion-timing optimization.

Low-order autoignition models are studied and compared for the purpose of model-based control of the ignition-delay, the results show that simple mathematical models are sufficient when anipulating the intake-manifold conditions. The results also show that the relation between the injection timing and the ignition delay is not completely captured by these types of models when the injection timing is close to top-dead-center. Simultaneous control of the ignition delay and the combustion phasing using a dual-path EGR system, thermal management and fuel injection timings is studied and a control design is presented and evaluated experimentally.

Closed-loop control of the pressure-rise rate using a pilot fuel injection is also studied and the multiple fuel-injection properties are characterized experimentally. Experiments show that the main-fuel injection controls the combustion timing and that the pilot-injection fuel could be used to decrease the main fuel injection ignition delay and thus the pressure-rise rate. The controllability of the pressure-rise rate was shown to be higher when the pilot injection was located close to the main-fuel injection. A pressure-rise-rate controller is presented and evaluated experimentally.

All experiments presented in this thesis were conducted on a Scania D13 production engine with a modified gas-exchange system, the fuel used was a mixture of 80 % gasoline and 20 % N-heptane (by volume).

DOCTORAL DISSERTATIONS

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


Olof Garpinger


Martin Hast


Jerker Nordh


Björn Olofsson


Andreas Stolt


Olof Sörnmo


Fredrik Ståhl

ANALYSIS AND DESIGN OF SOFTWARE-BASED OPTIMAL PID CONTROLLERS
Garpinger, Olof

A large process industry can have somewhere between five hundred and five thousand control loops, and PID controllers are used in 90–97% of the cases. It is well-known that only 20–30% of the controllers in the process industry are tuned satisfactorily, but with the methods available today it is considered too time-consuming to optimize each single controller. This thesis presents tools for analysis and design of optimal PID controllers, and suggests when and how to use them efficiently. High performing low-level controllers are also likely to be beneficial for higher-level advanced process control, thus promoting the economy of whole factories.

Controller design is often a trade-off between conflicting criteria, such as load disturbance attenuation, robustness, and noise sensitivity. In this thesis, a MATLAB-based software tool is used to solve a constrained optimization problem, with respect to all three requirements. This gives tuning of both the PID parameters and a low-pass filter time constant.

A large batch of benchmark models, representative for the process industry, has been used throughout the whole thesis for controller analysis. This includes comparisons between PID controllers derived using either optimization or tuning rules. Trade-off plots are also presented, which explicitly show the relationships between performance, robustness and the PID parameters.

A new procedure for software-based optimal PID design is suggested, which leads to a set of PID, PI, and I controllers. The user can then select the best performing controller with an acceptable control signal activity. It is shown that the resulting controllers are optimal or near optimal with respect to the three above mentioned criteria. The same procedure can also be used to analyze the benefit of the derivative part by comparing optimal PI and PID controllers with the same level of noise sensitivity. The efficiency of the procedure is demonstrated on an industrial friction stir welding machine. For a more wide-spread use of the proposed procedure, it is shown that better modeling techniques are needed, and guidelines for such methods are also included.

DESIGN OF LOW-ORDER CONTROLLERS USING OPTIMIZATION TECHNIQUES
Hast, Martin

In many applications, especially in the process industry, low-level controllers are the workhorses of the automated production lines. The aim of this study has been to provide simple tuning procedures, either optimization-based methods or tuning rules, for design of low-order controllers.

The first part of this thesis deals with PID tuning. Design methods or both SISO and MIMO PID controllers based on convex optimization are presented. The methods consist of solving a nonconvex optimization problem by deriving convex approximations of the original problem and solving these iteratively until convergence. The algorithms are fast because of the convex approximations. The controllers obtained minimize low-frequency sensitivity subject to constraints that ensure robustness to process variations and limitations of control signal effort.

The second part of this thesis deals with tuning of feedforward controllers. Tuning rules that minimize the integrated-squared-error arising from measurable step disturbances are derived for a controller that can be interpreted as a filtered and possibly time-delayed PD controller. Using a controller structure that decouples the effects of the feedforward and feedback controllers, the controller is optimal both in open and closed loop settings. To improve the high-frequency noise behavior of the feedforward controller, it is proposed that the optimal controller is augmented with a second-order filter. Several aspects on the tuning of this filter are discussed.

For systems with PID controllers, the response to step changes in the reference can be improved by introducing set-point weighting. This can be interpreted as feedforward from the reference signal to the control signal. It is shown how these weights can be found by solving a convex optimization problem. Proportional set-point weight that minimizes the integrated-absolute-error was obtained for a batch of over 130 different processes. From these weights, simple tuning rules were derived and the performance was evaluated on all processes in the batch using five different feedback controller tuning methods. The proposed tuning rules could improve the performance by up to 45% with a modest increase in actuation.

BAYESIAN INFERENCE FOR NONLINEAR DYNAMICAL SYSTEMS — APPLICATIONS AND SOFTWARE IMPLEMENTATION
Nordh, Jerker

The topic of this thesis is estimation of nonlinear dynamical systems, focusing on the use of methods such as particle filtering and smoothing. There are three areas of contributions: software implementation, applications of nonlinear estimation and some theoretical extensions to existing algorithms. The common theme for all the work presented is the pyParticleEst software framework, which has been developed by the author. It is a generic software framework to assist in the application of

particle methods to new problems, and to make it easy to implement and test new methods on existing problems.

The theoretical contributions are extensions to existing methods, specifically the Auxiliary Particle Filter and the Metropolis Hastings Improved Particle Smoother, to handle mixed linear/nonlinear models using Rao-Blackwellized methods. This work was motivated by the desire to have a coherent set of methods and model-classes in the software framework so that all algorithms can be applied to all applicable types of models. There are three applications of these methods discussed in the thesis. The first is the modeling of periodic autonomous signals by describing them as the output of a second order system. The second is nonlinear grey-box system identification of a quadruple-tank laboratory process. The third is simultaneous localization and mapping for indoor navigation using ultrasonic range-finders.

TOPICS IN MACHINING WITH INDUSTRIAL ROBOT MANIPULATORS AND OPTIMAL MOTION CONTROL

Olofsson, Björn

Two main topics are considered in this thesis: Machining with industrial robot manipulators and optimal motion control of robots and vehicles. The motivation for research on the first subject is the need for flexible and accurate production processes employing industrial robots as their main component. The challenge to overcome here is to achieve high-accuracy machining solutions, in spite of the strong process forces required for the task. Because of the process forces, the nonlinear dynamics of the manipulator, such as the joint compliance and backlash, may significantly degrade the achieved machining accuracy of the manufactured part. In this thesis, a macro/micro-manipulator configuration is considered to the purpose of increasing the milling accuracy. In particular, a model-based control architecture is developed for control of the macro/micro-manipulator setup. The considered approach is validated by experimental results from extensive milling experiments in aluminium and steel. Related to the problem of high-accuracy milling is the topic of robot modeling. To this purpose, two different approaches are considered; modeling of the quasi-static joint dynamics and dynamic compliance modeling. The first problem is approached by an identification method for determining the joint stiffness and backlash. The second problem is approached by using gray-box identification based on subspace-identification methods. Both identification algorithms are evaluated experimentally. Finally, online state estimation is considered as a means to determine the workspace position and orientation of the robot tool. Kalman Filters and Rao-Blackwellized Particle Filters are employed to the purpose of sensor fusion of internal robot measurements and measurements from an inertial measurement unit for estimation of the desired states. The approaches considered are fully implemented and evaluated on experimental data.

The second part of the thesis discusses optimal motion control applied to robot manipulators and road vehicles. A control architecture for online control of a robot manipulator in high-performance path tracking is developed, and the architecture is evaluated in extensive simulations. The main characteristic of the control strategy is that it combines coordinated feedback control along both the tangential and transversal directions of the path; this separation is achieved in the framework of natural coordinates. One motivation for research on optimal control of road vehicles in time-critical maneuvers is the desire to develop improved vehicle-safety systems. In this thesis, a method for solving optimal maneuvering problems using nonlinear optimization is discussed. More specifically, vehicle and tire modeling and the optimization formulations required to get useful solutions to these problems are investigated. The considered method is evaluated on different combinations

of chassis and tire models, in maneuvers under different road conditions, and for investigation of optimal maneuvers in systems for electronic stability control. The obtained optimization results in simulations are evaluated and compared.

ON ROBOTIC ASSEMBLY USING CONTACT FORCE CONTROL AND ESTIMATION
Stolt, Andreas

Force sensing provides robots the capability to accomplish tasks where physical interaction with the environment is required, such as assembly. Small position uncertainties can then be corrected for by sensing the contact forces. This thesis considers the problem of force-controlled assembly, including how tasks can be specified in a simple and intuitive way and how robust task execution under uncertainties can be accomplished.

A framework for performing robotic assembly is presented. An assembly tasks is composed of a number of skills, where skills both can be force controlled and be carried out using standard position-based control. The skills using force control are specified as sequences of constrained motions, where transitions between the motions are triggered by sensor events. These events can either be simple threshold levels, or be more advanced classifiers based on machine learning. A method for explicitly modeling and resolving uncertainties is presented, as well as a method for adaptation of force control parameters based on identification of a contact model. Specification of sensor-based skills usually requires expert knowledge. To make the specification procedure more easy and intuitive, this thesis presents a method where force-controlled skills can be specified on a high level, and where an executable low-level description is generated. Experimental implementations of multiple assembly scenarios are used to validate the methods and to investigate the potential for force-controlled assembly with industrial robots.

A force sensor may not always be available. The thesis presents two different methods for performing force estimation, based on the measured joint motor angles and the joint motor torques. Friction in the joints is the major disturbance when doing force estimation. A method to increase the accuracy of force estimation using dithering to decrease the effective friction level is proposed. Lead-through programming, to manually guide the robot, is useful for simple and intuitive robot programming. The thesis presents a method for performing such lead-through programming without any force sensor, based on disabling the low-level joint controllers, only feedforwarding the torque to compensate gravity.

Specification and execution of tasks based on external sensing is difficult for non-experts. The methods presented in this thesis all contribute to making it easier and more intuitive to use industrial robots for performing assembly tasks.

ADAPTATION AND LEARNING FOR MANIPULATORS AND MACHINING
Sörnmo, Olof

This thesis presents methods for improving the accuracy and efficiency of tasks performed using different kinds of industrial manipulators, with a focus on the application of machining. Industrial robots offer a flexible and cost-efficient alternative to machine tools for machining, but cannot achieve as high accuracy out of the box. This is mainly caused by non-ideal properties in the robot joints such as backlash and compliance, in combination with the strong process forces that affect the robot during machining operations. In this thesis, three different approaches to improving the robotic machining accuracy are presented. First, a macro/micro-manipulator approach is considered, where an external

compensation mechanism is used in combination with the robot, for compensation of high-frequency Cartesian errors. Two different milling scenarios are evaluated, where a significant increase in accuracy was obtained. The accuracy specification of 50 µm was reached for both scenarios. Because of the limited workspace and the higher bandwidth of the compensation mechanism compared to the robot, two different mid-ranging approaches for control of the relative position between the robot and the compensator are developed and evaluated. Second, modeling and identification of robot joints is considered. The proposed method relies on clamping the manipulator end effector and actuating the joints, while measuring joint motor torque and motor position. The joint stiffness and backlash can subsequently be extracted from the measurements, to be used for compensation of the deflections that occur during machining. Third, a model-based iterative learning control (ILC) approach is proposed, where feedback is provided from three different sensors of varying investment costs. Using position measurements from an optical tracking system, an error decrease of up to 84% was obtained. Measurements of end-effector forces yielded an error decrease of 55%, and a force-estimation method based on joint motor torques decreased the error by 38%.

Further investigation of ILC methods is considered for a different kind of manipulator, a marine vibrator, for the application of marine seismic cquisition. A frequency-domain ILC strategy is proposed, in order to attenuate undesired overtones and improve the tracking accuracy. The harmonics were suppressed after approximately 20 iterations of the ILC algorithm, and the absolute tracking error was reduced by a factor of approximately 50.

The final problem considered in this thesis concerns increasing the efficiency of machining tasks, by minimizing cycle times. A force-control approach is proposed to maximize the feed rate, and a learning algorithm for path planning of the machining path is employed for the case of machining in non-isotropic materials, such as wood. The cycle time was decreased by 14 % with the use of force control, and on average an additional 28 % decrease was achieved by use of a learning algorithm. Furthermore, by means of reinforcement learning, the path-planning algorithm is refined to provide optimal solutions and to incorporate an increased number of machining directions.

TOWARDS DEFENCE IN DEPTH IN DIABETES GLUCOSE SELF-MANAGEMENT

Ståhl, Fredrik

Diabetes is a disease characterized by insufficient capacity to regulate the blood glucose level. In insulin-dependent diabetes, multiple daily injections of insulin have to be administered. In-between scheduled visits to the care provider, the patient has to manage the glucose control independently. Insulin dosing is a non-trivial task and many patients find it difficult. This is reflected in the health statistics, that indicate that a majority of patients with diabetes have poor metabolic control with associate risks of several short and long term complications.

In this thesis, building blocks of a defence-in-depth approach to glucose self-management in insulin-dependent diabetes are investigated. Defence-in-depth is a concept where technical and administrative systems work in cohort to divert potentially dangerous conditions and events. In the context of insulin-dependent diabetes this amounts to avoiding low (hypoglycemia) and high (hyperglycemia) glucose values. Data from the European DIADvisor project and from a local trial conducted with patients from Skåne University Hospital were used in the thesis.

A basis for improved glucose control is understanding and knowledge of the glucose-lowering effect of insulin, the insulin action, and the corresponding glucose-elevating effect produced by meal intake. Individualized models of these impacts, and methods to improve the predictive capacity of these models, were developed. Interesting properties, such as, time-variability and nonlinear

effects, were found. The models allow for the glucose level to be predicted and different meal and bolus scenarios to be simulated. Using the models, the possibility to foresee and prevent nocturnal hypoglycemia was validated with good performance in a retrospective analysis on the collected data.

Recent advances in sensor technology have allowed for commercial systems where the glucose level is measured with a high sampling rate in the interstitial fluid. However, a known deficiency with this approach is the measurement lag introduced by equilibrium dynamics between the blood and interstitial compartments. A Kalman filter based approach to resolving this issue was developed and successfully validated in a case study.

Diabetes glucose dynamics is known to comprise both short and more long term time-variability. Merging different diversified models may prove to be a successful approach, as a means to improve performance and robustness under such conditions. A novel merging algorithm based in a Bayesian setting was developed. The suggested method admits for soft switching and interpolation between the different models based on an evaluation of the different predictors' recent performance, using a sliding data window, and by looking for data features identified to be correlated to switching. Different aspects of the merging approach were investigated, using a simulated dataset, and the concept was thereafter successfully validated, showing improved robustness to the prediction performance in comparison to relying on the individual prediction models.

Meal impact models were estimated for 56 different meal types, and a clustering analysis showed that a majority of these models could be represented by three base models. Cross-validation confirmed good predictive capacity. The insulin action and meal impact models were further used to assess whether clinical recommendations on postprandial glucose levels, issued by international patient and professional organizations, are realistic and achievable. An important finding was that the postprandial excursion of meals with rapid postprandial response may be impossible to restrain within the recommended boundaries for even moderate meal sizes. This difficulty is exaggerated for persons with slower than normal insulin action.

The above methods and models could contribute to improving already available technology in diabetes self-management such as, e.g., bolus dose guides in insulin pumps, warning systems in continuous glucose monitoring systems or in interpretation and implementation of postprandial recommendations.

A Bayesian method to allow several specialized prediction models to work in cohort was also developed. Validation on both simulated and real-world data confirmed that the prediction robustness increased.

Among these, the insulin model reconfirmed a previous result that the insulin action is heterogeneous across the glucose range, with elevated magnitude at low glucose values and reduced at high glucose values.

Research

This chapter contains the different projects that were ongoing during 2015

EXCELLENCE CENTERS

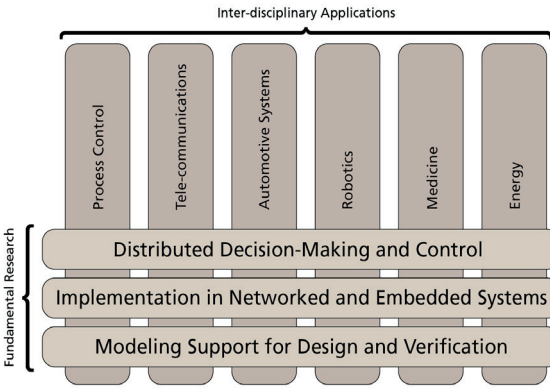
LCCC - LINNAEUS CENTER

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 below:



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. Most PhD projects emphasize fundamental research and general purpose tools, but they usually also have an application component involving industrial partners or colleagues from other disciplines.

LCCC-ACCESS workshop on Model-Based Engineering

The LCCC Linnaeus Center of Lund University and the ACCESS Linnaeus Center of KTH were jointly hosting this workshop on Model-Based Engineering (MBE) including Model-Based Systems Engineering (MBSE). The first two days of the workshop, May 4-5, 2015 covered state of the art, recent advances and future directions in MBE research and development, as well as efforts and transition to practice in industry. The third day, May 6 covered the needs for graduate and undergraduate education, as well as continuing education, and description of current and future efforts. The workshop was held at Ideon Research Park, Lund, Sweden. Organizing committee: John S. Baras (University of Maryland College Park), Anders Rantzer (Lund University), Karl Henrik Johansson (KTH), Eva Westin (Lund University).

The complexity of engineering and other systems have increased dramatically over the last fifteen years. Current and future systems include heterogeneous components from diverse technologies and physics, heterogeneous cyber components and almost always networked components. The recently emphasized class of Cyber-Physical-Systems (CPS) is just one dominant and ubiquitous example. In addition, humans are increasingly becoming elements of these complex systems, rather than being considered as outside the "system boundary". Requirements for the design, manufacturing and operation of these complex engineered systems are rapidly increasing in complexity and numbers. System design, manufacturing, operation and life-cycle performance measures, such as fast time to market, reduced costs, guaranteed safety and many others, have become increasingly complex and demanding. New advances in manufacturing, materials and processes, and world-wide supply chains are now involved in system design and manufacturing, leading to the emergence of a digital manufacturing and design innovation revolution (also known as Industrial Internet and fourth Industrial Revolution (Industrie 4.0)). This global environment has created the need for developing a rigorous approach to design, manufacturing and operation of such systems. Model-Based Engineering (MBE) is addressing this need through development of new methodologies and tools using models for the structure, behavior, requirements and performance of these complex systems. Model-Based Systems Engineering (MBSE) is at the center of these efforts and developments, and has replaced more traditional Systems Engineering (SE) methods and tools based on processes. Product Life-cycle Management (PLM) methods and tools have also advanced substantially and several new suites have emerged. Applications of these emerging new methods and tools have been initiated in aerospace, automotive, power utility grids, transportation, sensor and communication networks, and even healthcare systems. MBE and MBSE are now widely recognized as key promising but challenging fields for the future of science and technology towards addressing critical societal, environmental and human needs world-wide.

Picture taken at LCCC workshop on Model-Based Engineering in May 2015

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

Researchers: Karl-Erik Årzén, Bo Bernhardsson, Anton Cervin, Anders Rantzer, Martina Maggio, Jerker Nordh, Anders Mannesson, Anders Robertsson, Rolf Johansson, Yang Xu, Meike Stemman, Josefin Berner, Björn Olofsson, Jacob Antonsson, 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 (National Strategic Research Area)

ELLIIT is a network organization 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 ELLIIT, Director for the Lund part of ELLIIT, and area leader for the Embedded Systems area within ELLIIT. Bo Bernhardsson is an ELLIIT professor.

The Department participate in the following ELLIIT projects:

- Integrated Scheduling and Synthesis of Networked Embedded Event-Based Control Systems
- Tools and Languages for Modeling and Optimization
- Cooperative Cyber-Physical Systems
- Navigation and Perception
- Process Learning
- Optimal Maneuvers
- Large-scale Optimization for Systems Analysis
- Enabling End-User-Centered Energy Management Systems

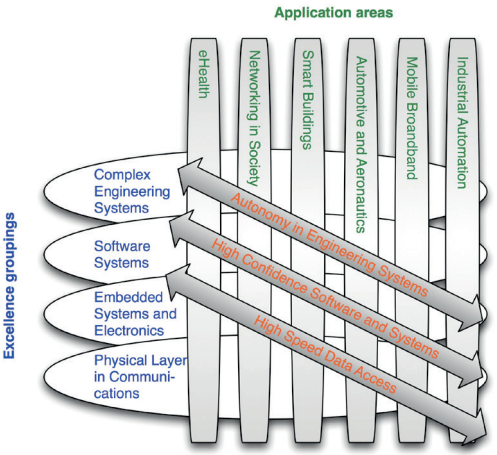


Illustration of the interaction between the themes, the application areas and the groupings (http://www.liu.se/elliit)

Evaluation of the project eLLIIT

A 5-year evaluation hearing took place end of 2014 and the result of the evaluation was given in May, summerized as follows; ELLIIT is an SRA spanning the research fields of communications, networks, control, electronics, embedded systems, software, autonomous systems, and complex systems; reaching highest international quality research in control theory. It has four participating higher education institutions - LiU (as host), Lund University (LU), Blekinge Institute of Technology (BTH) and Halmstad University (HH) – and has strong links to industry including an industrial board with representatives from Ericsson, ABB, Scania, Sectra, Schneider, Axis and SAAB. This board, along with the SRA's International Scientific Advisory Board, has provided valued guidance on which research programs to support and which to abandon. SRA funding has been used primarily to recruit high-quality researchers. Through the SRA funding ELLIIT has significantly strengthened cooperation between its participants; attracted >76 MSEK in new grants; filed several patents: and had a significant impact on education at all levels.

PIC - PROCESS INDUSTRIAL CENTER

Researchers: Josefin Berner, Olof Garpinger, Tore Hägglund, Martin Hast, Charlotta Johnsson, Ola Johnsson, Kristian Soltész

Funding: SSF

The Process Industry Centre PIC was founded in 2008 by the Swedish process industry and the Foundation for Strategic Research (SSF). Located at Lund University and Linköping University, the aim of PIC is to provide knowledge for the process industry to ensure future success. The academic disciplines of Chemical Engineering, Automatic Control and Production Economy form the centre together with several industrial partners from the process industry. The research projects are focused on the three topics; flexibility, controllability and availability.

The research program at Lund University, PIC-LU, is organized in a number of integrated projects. The joint research program, PIC-opic, is organised in three projects.

- **Optimal transitions**, was a collaboration between the two departments and partner companies Borealis, Siemens and Modelon AB mainly focused on flexibility, started in 2008. During phase I the project studied grade changes at a Polyethylene process at Borealis. During phase II it has studied model calibration for dynamic models for start-up of power plants at Siemens.
- **Disturbance management**, was a collaboration between Automatic Control and Perstorp AB, and availability was the research theme. It started in 2009. During phase I the project studied utility disturbances in Perstorp site at Stenungsund. In phase II it was focused on local disturbance management in low level control systems.
- **Quality by design and control**, was a collaboration between Novo Nordisk A/S, Pfizer and Chemical Engineering, started in 2008, with the main theme controllability. This project has grown and was divided in two subprojects. Subproject A has studied design and control issues while subproject B has studied modelling and model calibration.
- **Flexible design**, was a collaboration between Chemical Engineering, Lund University and K.A.Rasmussen and started in 2010, based on industrial funding. The theme was flexibility and was a research project with additional experimental resources.
- **Fed-batch control,** was a collaboration with Automatic Control, Chemical Engineering and Novozymes. The project started

in the second half of 2010 and has controllability as research theme.

- **Buffer Management and Inventories** is a collaboration between Automatic control, production economics and Perstorp AB. The aim is to combine traditional methods used in automatic control with traditional methods used for Inventory management.
- **Performance Metrics** is a collaboration between Automatic Control, production economics and Perstorp AB. The project focuses on finding production related key performance indicators suitable for use in the process industries. The project further aims at linking them to strategic initiatives and metrics of the company. The project includes active participation in the developing activities of the international ISO 22400 standard (Key Performance Indicators for Manufacturing Operations Management).
- **Economic Optimization** is a collaboration between Automatic Control, production economics and Perstorp AB. The project aims at minimizing the economic effects of utilitiy disturbances at the plant-wide level.

WASP | WALLENBERG AUTONOMOUS SYSTEMS PROGRAM

Wallenberg Autonomous Systems 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 Igaging Group at the Department of Matematics.

The program director for WASP is Professor Lars Nielsen, Linköping University and the coordinator for Lund University is Professor Karl-Erik Årzén.

Lund University currently has six university PhD students in WASP plus three industrial PhD students and participates in all six projects. The Department of Automatic Control has two university PhD students and two industrial PhD students and participates in the projects Autonomous Cloud and Localization and Scalability for Distributed Autonomous Systems.

WASP currently contains six challenging projects

Systems that – like people – can see, listen, smell and collect information from many different sources, and then act based on this. Automatic transport systems and decision-making support in the form of cognitive companions. These are two of the six projects that have been finalised in the Wallenberg Autonomous Systems Program, WASP. "The overarching aim is to create a platform for fundamental research and research training that can collaborate with leading Swedish companies in important fields such as autonomy and advanced software. To achieve this aim, some of Sweden's foremost researchers have come together around six important challenges," says Lars Nielsen, professor at Linköping University and programme director of WASP.

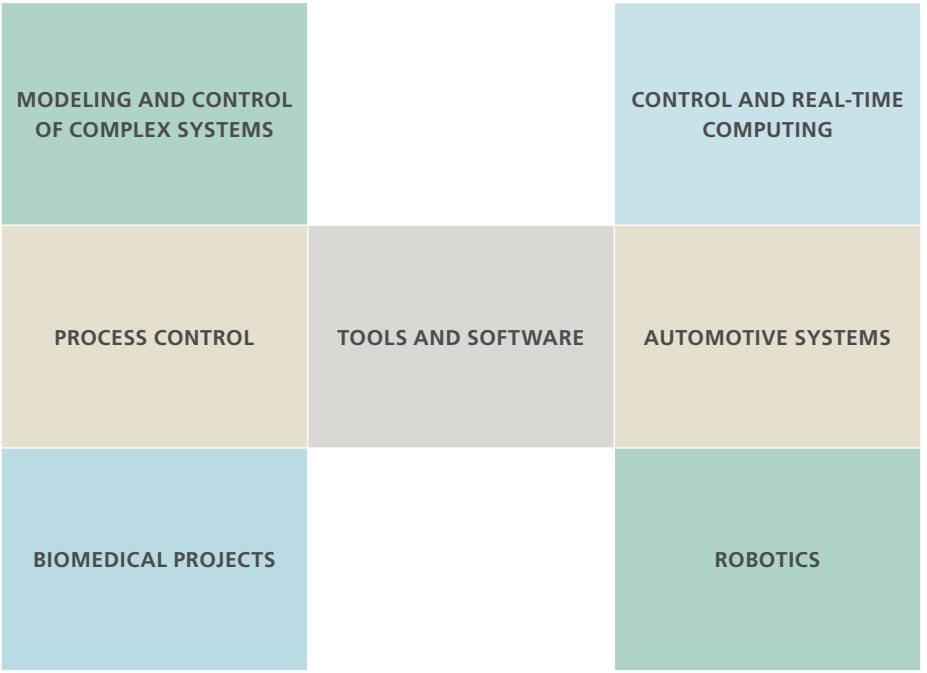
The six projects will start off the ten-year WASP research programme. Each project has an annual funding of between three and six million Swedish crowns, and employs researchers from at least two and often three universities. This is in addition to 26 doctoral students or post-docs, currently being recruited, and subsequently also a number of industry-based doctoral students.

The projects in summary:

- *Automatic transport systems* – will revolutionise and streamline the transport of people and goods, improve traffic flow and fuel economy and reduce crashes. Coordinated by Professor Bo Wahlberg, KTH Royal Institute of Technology.
- *Autonomous clouds* – the system will autonomously be able to distribute capacity and other resources that are physically located in the distributed cloud. Coordinated by Professor Karl-Erik Årzén, Lund University.
- *Interaction and communication with autonomous agents* – new systems for advanced decision-making support. "We will develop technology and methodology that enables people to interact and communicate with the intelligent systems of the future: vehicles, robots etc. We will be able to make decisions based on enormous volumes of information that are presented to us in a way that's both humane and easy to understand," explains Anders Ynnerman, professor at LiU and project coordinator.
- *Datadriven development of autonomous systems of systems* "Software is an enabler for smart, autonomous systems, and the challenge is to develop very large systems that constantly draw conclusions, learn and develop their own knowledge, based on their own actions. We will develop new methods, techniques and tools that will help the software-intensive Swedish industry to handle this challenge," says Jan Bosch, professor at Chalmers and project coordinator.
- *Localisation and scalability in autonomous systems* – how to efficiently localise and position vehicles, robots, people etc. in large-scale systems. Coordinator: Professor Fredrik Gustafsson, Linköping University.
- *Interaction, perception, learning and verification in interactive autonomous systems.* "Autonomous systems interact with their surroundings and gather information about the world around them by way of various sensors. To make the systems function better and adapt their behaviour to different users, we are going to develop learning methods based on combinations of sensors such as cameras, lasers and tactile sensors. This requires close collaboration between researchers in fields such as computer vision, robotics, control engineering, mathematics and artificial intelligence," explains Danica Kragic, project coordinator and professor at KTH Royal Institute of Technology.

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 seven major research areas are:



RESEARCH WORKING GROUPS AT THE DEPARTMENT

Power networks. *Responsible: Carolina Lidström*
Traffic control and distributed decision-making. *Responsible: Gustav Nilsson*
Cloud control and Networked Embedded Systems. *Responsible: Karl-Erik Årzén*
Robotics. *Responsible: Rolf Johansson*
Navigation and communication. *Responsible: Bo Bernhardsson*
Process control. *Responsible: Tore Hägglund*

MODELING AND CONTROL OF COMPLEX SYSTEMS

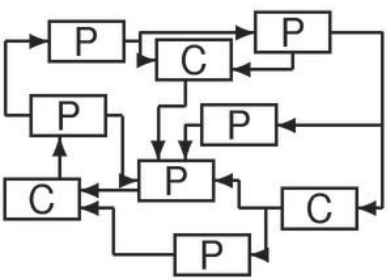
Distributed Decision-Making and Control
Active Control of Compressor Systems
Adaptive Control in Flying Vehicles
ICT platform for sustainable infrastructures
Numerical and Symbolic Algorithms for Dynamic Optimization
Energy and Building Management
Collaboration with the European Spallation Source
Low-rank approximation with convex constraints
Joint Positioning and Radio Channel Estimation
Marine Vibrator Control
A Stochastic Control Approach to Optimal Power System Operation
LISA 2 - Line Information System Architecture 2

DISTRIBUTED DECISION-MAKING AND CONTROL

Researchers: Anders Rantzer, Bo Bernhardsson, Giacomo Como, Christian Grussler, Daria Madjidian, Leonid Mirkin, Enrico Lovisari, Gustav Nilsson, Sei Zhen Khong

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 area is to meet this demand.



Distributed Control using Price Mechanisms

The idea to use price mechanisms for coordination of large scale systems has a long history in economics as well as in optimization theory. Our research is exploiting similar ideas for engineering applications involving interaction between many sub-systems. In particular, we study Model Predictive Control where the optimization problem is decomposed using Lagrange multipliers. The multipliers can be viewed as prices and the optimization problem is solved iteratively through price negotiations between the subsystems. Special algorithms, called accelerated

gradient methods, are exploited to speed up the iterations. Such methods are well established in the optimization literature, but using them for real-time control poses new challenges and opportunities.

Fundamental Limitations in Control Systems with Distributed Information

Theory for multivariable control has mainly 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 particular, industrial practice often relies on distributed control structures and there is a strong need for more systematic approaches to design of such structures and the corresponding information interfaces. During the past several years we have been actively contributing to an emerging theory for control with distributed information and a better understanding for the fundamental limitations imposed by the information structure.

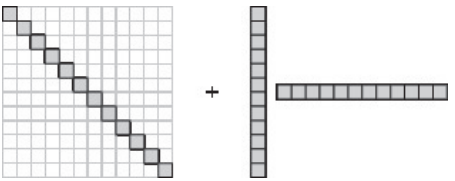
Control of Traffic Networks and other Monotone Systems

Traffic network models are often expressed in terms of a monotone dynamical system. This means that additional traffic can never lead to reduced congestion. The monotonicity property turns out to be very useful in analysis and synthesis of large scale systems, not only in traffic networks. Our research is devoted to fundamental questions regarding performance and robustness of traffic networks, but we are also trying to see how the methods can be applied to more general monotone systems.

Low-Rank Distributed Control

We study a class of distributed control laws, comprising a diagonal (decentralized) term perturbed by a low-rank component. See the figure below. A control law of this form reduces the information processing by aggregating information from all systems into a single quantity, which is then made available to each of the systems. These type of controllers appear as the optimal solution to a class of resource allocation problems in multi-agent applications, including wind farms.

Benefits from Symmetry in Robust Control



We study the advantages of symmetry in robust control. In the case of state feedback, an optimal control law can be given on a very simple form for stable finite-dimensional systems with symmetric state matrix. The control law is clearly related to the matrices of the system's state space representation. We exploit this fact both in synthesis and for distributed control purposes. For infinite-dimensional systems, we investigate the benefits of having the control law on closed-form, in synthesis for large systems. The control law is proposed for temperature control in buildings.

ACTIVE CONTROL OF COMPRESSOR SYSTEMS

Researchers: Rolf Johansson, Anders Robertsson, Alina Andersson in cooperation with Prof. Anton Shiriaev, Umeå University & NTNU, Trondheim and Dr. Leonid Freidovich, Umeå University.

Funding: VR

This project deals with a number of facts related to the output feedback stabilization of the Moore-Greitzer compressor model. We show that quadratic feedback stabilization of the surge subsystem of the three-state Moore-Greitzer compressor model, which ensures an absence of additional equilibria in the augmented with stall dynamics closed loop system, implies convergence of all solutions to the unique equilibrium at the origin. Then some steps in developing such output feedback controller for surge subsystem are discussed, and a family of controllers is presented. Based on our new theoretical results on integrability, stability, nonlinear dynamic output feedback control, we wish to pursue active control application to compressor systems and experimental verification.

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.

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, Magnus Perninge, Richard Pates, 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.

NUMERICAL AND SYMBOLIC ALGORITHMS FOR DYNAMIC OPTIMIZATION

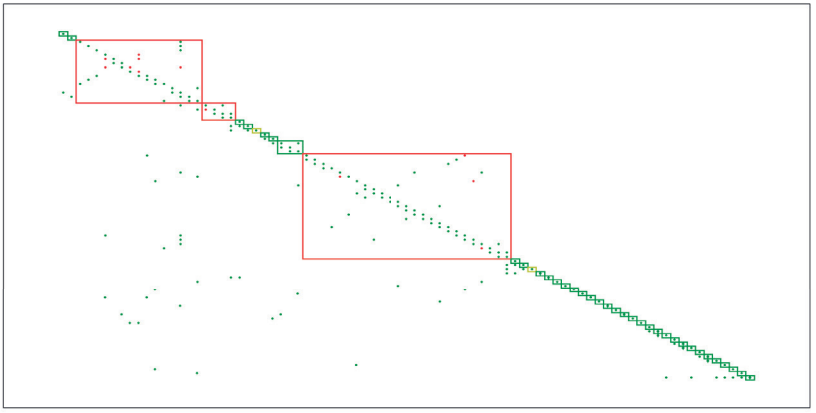
Researchers: Fredrik Magnusson, Johan Åkesson (Modelon), Christian Andersson (Numerical Analysis)

The target of this project is the development of algorithms for numerical solution of large-scale, DAE-constrained, non-convex dynamic optimization problems. The project targets both optimal control and parameter estimation as well as other forms of dynamic optimization. Applications include minimization of material and energy consumption during set-point transitions in power plants and chemical processes, minimizing lap times for vehicle systems, trajectory optimization in robotics and identifying unknown parameter values of models using measurement data.

The first step of the project has been to implement state-of-the-art algorithms based on collocation methods and integrate them with the high-level, object-oriented modelling language Modelica and its extension Optimica. This allows basic users to conveniently formulate and solve problems of moderate difficulty without worrying about the details of the solution algorithms, while still allowing advanced users to tailor the algorithm as needed for complex problems. This implementation is a part of the open-source JModelica.org project. Two important third-party tools used within the project is CasADi, for automatic differentiation, and IPOPT, for solution of non-linear programs.

The current research direction is to symbolically process the differential-algebraic equation system describing the dynamics to create a block triangular structure of the incidence matrix by employing graph algorithms, as illustrated below. This structure facilitates analytic solution of many of the algebraic equations, removing the need to expose these to the numerical optimization algorithm. This drastically reduces the number of optimization variables, and may also result in a better conditioned problem, thus potentially improving both convergence speed and robustness of iterative solvers.

The applicability of the algorithms are explored in other application-oriented research projects, in collaboration with other research groups from both academia and industry.



ENERGY AND BUILDING MANAGEMENT

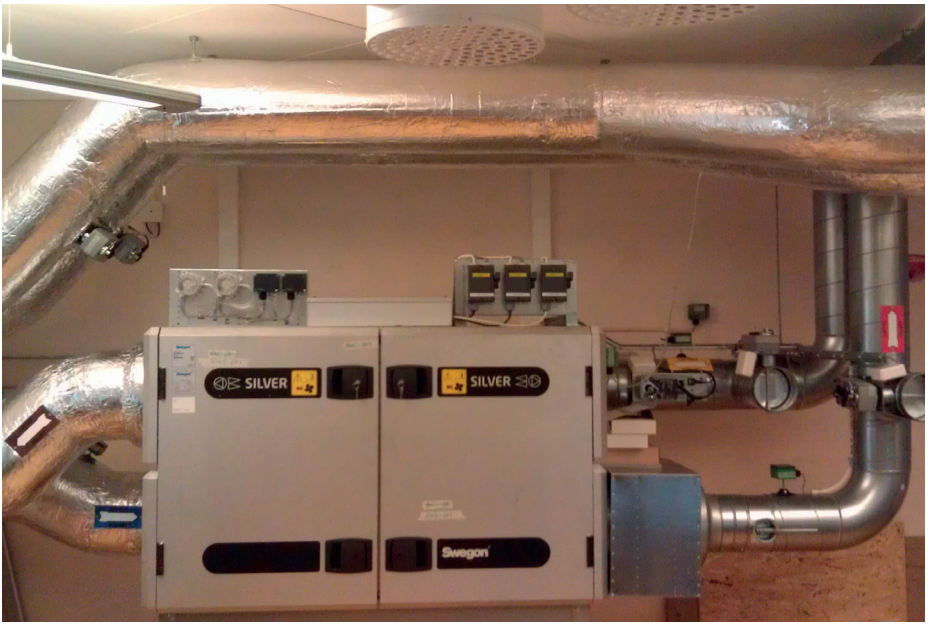
Researchers: Josefin Berner, Meike Stemmann, Anders Rantzer

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 is practice. Automatic tuning can help to overcome this problem.

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 the overall performance. This is compared to a Model Predictive Controller controlling the temperature of all rooms at the same time.



COLLABORATION WITH THE EUROPEAN SPALLATION SOURCE

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

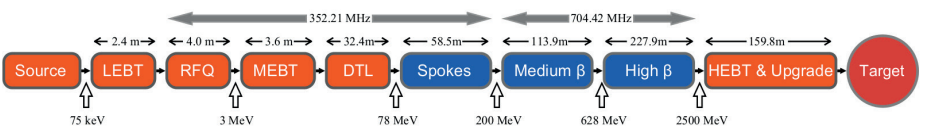
Funding: European Spallation Source

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.

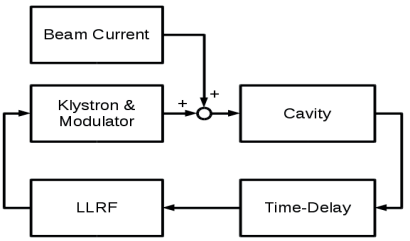
Control for the Radio-Frequency System

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.

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.

JOINT POSITIONING AND RADIO CHANNEL ESTIMATION

Researchers: Bo Bernhardsson, Anders Mannesson

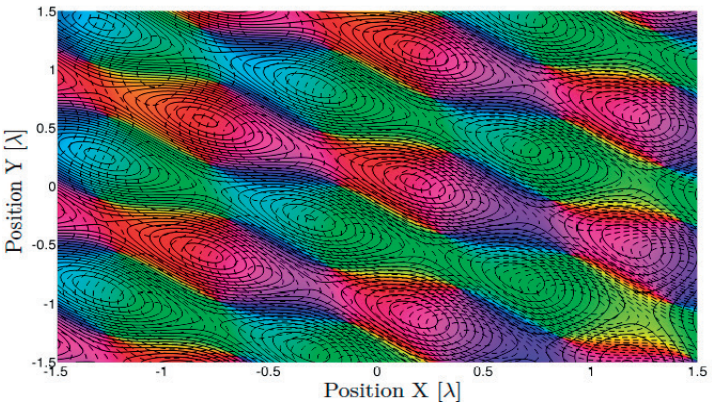
Funding: VR

The project works with algorithms to combine information from gyros, accelerometers and compass sensors with radio channel estimation and to determine the fundamental properties of such schemes. The hope is to enable two technology advancements:

- a new method for significantly reduced drift in low cost navigation systems
- improved radio channel estimation for moving terminals, suitable for MIMO systems

Initial research show promising result as presented in the licentiate thesis by Anders Mannesson.

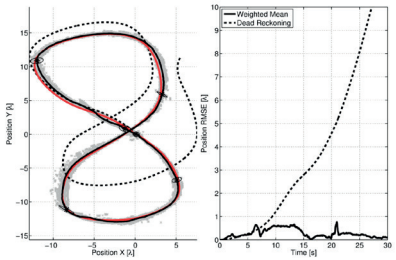
The work is based on angle of arrival estimation using antenna arrays which is a well studied problem with many different algorithms resolving the individual rays impinging on the array. However, less attention has been given to so called virtual array antennas where moving receiver elements are used. By tracking the movement of the element, an array with properties similar to a stationary array with multiple elements is formed. By combining the IMU and the radio channel information, a map of the local radio environment can be obtained, such as in this picture illustrating the complex valued radio

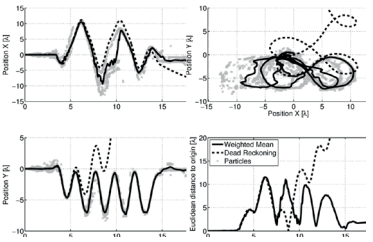


channel for three impinging planar radiowaves in a noise-free situation (see picture above)

Tightly coupled nonlinear state estimation algorithms between IMU signals and radio channel estimates are used to simultaneously estimate this map and obtain improved pose estimates.

The major challenge is to battle the drift in sensors and radio crystal oscillators. We work with both real-world measurements and simulations to evaluate performance. Initial experiments show promising results. The following figure shows performance (simulations left, real experiments right) with realistic radio and IMU imperfections. There is a dramatic improvement by including radio channel information compared to using dead reckoning, especially for movements longer than 10 seconds.





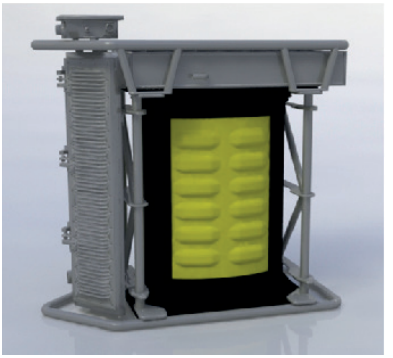
Our future research now focuses on improving radio channel estimation and prediction by adding IMU information and using motion models.

MARINE VIBRATOR CONTROL

Researchers: Bo Bernhardsson, Olof Sörnmo

Funding: PGS

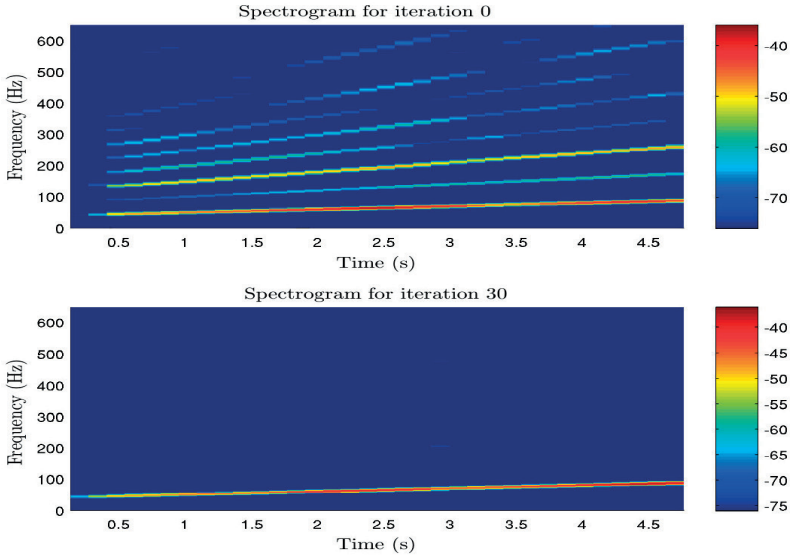
The objective is to model and control large underwater loudspeakers, known as marine vibrators, that are used to generate acoustic signals.



Performance requirements on out-of-band spectrum of the acoustic signal are achieved by careful characterization of the dynamical behavior of the vibrators and use of frequency-domain Iterative Learning Control (ILC). This has been found to successfully reduce the impact of nonlinearities such as friction and backlash. A 40 dB suppression of out-of-band harmonics has been acheived in experiments (in air).

The research is described in detail in the article "Frequency-Domain Iterative Learning Control of a Marine Vibrator", which has been accepted for publication in the journal "Control Engineering Practice".

The project is funded by the Norwegian company PGS.



A STOCHASTIC CONTROL APPROACH TO OPTIMAL POWER SYSTEM OPERATION

Researchers: Magnus Perninge

Funding: VR

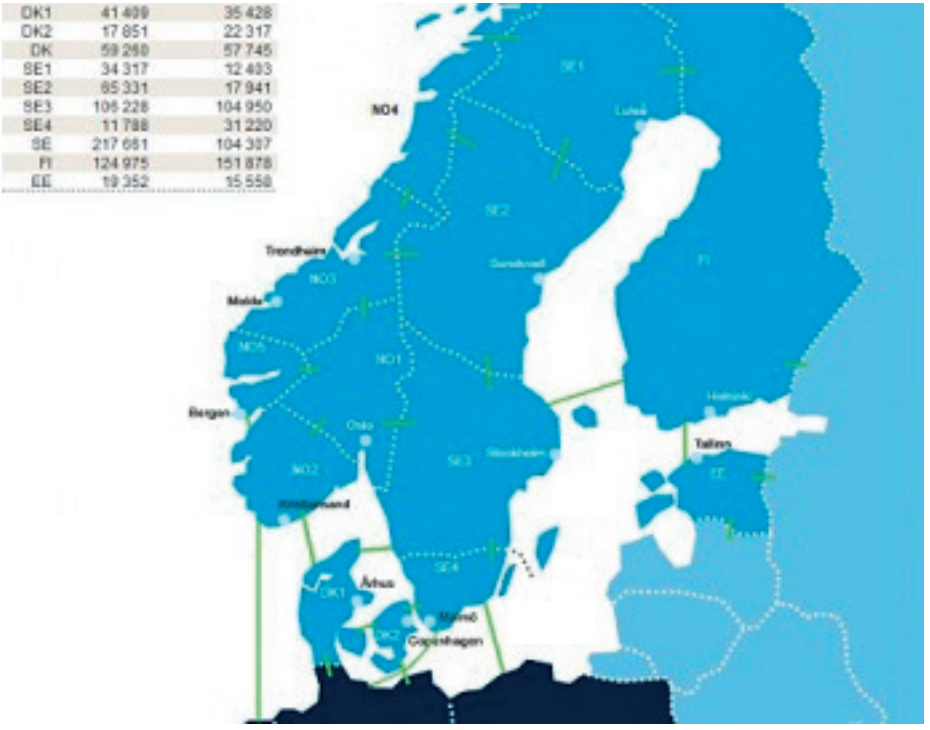
One of the main challenges when operating a power system is the economic re-dispatch performed to meet the continuously changing consumption patterns. When assuming the market structure of most deregulated power markets, with a specific power market designated to re-dispatch, the re-dispatch problem becomes an optimal switching problem with delays.

This aim of this project is therefore devoted to numerical solution techniques for large-scale stochastic optimal switching problems with delays.

Stochastic optimal switching problems are a subset of stochastic optimal control problems where the control set is finite and there is a fixed cost (or reward) associated to switching between the different points of the control set.

Stochastic optimal switching has a number of other important applications, such as mineral extraction, electricity generation optimization, gas storage, traffic control, etc. Almost all of which have switching delays.

Although the stochastic optimal switching problem has been solved in a rather general setting, most numerical methods suffer from the curse of dimensionality (which becomes even more apparent in the presence of delays).



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.

CONTROL AND REAL-TIME COMPUTING

Event-Based Estimation and Control
Co-Design of Robust and Secure Networked Embedded Control Systems
LUCAS - Lund Center for Applied Software Research
Cloud Control
Power and temperature control for large-scale computing infrastructures
Feedback Computing in Cyber-Physical Systems

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, Anton Cervin, Bo Bernhardsson

Funding: Swedish Research Council

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.

We are currently investigating sub-optimal event-based estimation and control schemes that allow a substantial reduction in design complexity while at the same time achieving better performance and lower resource utilization than periodic schemes.

CO-DESIGN OF ROBUST AND SECURE NETWORKED EMBEDDED CONTROL SYSTEMS

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

Funding: ELLIIT and LCCC

This project was previously named Integrated Control and Scheduling.

Modern embedded control systems comprise periodic and sporadic software tasks that control several physical processes and execute on platforms with multiple computation and communication components. The project will focus on the complex system timing induced by resource sharing among the tasks, which is one of the main characterizations of the control quality. This control quality, which is affected negatively by long and varying computation and communication delays in the control loop, will be considered during system-level scheduling and optimization, as well as during controller synthesis by delay-compensation techniques.

Many control systems have time-varying resource demands, implying that scheduling policies and control strategies must be adapted at runtime to provide high control quality and efficient resource usage. Such variations are inherent in event-based control, which is an emerging technology in resource-constrained systems, but also occur depending on the states of the controlled processes or as a result of process disturbances and mode changes. The project will therefore also consider runtime optimization techniques to address such variations.

The project aims to push the state of the art of integrated control and computer systems design in several directions. We shall develop design methods for control-quality optimization of embedded control applications running on distributed execution platforms, which, for example, are very common in the automotive systems domain. Our subsequent aim is to develop design-time and runtime optimization methods that trade off control quality with the varying resource requirements present in multi-mode and event-based control systems. The long-term objective of the project is to develop an optimization and resource-management framework to be used for the design and implementation of future resource- constrained and adaptive embedded control systems.

LUCAS - LUND CENTER FOR APPLIED SOFTWARE RESEARCH

Researchers: Karl-Erik Årzén, Rolf Johansson, Anders Robertsson, Anton Cervin, 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.

CLOUD CONTROL

Researchers: Karl-Erik Årzén, Bo Bernhardsson, Anders Robertsson, Anton Cervin, Anders Rantzer, Martina Maggio, Alessandro Papadopoulos, Manfred Dellkrantz, Jonas Dürango, in collaboration with Maria Kihl's group at the Dept of Electrical and Information Technology, Lund University and Erik Elmroth's group at Umeå University

Funding: VR

We take a control theoretic approach to a range of cloud management problems, aiming to transform today's static and energy consuming cloud data centers into self-managed, dynamic, and dependable infrastructures, constantly delivering expected quality of service with acceptable operation costs and carbon footprint for large-scale services with varying capacity demands. Such data centers will form the backbone of the digitalized society by providing unparalleled information storage and processing capabilities.

Today's explosive growth of the Internet and mobile connectivity hints at a digitized society where information is created, stored, processed, and distributed at a previously unparalleled rate, already today including, e.g., multimedia services as online TV and music, social networks, scientific applications, and business services such as e-commerce, online banking, enterprise applications, etc. Whereas the Internet is becoming ubiquitous and provides reasonably mature communication abilities, significant advancements are required to create the future cloud data centers that will form a backbone for information processing and storage, and thus be a key enabler of the digitized society.

However, with a continued extreme growth in capacity demands, today's cloud data center infrastructures are literally jeopardizing the continued development of the digitized society by simply being too static, providing too low Quality-of-Service (QoS), and by consuming ridiculous amounts of energy. Today's data center infrastructures are not even near being able to cope with the enormous and rapidly varying capacity demands that will be reality in a near future. So far, very little is understood about how to transform today's data centers (being large, power-hungry facilities, and operated through heroic efforts by numerous administrators) into a self-managed, dynamic, and dependable infrastructure, constantly delivering expected QoS with reasonable operation costs and acceptable carbon footprint for large-scale services with sometimes dramatic variations in capacity demands.

To meet these challenges, the project addresses a set of fundamental and inter-twined automanagement challenges assuming that there during execution are stochastic variations in capacity needs and resource availability, as well as changes in system response and operation costs (in monetary and energy terms). The challenges include how much capacity to allocate at any time for an elastic application, where to allocate that capacity including optimizing complete data center energy efficiency, if to admit an elastic service with unknown lifetime and future capacity demands, as well as how holistic management can be performed to optimize the various management tools' concerted actions.

This cross-disciplinary project builds on a collaboration between Umeå University and Lund University with complementing expertise on cloud management and control of computing systems. The collaboration addresses fundamental algorithmic challenges that in industrial collaborations have been identified as crucial.

The project is funded by a 20 million SEK framework grant from the Swedish research council (VR).

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. The project originated by a publication at PACT 2013 (Parallel Architectures and Compilation Techniques) entitled "ThermOS: System Support for Dynamic Thermal Management of Chip Multi-Processors". It has lead in 2014 to the publication of the article "PCP: A Generalized Approach to Optimizing Performance Under Power Constraints through Resource Management" at ICAC 2014 (International Conference on Autonomic Computing). The follow up on this research has been presented at RTAS

2015 (21st IEEE Real-Time and Embedded Technology and Applications Symposium) with the paper POET: a portable approach to minimizing energy under soft real-time constraints and at FSE 2015 (Foundations on Software Engineering) with the paper Automated multi-objective control for self-adaptive software design.

FEEDBACK COMPUTING IN CYBER-PHYSICAL SYSTEMS

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

Funding: VR Framework Grant

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 divided into three parts:

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

PROCESS CONTROL

PICLU
PID Control
Automatic Tuning
Decentralized Control Structures
Optimizing fermentation control for B. licheniformis
PiiA-Metrics

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.

Most of the process control research is today performed within the Process Industrial Center at Lund University, PICLU.

PROCESS INDUSTRIAL CENTRE AT LUND UNIVERSITY

Researchers: Josefin Berner, Olof Garpinger, Tore Hägglund, Martin Hast, Charlotta Johnsson, Ola Johnsson, Kristian Soltesz

Funding: SSF

With support from the Swedish Foundation for Strategic Research (SSF), the process industrial centre PIC-LU was established in collaboration with the department of Chemical Engineering.

The overall goal of PIC-LU is to establish, in cooperation with Swedish process industry, an internationally leading centre for research and professional training in process optimization and control.

In the research program, methodology and tools for modelling, optimization, and control of industrial processes are developed, in order to improve production systems with respect to flexibility, controllability, and availability. The methodology and the tools are developed from specific solutions to process control problems suggested by the industrial partners. The goal is to make the results from PIC-LU industrially relevant, not only for the participating industries, but on a wide scale in process operation and automation.

In the competence development program, the main goal is to increase the competence level of process optimization and control in industry as well as in academy. The goal will be reached in two ways; through an educational program at different levels for staff in process industry, and by directed efforts in MSc and PhD programs at the university.

PROCESS INDUSTRIAL CENTRE – OPTIMIZATION, PERFORMANCE, INTEGRATION AND CONTROL (PIC-OPIC)

Researchers: Charlotta Johnsson and Tore Hägglund in cooperation with researchers from Dept of Chemical Engineering at Lund University as well as researchers at Linköping Univeristy

Funding: SSF

With support from the Swedish Foundation for Strategic Research (SSF), the PIC-opic project was established in 2012 in order to strengthen the integration between the various hierarchical control level found in companies today. Generally, the lower levels of the automation hierarchy are focused on operational decisions and thereby close to the real production and real time control and measurements, whereas the higher levels are closer to strategic decisions and thereby closer to economical performance evaluations. PIC-opic is a joint research between Lund University and Linköping University. It consists of three (3) subprojects with the aim of integrating different levels in the hierarchy. Subproject A focuses on buffer management and inventories, subproject B focuses on key performance indicators and subproject C focuses on economical optimization. The three projects all incorporate knowledge and personnel from the two research centres PIC-LI and PIC-LU.

PID CONTROL

Researchers: Karl Johan Åström, Josefin Berner, Olof Garpinger, Tore Hägglund, Martin Hast and Kristian Soltész

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:

Measurement noise filtering for PI and PID controllers

Measurement signals are always corrupted with noise.This will be reflected in the control signal behaviour in e.g. high variance or large inter-sample jumps if considering a discrete time setting. Previous work on PI and PID controllers often focus on proportional-, integral- and derivative gains at design but the filter action is added afterwords such that a reasonable sensitivity to noise is given. However, the filter changes phase and gain of the controller and the initial tuning may not give satisfying results.

In this project, we investigate the trade-offs between load disturbance attenuation, robustness and the undesired control activity generated by measurement noise. The goal is to find design rules that take all these aspects into account in the PID design, where the measurement noise filter is included.

A new methodology that uses a second order filter to attenuate the fluctuations of the control signal due to measurement noise, and which tuning parameter is given by the filter time constant T_f, has been derilved. The main contributions are:

- Filtering design criteria for attenuation of measurement noise, which include the Control Bandwidth, the Standard Deviation of the Control Signal (SDU), and the

Noise Gain.

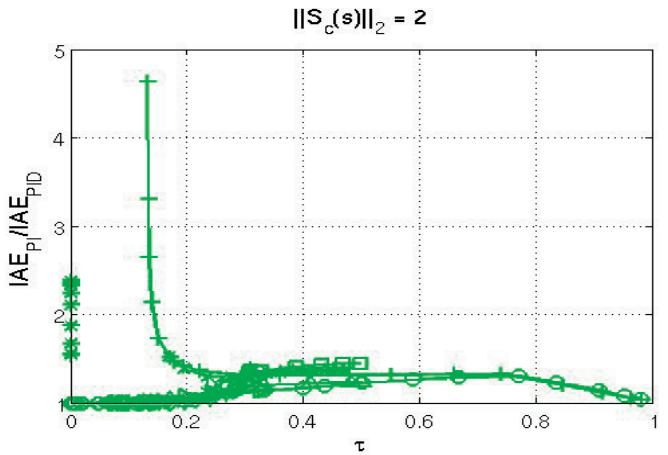
- An iterative method to calculate the filter time constant T_f based on the gain crossover frequency, wich considers the tradeoffs between performance, robustness, and measurement noise attenuation.
- Simple rules derived from the results obtained from the iterative method, which allow to find the filter time constant for common PID tuning rules based on FOTD models.
- Simple rules to find the added dynamics in the nominal FOTD model due to filter introduction, which leads to the recalculation of the controller parameters.

Software tools for design of PID controllers

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.

The optimal solutions to the extended optimization problem can also be used to compare the performance of PI and PID controllers to examine the benefit of the derivative part for different processes. Assuming continuous time white Gaussian noise with unit spectral density, it is possible to derive optimal PI and PID controllers with the same robustness and noise sensitivity constraints. The ratio of optimal PI performance divided by optimal PID performance for the case of medium noise sensitivity and high robustness is plotted in the figure. Each symbol represents a process in a batch of 134 models representative for the process industry. These have been classified with respect to their normalized time delay, τ. Processes with τ close to zero or one generally benefit less from the derivative part than processes in between. Two process types, however, benefit more from derivative action than others, namely those with two identical poles and little delay as well as second order processes with one integrating pole and little delay.



In order to use software-based optimal design methods like the one described, it is important to have better modeling tools than what is normally available in the process industry. A simple step response test have been shown insufficient to design PI and PID controllers that are close to optimal. Research have shown that process information around the phase -125° is sufficient to find first order time delayed models for optimal PI control. For optimal PID control the model needs to be accurate around a larger span of phase angles from -125° down to around -235°. With the right modeling tools it should then be fairly easy to incorporate optimal software tuning into a new generation of autotuners that will be far better than any existing PID tuning rules.

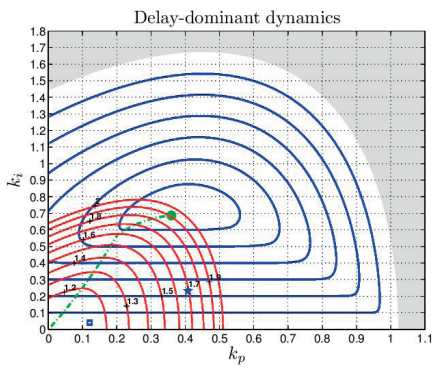
PID design by convex optimization

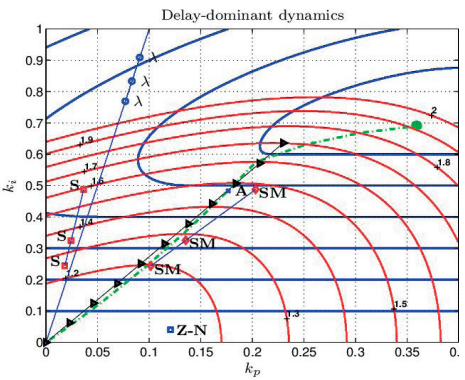
Convex optimization has grown to become a mature and powerful tool in a vast number of research fields. Design of PID controllers subject to robustness constraint is not a convex optimization problem, however, it fits well into the framework of the convex-concave procedure. Using that procedure, tuning 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.

Criteria and Trade-offs in PID Design

Control design is a rich problem which requires that many issues such as load disturbances and set-point tracking, model uncertainty, and measurement noise are taken into account. In this work we introduce trade-off plots for PI and PID controllers, which give insight into the design methods, criteria and design compromises.

The trade-off plot below is drawn for PI control of a second order delay-dominant process. The right plot is a magnification of the lower-left part of the left plot.The blue level curves show constant values of Integrated Absolute Error (IAE), equal to 1/ki (kp is proportional gain and ki is integral gain), during a unit step load disturbance on the process input. The red level curves show constant values of max(Ms,Mt), where Ms is the max norm of the sensitivity function and Mt is the max norm of complementary sensitivity. The green, dash-dotted, line shows the loci of IAE optimal controllers for different values of max(Ms,Mt) and the green dot shows the absolute minimum. Five different tuning methods are shown in the plot, namely: Ziegler-Nichols step response method (Z-N), Lambda tuning, Skogestad's two SIMC methods (S and SM) and AMIGO tuning. The black line marked with triangles is a parametrization of the optimal controllers.





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.

Another approach for automatic tuning is to conduct 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. The experiment data can also be used to find a higher order model using numerical parameter estimation methods. From the achieved model the parameters of a PI or PID controller can be tuned either by existing tuning rules or by optimization methods.

This autotuner is still under development, but has been tried in both simulations and on an industrial air handling unit with promising results. The aim is to continue the development of the autotuner for SISO systems, as well as adapting it to handle MIMO systems.

DECENTRALIZED CONTROL STRUCTURES

Researchers: Martin Hast, Tore Hägglund

There is an unfortunate gap between the centralized computational approaches of multivariable control theory and the common practice to design local control loops disregarding couplings and interaction. Today it appears that both approaches has reached a point of refinement where the gap can be reduced from both sides. This project aims to revise and improve the basic modules for decentralized control, and to develop new. The ideas to be investigated in this project are relevant not only for process control but is also of interest for general classes of multi-variable systems.

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. There are surprisingly few such methods presented in the literature, and the methods do normally not take the feedback control into account in the design.

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. There are methods available that manages to handle some of these disturbances, but no efficient method exists that handles all disturbances in both loops. The goal of the project is to obtain such a procedure.

OPTIMIZING FERMENTATION CONTROL FOR *B. LICHENIFORMIS*

Researchers: Ola Johnsson, Charlotta Johnsson, Tore Hägglund

This project is performed in collaboration with Novozymes A/S and Dept of Chemical Engineering, Lund University within the PICLU centre.

The project will focus on developing, improving and optimizing fermentation control strategies for the *B. licheniformis* fed batch processes. This process can produce vast amounts of protein but is sensitive to overdosing and process disturbances which lead to process variations and possibly crashed fermentations. There is thus a strong motivation for developing more robust control strategies for this process. The project aim is to develop a general method for finding optimal control strategies for various *B. licheniformis* production strains.

As part of this project, a general control strategy for control of bacterial growth in fed-batch processes has been developed and tested in pilot scale. Currently, the project is focused on implementing this control strategy in production scale for trials in industry. Several pre-studies have been performed to verify that the strategy can be successfully applied for control of real industrial processes.

PIIA - METRICS (NYCKELTAL FÖR SVENSK PROCESSINDUSTRI)

Researcher: Charlotta Johnsson

Funding: Vinnova

PiiA-Metrics is a research project funded by VINNOVA's strategic innovation program PiiA. PiiA-Metrics involves people from both academia (Lund University, and Linköping University) and industry

Beskrivning:
I forsknings-projektet "KPIer för svensk processindustri" skall bl.a. nyckeltal (KPIer – Key Performance Indicators) som används inom svensk processindustri identifieras. Det gäller produktionsnära/operationella nyckeltal och övergripande/strategiska nyckeltal.

Projektet har 3 delprojekt (WP-work packages) och fokuserar på att svara på frågorna "Vilka nyckeltal används i svensk processindustri idag?", "Skiljer sig nyckeltalen åt beroende på karaktäristiska företagsegenskaper?" samt "Hur kan nyckeltal utbytas mellan olika mjukvaruapplikationer?"

WP1: Vilka nyckeltal används inom svensk process industri idag?
- SWP1-1: sammansättning av arbetsgrupp.
- SWP1-2: insamling av vanligt förekommande nyckeltal.
- SWP1-3: kartläggning av de insamlade nyckeltalen.

WP2: Skiljer sig nyckeltalen åt beroende på karaktäristiska företagsegenskaper?
- SWP2-1: verifiering av topologin.
- SWP2-2: kartläggning av vanliga nyckeltal (jmfr WP1-3).
- SWP2-3: strukturering av nyckeltalen enligt topologin.

WP3: Hur kan nyckeltal utbytas mellan olika mjukvaruapplikationer?
- SWP3-1: verifiering av UML-modell (se standarden ISO 22400)
- SWP3-2: framtagande av implementationsoberoende modell, dvs kpiML
- SWP3-3: verifiering av kpiML.

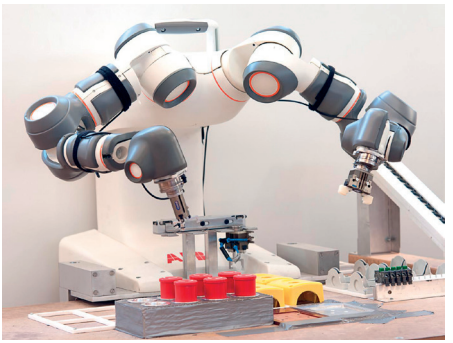
ROBOTICS

Robotics Research
Robotics Lab
SMErobotics
Flexi-Fab
SARAFun

ROBOTICS RESEARCH

Researchers: Rolf Johansson, Anders Robertsson, Olof Sörnmo, 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 offers 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



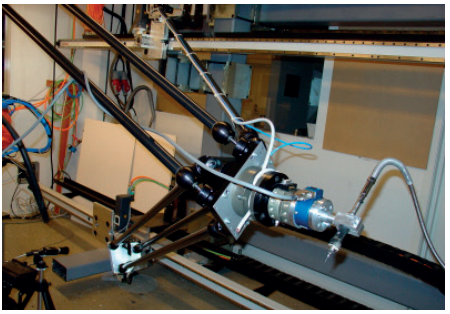
The laboratory for robotics and real-time systems is centered around industrial manipulators with open control system architectures. In the lab we have several generations of robots from an elderly ABB IRB6 robot, an ABB IRB2000 robot, an ABB Irb2400 (S4CPlus) to the more modern ABB IRB140 (IRC5), Gantry-Tau 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

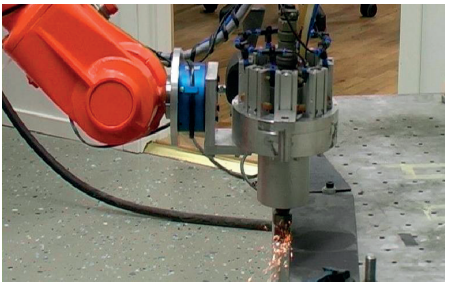
to integrate simultaneous control of force and position according to ideas of impedance control in which stability is an important theoretical issue. A major topic in this project is to integrate aspects of control, sensor fusion and application demands using robot vision and force sensing. Another project 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.

SMEROBOTICS

Researchers: Rolf Johansson, Anders Robertsson, Björn Olofsson, Olof Sörnmo

Funding: European Union FP7, under the programme SMErobotics

Over two-thirds of European workers in manufacturing are employed in small and medium-sized enterprises (SMEs). Their primary means of competition is to respond rapidly to changing production needs and to keep product quality at a very high level. While robots are able to carry out repetitive tasks to a high standard, they do not meet the demands of SMEs for high flexibility. Today's robots know only their nominal task, which limits their ability to deal with frequent changes in the manufacturing process. For the operation of robots in an SME environment, which is typically less structured and involves more uncertainties than large-scale or mass-production industries, the currently available solutions result in overly complex system integration.

Instead, cognitive abilities should be included in the equipment and cognition should take place in both the robot and the human, such that the worker's knowledge can be fully utilised and productivity demands can be met. Additionally, the concepts and symbols used in dialogues need to have a common grounding in order to guarantee ease of use.

Therefore, we propose the SMErobotics work system, which covers all phases of the robot lifecycle and in which humans and robots can together deal with SME manufacturing uncertainties and are symbiotically able to learn from each other and to learn from the past handling of uncertainties. The SMErobotics vision is to deploy such robots on SME shop floors, with the benefit of long-term improvements in productivity.

The SMErobotics initiative pays careful attention to SME-related issues and scientific challenges, as is reflected by its strong industrial involvement supported by leading researchers and building on successful collaboration between industry and academia as well as on demonstration-driven research from the SMErobot project.

Additional partners will be included in order to widen the initiative's impact by transferring project results to European pilot applications of SME-compatible cognitive robot systems.

FLEXIFAB - FLEXIBLE FABRICATION OF LIGHTWEIGHT ALUMINUM STRUCTURES

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

Funding: European Union FP7, under the programme FlexiFab

The FlexiFab system will provide the following key competitive advantages to the European welding Industry

- Enable European fabricators, metal-workers and welding companies to effectively compete in the growing use of aluminum alloys in the light-weight transport sector.
- Capitalising on the increasing pressure to replace traditional iron and steel material with aluminum alloys to reduce weight and thus fuel consumption of vehicles, trains, ships/boats and aeroplanes.

- Reduce the costs associated with the fabrication of aluminum structures, especially focused on components used within the transport sectors.

RobotLab@Lund will mainly work on the sensor integration, logging for weld status for automated quality assurance and control system of industrial robots for the frictions stir welding process.

The system will use friction stir welding technology (FSW), invented by one of the project partners, TWI, in the beginnining of the 1990s. The welding method offers a number of benefits for aluminum joining/welding such as:

- Excellent weld mechanical properties.
- A mechanised repeatable process.
- No special pre-weld edge profiling or cleaning required.
- No shielding gas required.
- Low distortion and shrinkage due to solid-state nature of welding process.
- Welding in any position.
- High efficiency processing with very low energy consumption.
- Ability to weld the 'non-weldable' aluminium alloys such as the 2000 and 7000 series
- Operator Health & Safety benefits:
  1. No harmful welding fumes or hot metal spatter
  2. No UV radiation hazards.

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 bimanual 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.

AUTOMOTIVE SYSTEMS

KCFP, Closed-Loop Combustion Control

Projects devoted to vehicle dynamics and combustion control run in cooperation with major car manufacturers.

KCFP, CLOSED-LOOP COMBUSTION CONTROL

Researchers: Rolf Johansson, Gabriel Ingesson in cooperation with Lianhao Yin, Prof. Per Tunestål and Prof. Bengt Johansson, 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 premixed combustion (PPC) using closed-loop control;
- Control-oriented modeling and simulation of combustion processes;
- Model-based control and optimization evaluated on test beds.

Within the project a cycle-resolved physics-based HCCI model has been developed. The model includes a low-complexity model of the cylinder wall temperature dynamics in order to capture the relevant time-scales of transient HCCI when only small amounts of hot residuals are trapped in the cylinder. The temperature evolution of the gas charge is modeled as isentropic compression and expansion with three heat transfer events during each cycle.

Model predictive controllers based on linearizations of the model have been designed and evaluated experimentally. The considered control signals were the inlet valve closing and the intake temperature. The control performance was evaluated in terms of response time to set-point changes and the resulting output variance. The benefits of using hybrid models comprised of several linearizations of a nonlinear model have also been investigated.

During 2011, a continuous-time model of partially premixed combustion was developed and implemented in the Modelica language. The JModelica.org framework was used to formulate optimization problems on the resulting model. One use of this possibility is automatic calibration of the model parameters.

BIOMEDICAL PROJECTS

Closed-loop Drug Delivery

CLOSED-LOOP DRUG DELIVERY

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

Funding: VINNOVA through the PiiAuto postdoc project grant, LTH postdoc grant.

Objective
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 scenarios, foremost in intensive care, where it has the potential to increase the availability of specialized physicians.

Description
The project faces the following challenges:

- Development of relyable hardware for interfacing infusion pumps and medical sensors to a computer running the control module.
- Development of user-independent experiment design and system identification methods, to obtain and update models of the controlled dynamics (which are typically highly patient-specific and slowly time-varying).
- Automatic controller synthesis based on obtained models.
- Application-specific (medical) challenges and constraints. This also incluses safe operation, logging capabilities and a hirarchical alarm system.

The collaboration with Igelösa is motivated by one of their research projects, relying on intravenous drug delivery under closed-loop control.

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

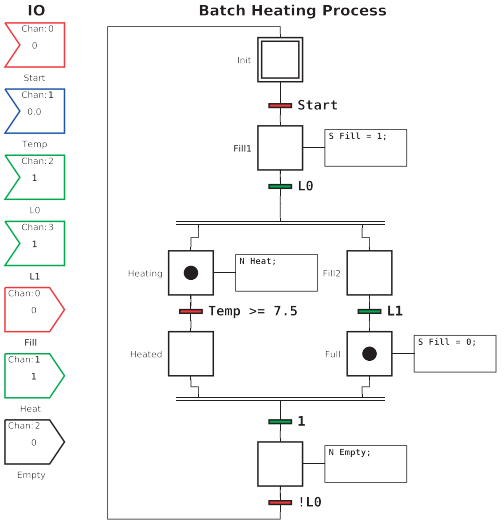
Grafchart is a language for supervisory level sequence control and procedure handling that has been developed at the department since 1991. Grafchart is based on ideas from Grafcet/Sequential Function Charts, Petri nets, Statecharts, and object-oriented programming.

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.

During 2014, integrated support for LabComm and OPC UA has been added, socket I/O has been improved, a control library with a PID controller and an interactive education module has been added, and JGrafchart has been split into separate modules for editing, compilation, and execution. There have been five public releases of JGrafchart, for more details see the release notes.



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.

During 2015, TrueTime has been extended with a number of advanced on-line scheduling algorithms, incorporating new kernel functionality that has been developed at the Department of Real-Time Systems at Technische Universität Kaiserslautern. TrueTime has also been upgraded to work with the latest versions of Matlab on Mac, Linux, and Windows.

External Contacts

External contacts during 2015, both academic and industrial

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

- Charles University in Prague, Dept of Distributed and Dependable Systems, Czech Republic
- City College London, Dept of Informatics. England
- Czech Technical University, Faculty of Information Technology, Czech Republic
- DFKI, SmartFactory, Kaiserslautern, Germany
- Dublin City University, Ireland
- ETH Zurich, Automatic Control Laboratory, Switzerland
- European Innovation Academy, EU
- Hasso Plattner Institute for Software Systems Engineering, Software Competence Center Hagenberg Imperial College, London, Dept of Computing, England
- INRIA / University of Lille, France
- Institute for Mathematics and its Applications (IMA), University of Minnesota, USA.
- KU Leuven, Dept of Mechanical Engineering, Belgium
- Linköping University, ISY, Sweden
- Linneaus University, Dept of Computer Science, 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 Electrical and Information Technology, Lund, Sweden
- Massachusetts Institute of Technology, Computer Science and Artificial Intelligence Laboratory, USA
- Norwegian University of Science and Technology (NTNU), Dept of Chemical Engineering, Trondheim, Norway
- Norwegian University of Science and Technology, Dept of Engineering Cybernetics,
- Politecnico di Milano, Milano, Italy.
- Politecnico di Milano, Dipartimento di Elettronica, Informazione e Bioingegneria, Italy
- Scuola Superiore Sant'Anna, Dipartimento di Informatica, Italy
- Umeå University, Dept of Computing Science, Sweden
- Umeå University, Dept. of Applied Physics and Electronics, 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, Institute of Software Technology, Germany
- University of Brescia, Italy
- University of British Columbia (UBC), Electrical and Computer Engineering in Medicine (ECEM), Vancouver, Canada
- University of California, Saturdja Center for Entrepreneurship and Technology, Berkeley, USA USA
- University of Chicago, Department of Computer Science, USA
- University of Connecticut, Department of Chemical & Biomolecular Engineering, USA
- University of Oxford, Department of Computer Science, England
- University of Toronto, Department of Computer Science, Canada
- University of Trento, Dipartimento di Informatica, Italy
- Zheijang University (ZJU), Control Science and Engineering, Hangzhou, China

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;

- 3E, Belgium
- ABB CRC, Västerås, Sweden
- ABB Robotics, Sweden
- Akzonobel, Ningbo, China
- Corebon, Sweden
- European Spallation Source (ESS), Lund Sweden
- Fraunhofer IPA, Stuttgart, Germany
- Gudel AG, Switzerland
- Igelösa Life Science AB, Igelösa, Sweden
- Institut Pasteur, Paris, France
- Mitsubishi Electric Research Laboratories, Massachusetts
- Modelon AB, Sweden
- Novozymes AS, Denmark
- Perstorp AB, Sweden
- RedHat, Manchester, UK
- SAAB AB, Linköping, Sweden
- Schneider Electric Buildings ab, Malmö, Sweden
- TWI Ltd, UK
- United Technologies Research Center (UTRC), Shanghai, China

EUROPEAN COLLABORATION

During 2015 the department was involved in the 7th Framework Program of the European Commission and Horizon 2020, in the below listed projects;

- SMErobotics Consortium
- Flexi-Fab Consortium
- SARAFun

Staff

During 2015 the staff situation at Automatic Control remains firm. Three new PhD students have been employed. We have also had the pleasure of hosting international guests for shorter or longer periods.

In the coming parts the personnel and its activites will be described.

Picture taken at Kick-off in August 2015

STAFF

PERSONNEL AND VISITORS

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

ASSOCIATE PROFESSORS
Cervin, Anton
Como, Giacomo
Johnsson, Charlotta

ASSISTANT PROFESSORS
Giselsson, Pontus
Maggio, Martina

RESEARCH ENGINEERS
Andersson, Leif (30%)
Andersson, Pontus
Blomdell, Anders
Holmstrand, Martin (until October)
Nilsson, Anders

ADMINISTRATORS
Nilsson, Ingrid (80%)
Nishimura, Mika
Rasmusson, Monika (65%)
Westin, Eva

POSTDOCTORS
Chong, Michelle (from August)
From, Pål Johan
Khong, Sei Zhen (until August)
Papadopoulos, Alessandro V.
Pates, Richard (from October)
Soltész, Kristian (from February)

RESEARCHER
Perninge, Magnus

PHD STUDENTS
Andersson, Alina (b. Rubanova) (until May)
Antonsson, Jacob
Bagge Karlsson, Fredrik
Berner, Josefin
Dellkrantz, Manfred
Dürango, Jonas
Fält, Mattias (from August)
Garpinger, Olof (until August)
Ghazaei, Mahdi
Grussler, Christian
Hast, Martin (until August)
Ingesson, Gabriel
Johnsson, Ola
Karlsson, Martin
Lidström, Carolina
Lindberg, Mikael (until June)
Magnusson, Fredrik
Mannesson, Anders
Millnert, Victor
Nayak Seetanadi, Gautham (from September)
Nilsson, Gustav
Nordh, Jerker (until September)
Olofsson, Björn (until September)
Petersson, Anders (50%)
Sörnmo, Olof
Ståhl, Fredrik
Stemmann, Meike
Stolt, Andreas
Thelander Andrén, Marcus (from August)
Troeng, Olof
Xu, Yang

SHORTER AND LONGER STAYS

Annergren, Mariette; visiting PhD student, KTH
Capurso, Martino; MSc student, Politecnico di Milano, Italy (from September)
Fouquet, Manon; visiting PhD student, EDF/ Supélec, France (September-December)
Grimstad, Lars; visiting PhD student, NMBU, Norway (September-December)
Ilic, Marija; visiting professor, University of Carnegie-Mellon, USA (June-July)
Mercader Gómez, Pedro visiting PhD student, University of Murcia, Spain (April-June)
Miao, Xia; visiting PhD student, University of Carnegie-Mellon, USA (June-July)
Mirkin, Leonid; visiting professor, Technion, Israel (February)
Yamada, Takayoshi; visiting professor, Gify University, Japan (until February)
Zino, Lorenzo; visiting PhD student, University of Torino, Italy (September-December)

STAFF ACTIVITIES

Andersson, Alina

Her research is part of the project Active Control of Compressor Based on New Methods of Nonlinear Dynamic Feedback Stabilization in cooperation with Prof. A Shiriaev, Umeå University.

She has been a PhD student since October 2009. She presented her Licentiate thesis *Analytic Parameterization of Stabilizing Controllers for the Moore-Greitzer Compressor Model* in May.

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 resigned formally in 2012, but was immediately rehired on 30%.

A large part of his time the past year has been spent updating the department publication database with entries for older publications. The aim has been to have all publications going back to the department start in 1965 registered in the database, to a large extent including fulltext.

Andersson, Pontus

MSc, Research Engineer at the department since 2012. His main tasks include maintenance and development of laboratory equipment and also mechanic and electronic design and implementation. Involved in various projects in the Robotics Lab.

During 2015 Pontus has worked part time for the European Spallation Source in a research project for high-accuracy temperature control for the RF system of the proton accelerator.

Antonsson, Jacob

Jacob Antonsson has been a PhD student at the department since august in 2013.

He is interested in statistical modeling and inference for complex systems, such as nonlinear state-space models and high-dimensional regression models. He tries to apply state-of-the-art research results in those areas in applied fields

like statistical genetics and robotics.

During 2015 he has been working with statistical modeling of data related to the human immune system within the Milieu Interieur project at the Pasteur Institute in Paris.

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.

Co-director for the strategic research area ELLIIT on IT and mobile computing. Coordinator for the Lund part of WASP (Wallenberg Autonomous Systems Program).

During the year he has primarily been involved with WASP and the VR project Feedback Computing for Cyber-Physical Systems. He has been responsible for and taught the undergraduate course Real-Time Systems. He is partly or fully involved in the supervision of four 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 PhD students on PID control and automatic tuning. Tutored a PhD student on System Identification.

He was a Member of the United Technology Technical Advisory Committe for Systems and Control.

Bagge Carlson, Fredrik

With the department since June 2013 and graduate student since January 2014. Teaching assistant and project supervisor in Predictive Control.

Researcher in EU project SARAFun with focus on force estimation techniques and robot learning and control.

Berner, Josefin

Tech. Lic., MSc in Engineering Physics, PhD student since August 2012.

Her research interests are in automatic tuning of PID controllers and within the ELLIIT project on control of energy usage in buildings. In May this year she presented her licentiate thesis, *Automatic Tuning of PID Controllers based on Asymmetric Relay Feedback*.

During the year she has also taken some courses, been a teaching assistant in the course on market-driven systems and supervised Master Thesis students.

Bernhardsson, Bo

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

Director of Studies for the PhD education during first half of 2015, a duty then handed over to Anton Cervin. He is also vice head of the department and a member of the LCCC board.

During 2015 Bo Bernhardsson has worked 20 percent for the European Spallation Source with the design of the RF system for the proton accelerator at the European Spallation Source. His research interests are in linear systems, applications of control theory and the connection between communication theory and control theory.

During 2015 he taught one of the basic courses in Automatic Control. He is the supervisor or cosupervisor of 11 PhD students.

During the year Bo was also "Jubileumsgeneral" for the 50 year celebration of the Automatic Control Department.

Blomdell, Anders

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

During 2015 the Linux computers in the Robotics Laboratory got a long overdue upgrade to newer versions. The build system for our local Fedora/Linux packages got a much needed overhaul. A good resilient solution for our server storage needs is still lacking.

In short, 2015 was a year devoted to important but boring consolidation.

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.

During January and February he was on 50% leave of duty to work as a consultant.

He is currently supervising or co-supervising two PhD students. During 2015 he was lecturer in the undergraduate courses Systems Engineering/Process Control and Multivariable Control, and he was supervisor or examiner for six 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. In Nov 2015, she visited Institute for mathematics and its Applications(IMA) at the University of Minnesota for research collaborations.

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. He is a broad member of LCCC and is serving as main supervisor of Gustav Nilsson. His research interests are in Dynamics, Information, and Control in Networks, with applications to transport and infrastructure networks, as well as social and economic networks.

He is recipient of the 2015 George S. Axelby Outstanding Paper Award for the paper coauthored with Ketan Savla, Daron Acemoglu, Munther A. Dahleh, and Emilio Frazzoli `Robust Distributed Control of Dynamical Flow Networks. Part II: Strong Resilience, Equilibrium Selection, and Cascading Failures,' published in the IEEE Transactions on Automatic Control, vol. 58, no.2, pp. 333-348, February 2013.

He has received a Project Research Grant on Resilient Control of Dynamical Network Flows from the Swedish Research Council (VR) for the period 2016-2019.

In 2015, he has taught two master level courses: Nonlinear Control (FRTN05, Fall) and the newly developed Network Dynamics (FRTN30, Spring). In October 2015, he was a visiting researcher at the Institute for Mathematics and its Applications, University of Minnesota.

In December 2015, he has joined the Editorial Board of the IEEE Transactions on Network Science and Engineering. In September 2015 he has served as chair of the International Program Committee of 5TH IFAC workshop on Distributed Estimation and Control in Networked Systems (NecSys 2015). In March 2015, he served as opponent at the School of Electrical Engineering of the Royal Institute of Technology (KTH).

Dellkrantz, Manfred
MSc in Engineering Computer Science since November 2011, PhD student at the department since June 2012. Works with delay compensated elasticity control and load balancing of applications deployed in cloud environments. Involved in teaching the Real Time Systems course during the spring.

Dürango, Jonas
MSc in Engineering Physics, with the department as a PhD student since 2010, supervised by Bo Bernhardsson and Martina Maggio.

In the last year he has mainly been working on performance aware cloud applications within the Cloud Control project.

He has also been active in teaching graduate courses at the department, specifically the courses in predictive control and multivariable control, as well as taking courses himself.

Eker, Johan
Johan is an Adjoint Professor at 20% and a Principal Researcher at Ericsson Research at 80%. His main research areas are resource management for real-time systems, cloud computing and tools and methodologies for many- and multicore systems.

During 2015 he and Jorn Janneck from Department of Computer Science developed and gave a course on the fundamentals of cloud computing.

Fält, Mattias
With the department since August 2015.

Teaching assistant in Automatic Control, Basic Course and Multivariable Control. Project supervisor in Mathematical Modelling.

Have been working on joint position and radio channel estimation as well as a line search method for large scale convex optimization.

Presented work on scalable synthesis of correct by construction controllers at IROS, Hamburg, Germany, September 2015.

Garpinger, Olof
Olof is doing research on software-based optimal design methods for PID control and is part of the Process Industrial Centre at Lund University. He is supervised by Professor Tore Hägglund.

He defended his thesis *Analysis and Design of Software-Based Optimal PID Controllers* in May.

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.

In March 2015, he defended his licentiate thesis titled *Topics in Trajectory Generation for Robots*. During 2015, he developed a hand with 12 degrees of freedom similar to the design of Prof. Takayoshi Yamada. This "dexterous hand" is now available as a research platform as well as for student projects.

The paper *Real-Time Trajectory Generation using Model Predictive Control* by Mahdi Ghazaei et al was nominated as a finalist for the best student paper award at IEEE CASE, Gothenburg, Aug. 2015.

He obtained a travel grant from Royal Physiographic Society of Lund for presenting the paper *An Analytic Solution to Fixed-Time Point-to-Point Trajectory Planning* at IEEE CCA, Sydney, Australia, Sep. 2015.

He supervised Martino Capurso from Politecnico di Milano for the master's thesis "Sensorless Kinesthetic Teaching of Manipulator Assisted by an Observer Based Force Control." In the capacity of teaching assistant and lab supervisor, he was involved in basic control, nonlinear, applied robotics, and project in automatic control courses.

Giselsson, Pontus
Pontus is currently Assistant Professor at the Department of Automatic control since January 2015. He received his MSc from Lund University in 2006 and his PhD from the Department of Automatic Control in at Lund University 2012.

The academic years 2013-2014 Pontus spent at Stanford University under the supervision of Prof. Stephen Boyd. His research interest is in convex optimization and its wide range of applications.

During 2015, he developed and taught a graduate level course on large-scale convex optimization. Currently, he is assistant supervisor to three PhD students.

Grussler, Christian
Since 2012, I am a PhD-student at Lund University. So far, my research interests included Model reduction, Cone invariant systems, Low-rank approximations and Optimization.

During 2015, I was a teaching assistant in the courses: Basic Course in Control, Systemteknik/Processreglering and Non-Linear Control and Servo Systems.

In 2015 I have presented a paper on "On optimal low-rank approximation of non-negative matrices" at the 54th IEEE Conference on Decision and Control.

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

He is responsible for two of the basic courses

in Automatic Control in the engineering program, and main research interests include process control, PID control, adaptive control, control loop monitoring and diagnosis. Main research activities during the year have been design of PID controllers and decentralized control structures.

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

Hast, Martin
MSc in Engineering Physics, PhD student since February 2010. Martin's research interests are in optimal controller design for disturbance attenuation for both feedforward and PID-controllers, supervised by Prof. Tore Hägglund. Martin has worked together with Karl Johan Åström and Stephen Boyd on tuning of SISO and MIMO PID-controllers using convex optimization methods. Work related to tuning rules for low-order feedforward controller has also been conducted and tuning rules for optimal set-point weighting has been developed.

Martin defended his thesis *Design of Low-Order Controllers using Optimization Techniques* in June.

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 and the work is mostly experimental.

Gabriel also defended his Licenciate Thesis *Model-Based Control of Gasoline Partially Premixed Combustion*

Gabriel has during the year been a teaching assistant in the Multi-Variable Control course and in the Real-Time Systems course.

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 FlexiFab, KCFP Control, SARAFun, SMErobotics, and VR Active Control. 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
Research Associate, PhD (1999). Charlotta has been at the department since 1993 except for 4 years (2000-2004) when she worked in industry.

Charlotta's main research interest is in Production Control, Operations Management, Pedagogy and Innovation.

She is part of the management team for the research centers LCCC, PIC-LU and LISA2.

Johnsson, Ola
Tech. Lic, MSc in Biotechnical Engineering, graduate student since August 2010. Works within the field of fermentation control, in cooperation with Novozymes A/S.

Spent 2015 performing experiments in production scale fermentation processes at Novozymes for development and evaluation of a process monitoring method, as well as finalizing a PhD thesis titled 'Perturbation-based Control of Industrial Fed-batch Bioprocesses' for presentation 2016-01-15.

Karlsson, Martin
He has worked as a Ph.D student since April 2014. My research interests are within state estimation, and robot learning and control.

In 2015, he has been working within the EU projects SARAFun, with focus on robot learning for assembly tasks, and FlexiFab, in which friction stir welding performed by a manipulator is developed.

He has worked as a teaching assistant in Systems Engineering/Process Control, Applied Robotics and Projects in Automatic Control.

Lidström, Carolina
MSc in Engineering Physics since May 2013. PhD student at the department since June 2013. Her research interests include scalable and distributed control, with applications in power networks.

From late September to end of October 2015, she was a visiting student at the Institute for Mathematics and its Applications, Univeristy of Minnesota, Minneapolis, USA.

During the year she has been a teaching assistant in two courses, Physiological Models and Computation and Network Dynamics, and co-supervised a Master's thesis project.

Maggio, Martina
Martina Maggio has been a Postdoctoral Researcher at the department since January 2012 and recently became an Assistant Professor in August 2014. She is leading the project on control for power and temperature in computing datacenter, that has strong connections with the cloud control project. During 2015, she has been teaching the Real-Time Systems and the Basic Automatic Control course at the Zhejiang University, China. She also supervised a thesis on resource allocation for camera platforms, performed in a joing collaboration with Axis Technology. She is co-supervising Jonas Dürango and Gautham Nayak Seetanadi towards their PhD studies.

Her research interests are at the border between computing systems and control theory. In the cloud control project, she is mainly working on control for software applications. Software applications are now largely deployed in public or private clouds. Cloud applications and infrastructures should withstand rapid changes and sudden variations, like flash crowds. Usually these variations are supposed to be absorbed by the cloud provider, with autoscaling mechanisms. This project applies control theory to cloud computing, to build reliable and dependable infrastructures and applications, even when the cloud provider does not take care of absorbing fluctuations. Applications can handle these variations through a similar mechanism to brownouts in power grids. Building a brownout-compliant application requires minimal modifications to the original source code.

She is also involved with embedded systems research. In modern computing systems applications must share finite computational resources in a coordinated way. Some application are also able to dynamically adjust their requirements to provide different service levels. Traditionally the problem of distributing the resources and selecting the applications service levels are treated jointly, to produce an optimal solution, however with a high overhead. Her research aims at decoupling the resource allocation and the application adaptation problem, lowering the complexity of both the application manager and the resource manager. This also apply to power and temperature requirements, that should be fulfilled despite changing environment and execution platform

Magnusson, Fredrik
M.Sc. in Engineering Mathematics (2012), Ph.D. student since February 2012.

Fredrik's research regards numerical and symbolic algorithms for solution of non-convex dynamic optimization problems and is a part of the research area Modeling Support for Design and Verification of LCCC.

He was a teaching assistant in the basic control course and the multivariable control course, and also supervised a Master's thesis.

Mannesson, Anders
Lic. Tech., graduate student since June 2010. He joined the department after working 4 years as analog ASIC designer in the electronics industry. He is now working together with Prof. Bo Bernhardsson on improving positioning, radio channel estimates, and link adaptation within the ELLIIT project. His main research topics involves estimation, statistical signal processing, and optimization.

In June 2013, he defended his licentiate thesis called *Joint Pose and Radio Channel Estimation*. During the year he has been a teaching assistant for the undergraduate course Predictive Control. He plans to defend his thesis in the spring of 2016.

Millnert, Victor
PhD student at the department since September 2014. His research interest is within cloud computing.

He has been a teaching assistant for the Basic Control Course, as well as for the Real-Time Control course.

Nayak Seetanadi, Gautham
He is currently a PhD student working on feedback control in cyber-physical systems. My current project involves control of bandwidth allocation with quality of service.

He has been a TA for the basic course AK. He is currently TA for the systems engineering course and I will be a teaching assistant for the 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 FP7 SMERobotics project, trying to use compiler technology knowledge and tools for managing formal knowledge and ontologies with the goal to make industrial robots easier to use.

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

His research interests are modeling and distributed control of large scale systems with applications in traffic networks.

In September and October he participated in part of the program "New Directions in Mathematical Approaches for Traffic Flow Management" at Institute for Pure and Applied Mathematics (IPAM), UCLA, CA.

During the year, he has been involved in the teaching and development of the new master's level course in Network Dynamics and also done some development and teaching in the course Physiological Models and Computations.

Nilsson, Ingrid
Finance 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.

Nishimura, Mika
Born in Japan. Administrator at the department since 2014. She handles student registration and exam results in Ladok and also registers public journals at the department.

She has contact with the printing office about dissertations and other publications. She is responsible for the library, including updating in Libris, and archives and for purchase of office supplies, books and furniture. She updates parts of the web pages and keeps keys in order among other service oriented tasks.

She also teaches Japanese at Folkuniversitetet in Lund.

Nordh, Jerker
MSc in Engineering Physics, graduate student since August 2010.

The research has been focused on applications of non-linear estimation and the development of software to aid in the application of particle methods for non-linear estimation.

In June he defended his doctoral thesis *Bayesian Inference for Nonlinear Dynamical Systems - Applications and Software Implementation.*

Olofsson, Björn
Ph.D. in Automatic Control, employed at the department since August 2010. He defended his Ph.D. Thesis, *Topics in Machining with Industrial Robot Manipulators and Optimal Motion Control*, in September 2015.

During the year, he has also been active in an EU/FP7-project, SMErobotics, as well as in a research project for high-accuracy temperature control of the phase-reference distribution system at ESS. He has also taken active part in the teaching at the department, both within the undergraduate engineering programs and by supervision of Master Thesis projects.

Papadopoulos, Alessandro Vittorio
MSc in Computer Engineering (2010), PhD in Information Technology – Systems and Control (2014). He joined the department as a Postdoctoral Researcher in January 2014. His research interests are cloud control, feedback computing, real-time and embedded systems, cyber-physical systems, modeling and simulation of complex systems, evolutionary game theory, and human-robot interaction.

He has taught the undergraduate Real-Time Systems course together with Prof. Karl-Erik Årzén.

Pates, Richard
He joined the department as a Postdoctoral Researcher in October 2015.

His research interests are primarily in the area decentralised control for networks, with applications to large scale electrical power systems.

Since joining he has become involved with an existing voltage stability project within the group, as well as working on general synthesis tools for electrical networks.

He is also a co-supervisor of a masters student working on systems with recycle.

Perninge, Magnus
Postdoc. since January 2013.

His research interests are: Power system stability and control, stochastic control, operations research. He is working in the project "A Stochastic Control Approach to Optimal Power System Operation", funded by the Swedish Research Council.

He is assistant supervisor for PhD-student Carolina Lidström.

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 robustness, optimization and distributed control.

Anders is the main supervisor for several PhD students. During 2015, he was teaching the courses "FRT095 Mathematical Modelling" and "FRT130 Control Theory" at the MSc level and "FRT125F Robust Control" at the PhD level.

Anders also served as chairman of the Swedish Scientific Council for Natural and Engineering Sciences. He spent September 2015 to May 2016 as visiting researcher and coorganizer of a thematic period on Control Theory at Institute for Mathematics and Its Applications, University of Minnesota.

Rasmusson, Monika
Financial administrator at the department since August 2011. As a part of the administrative team, her work includes reimbursements, travel bills, reporting projects, involvement in the budgetprocess among other 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 with the LUCAS project, the

Robotics Lab, The Linneaus Centre LCCC, ELLIIT network, and the EU funded projects SaraFUN (H2020), SMErobotics (FP-7), and Flexifab (FP-7). 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, Ericsson AB, and within the VR-funded CloudControl-project together with Umeå University.

He has been course responsible in project courses on automatic control (FRT090), Applied robotics (MMKF15), Multivariable Control (FRTN10), and been supervisor for project groups in mechatronics and participated in the teacher education at Vattenhallen, LTH.

He has acted as advisor/co-advisor for (3+6) PhD students and several Master's Thesis project.

Sörnmo, Olof
Lic. Tech., PhD student since 2010. Olof's research focuses mainly on improving machining processes performed with industrial manipulators, considering both positioning accuracy and cycle-time minimization. During 2015, Olof finalized and defended his thesis *Adaptation and Learning for Manipulators and Machining*.

Ståhl, Fredrik
Lic. Tech. (2012). Graduate student since 2008 (part-time 2008-2012). Fredrik's main research interests focus on modeling, identification and prediction of blood glucose dynamics.

Fredrik defended his Doctoral Thesis *Towards Defence in Depth In Diabetes Glucose Self-Management* in December.

Stemmann, Meike
Lic. Tech., graduate student since November 2009. She is working together with Anders Rantzer on control of energy usage in buildings, within the eLLIIT project. Within this project, she is looking at the possibilities of improving temperature regulation and occupant comfort by using PID control and decoupling networks.

During 2015, she worked on two examples of applying decoupled PI control to the area of building control. The first one concerns the decoupling of the temperature dynamics of adjacent rooms. The second one uses a decoupling PI controller to reduce the interaction between the control of CO2 level and room temperature by a ventilation system. For this, experiments have been performed at a test-lab at KTH in Stockholm.

Stolt, Andreas
PhD (2010). During 2015 he finalized and defended his PhD thesis *On Robotic Assembly using Contact Force Control and Estimation*.

Andreas main research focus is force controlled compliant assembly and sensor-less force control with industrial robots. During 2015 he was involved in teaching the project course in Automatic Control.

Thelander Andrén, Marcus
MSc in Engineering Physics (2015), and a PhD student at the department since August 2015. His main research interests are in event-based estimation and control.

During the autumn of 2015 he has also been taking courses and been a teaching assistant and lab supervisor in the basic course in Automatic Control.

Troeng, Olof
MSc (2012). PhD student since Oct 2014. He is working with low level radio frequency control (LLRF) of the accelerating fields in the linear accelerator at the European Spallation Source.

During the year he has analyzed different aspects of the control problem, modeled the achievable performance and assisted in the development of requirements on RF system components. He has visited existing accelerator facilities and presentated at specialized workshops.

Olof has been a teaching assistant in the courses on market-driven systems and nonlinear control as well as supervised four projects in the project course.

Westin, Eva
PhD in French linguistics.

Administrator at the department since 2008 and administrative coordinator from 2012. She handles the overall responsibility of human resources, guests and conferences. She also handles part of the process for research studies.

Eva is the project administrator for the LCCC Linnaeus project.

She is part of the workplace health and safety team at the department. She is also part of the Equality group at the Faculty of Engineering and works with these questions at the Department.

During November and December, Eva has worked part time at the Swedish Migration Office in Malmö within a cooperation between Swedish authorities, in this case Lund University, and the Swedish Migration Office.

Eva was the co-supervisor of a PhD thesis in French linguistics, defended in June 2015, at the Center of Languages and Literature (SOL) at Lund University.

Wittenmark, Björn
He joined the department in 1966 and took his PhD in 1973. He became full professor at the department 1989. His main research interests are adaptive control, sampled-data systems, and process control.

He is emeritus professor at the department since 2010.

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.

During this year he was a teaching assistant in Automatic Control course, in Lund University and Zhejiang University.

AUTOMATIC CONTROL 50 YEARS

The Department of Automatic Control turned 50 years in 2015, and this was celebrated with a jubilee conference on May 29. More than 120 persons showed up for the occasion, including the majority of all previous employees as well as members from Joint Services in the M-building.

The conference started outdoors with the hoisting of a special control flag under ceremonious forms. Then followed the official opening in M:A by the Dean of LTH, Viktor Öwall. C.H. Walde traced the origins of the department to Karl Johan Åström's years at KTH. This was followed by a overview of the department's early years by Björn Wittenmark and a more recent historical expose by Lars Nielsen.

A special historical lunch buffet had been prepared, with typical dishes from the different decades. A tour of the M-building followed, with visits to the Robotics Lab, the Motor Lab and the Course Laboratory. In the afternoon program, Karl Johan Åström talked about the future of control, while Gustaf Olsson spoke on the world-wide challenge of energy and water from a systems engineering perspective. Examples of recent research trends and topics in control were given by Karl-Erik Årzén, Charlotta Johnsson, and Bo Bernhardsson. The conference ended with a dinner at Luftkastellet in Malmö.

The jubilee conference was partially sponsored by Royal Physiographic Society of Lund.

In the following pages there is a collage of pictures from this event.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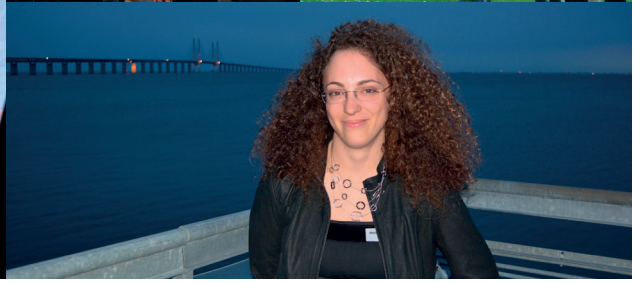


AWARDS

GRANTS

Grant from Institute for Pure and Applied Mathematics

This autumn, Gustav Nilsson received a 5,200 USD traveling and housing grant from Institute for Pure and Applied Mathematics, UCLA, Los Angeles, USA.

Maja and Erik Lindqvist Foundation Award

The board of the "Maja and Erik Lindqvist foundation" awarded Martina Maggio, and the Department of Automatic Control, at Lunds Tekniska Högskola, with 315 000 SEK, for investment to equip a cloud laboratory that will be used in the cloud control project

Grant from Hans Werthén Fund

Kristian Soltesz received a grant from Hans Werthén fund through IVA, to partially finance his collaboration with Sigurd Skogestad's group at NTNU in Norway.

Grants from Royal Physiographic Society

Jacob Antonsson recieved a travel grant for young scientists and PhD students from Royal Physiographic Society in Lund.

Mahdi Gazaei received a travel grant for his participation in IEEE Multi-Conference on Systems and Control (MSC2015), Manly Beach, Sydney.

ICRA-nomination finalist

The paper, *Detection of Contact Force Transients in Robotic Assembly,* has been selected as a finalist for the following awards at 2015 IEEE Int. Conf. Robotics and Automation (ICRA 2015) in Seattle, May, 2015: "Best Conference Paper Award", "Best Student Paper Award" and "Best Automation Paper Award". The paper was written by Andreas Stolt*, Anders Robertsson, Magnus Lindroth, Rolf Johansson.

Financial Support from University of Minnesota

Michelle Chong received financial support to visit the Institute for Mathematics and its Applications (IMA) at the University of Minnesota (1 month).

Best Student Paper Award- Finalist

Finalist from the 2015 IEEE International Conference on Automation Science and Engineering (CASE2015), in Gothenburg, August 2015, for the paper entitled *Real-Time Trajectory Generation Using Model Predictive Control*, written by M. M. Ghazaei Ardakani, B. Olofsson, A. Robertsson, R. Johansson.

ASSIGNMENTS

BOARD MEMBER

Årzén, Karl-Erik
Vice Chairman of the Board for the ELLIIT strategic research area project.
Member of the Program Management Group for the Wallenberg Autonomous Systems Program (WASP).
Member of the Strategic Management Board for the EMSIG Special Interest Group on Embedded Systems.
Member of Research Board of Mathematics, Physics & Information and Communication Technology, 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).

Eker, Johan
Member of steering committee of HiPEAC - European Network of Excellence on High Performance and Embedded Architecture and Compilation.
Member of leadership team Ericsson Research Cloud Technology.

Johnsson, Charlotta
Board Member at PTW at Högskolan Väst, Trollhättan, Sweden.
Board member at SESAM-Sverige, a network for industrial automation.
Board member at SmartFactory TU Kaiserslautern, Germany.

Hägglund, Tore
Expert member in legal proceedings for patent at Svea Court of Appeal.

Rantzer, Anders
Chairman of the Scientific Council for Natural and Engineering Sciences within the Swedish Research Council.
Member of the steering committee for the International Symposium on Mathematical Theory of Networks and Systems.

Wittenmark, Björn
Board member of the research program PIC-LU.
Member of Editorial Board: Journal of Forecasting.
Member of the research board of Gyllenstiernska Krapperupsstiftelsen.

MEMBER OF INTERNATIONAL PROGRAM COMMITTEE (IPC)

Årzén, Karl-Erik
General Chair for Euromicro Conference on Real-Time Systems (ECRTS), Lund, Sweden, July 7-10, 2015.
Program Co-Chair for Feedback Computing 2015, Seattle, WA, April 13, 2015.

Finance Chair for the Real-Time Systems Symposium (RTSS), San Antonio, Texas, December 1-4, 2015.
Member of the Program Committee for the Real-Time Systems Symposium (RTSS), San Antonio, Texas, December 1-4, 2015.
Member of the Program Committee for DATE 2015 (Design, Automation & Test in Europe), Grenoble, France, March 9-13, 2015.
Member of the Program Committe for EMSOFT 2015 (The 15th ACM SIGBED International Conference on Embedded Software), Amsterdam, The Netherlands, October 4-9, 2015.
Member of the Program Committee for 3rd IEEE International Conference on Cloud and Autonomic Computing, CAC 2015, Boston, MA, September 21-25, 2015.

Cervin, Anton
Member of the IPC for the 27th Euromicro Conference on Real-Time Systems, Lund, Sweden.

Eker, Johan
Program committee member for DCC ACM SIGMETRICS Workshop Distributed Cloud Computing.
Program committee member for SIPS - IEEE Workshop on Signal Processing Systems.
Program committee member ICASSP - IEEE Int. Conf. on Acoustics, Speech and Signal Processing.
Program committee member for SIES - IEEE International Symposium on Industrial Embedded Systems.
Program committee member for HiRES - Workshop on High-performance and Real-time Embedded Systems.
Program committee member for MCC - Swedish Multicore Conference.
Project Reviewer for the ARTEMIS/ECSEL project PaPP, 2013 -- 2015.
Project Reviewer for the FP7 project DREAMS.

Hägglund, Tore
International Workshop on Event-Based Systems (EBS 2014), Barcelona, Spain.

Maggio, Martina
Program chair of the 13th IEEE International Symposium on Parallel and Distributed Processing with Applications (ISPA), Helsinki, Finland, 2015.
Local chair of the 27th Euromicro Conference on Real-Time Systems (ECRTS), Lund, Sweden, 2015.
Program co-chair of the 1st workshop on Control Theory for Software Engineering (CTSE), co-located with ESEC/FSE, Bergamo, Italy, 2015.
Program Committee Member of the Cyber-Physical Systems Track of IEEE Real-Time Systems Symposium (RTSS 2015).
Program Committee Member of the 3rd IEEE International Conference on Cloud and Autonomic Computing (ICCAC 2015).
Program Committee Member of the 6th International Workshop on Analysis Tools and Methodologies for Embedded and Real-time Systems (WATERS 2015).
Program Committee Member of the 9th Junior Researcher Workshop on Real-Time Computing at RTNS 2015.
Program Committee Member of the 1st International Workshop on Software Engineering for Smart Cyber-Physical Systems (SesCPS 2015).
Program Committee Member of the 10th International Workshop on Feedback Computing (Feedback computing 2015).

Program Committee Member of the 20th IEEE International Conference on Emerging Technologies and Factory Automation (EFTA 2015).
Program Committee Member of the 7th Workshop on Adaptive and Reconfigurable Embedded Systems (APRES 2015).
Program Committee Member of the NASA/ESA Adaptive Hardware and Systems 2015 (AHS 2015).
Program Committee Member of the 20th IEEE International Conference on Embedded and Real-Time Computing (RTCSA 2015).

Papadopoulos, Alessandro Vittorio
2015 ECRTS: Euromicro Conference on Real-Time Systems – Local Chair.
Program Committee member in 2015 IEEE ISPA: 13th IEEE International Symposium on Parallel and Distributed Processing with Applications.
Program Committee member in 2015 CTSE: 1st International Workshop on Control Theory for Software Engineering.

Rantzer, Anders
Chairman of the IPC for European Control Conference, Ålborg, 2016.

OPPONENT AND MEMBER OF EXAMINATION COMMITTEE

Bernhardsson, Bo
Member of the examination committee for Anders Nejdel, EIT, Lund University.

Cervin, Anton
Faculty Opponent at the PhD defence of Nima Khalilzad, Mälardalen University, November 5.

Eker, Johan
External PhD thesis evaluator for Stefan Schorr, Technische Universität Kaiserslautern, March.
Opponent at licentiate thesis of Essayas Gebrewahid, Halmstad University, March.
External PhD thesis evaluator for Helena Gruhn at Technische Universität Berlin, December.

Giselsson, Pontus
Opponent to Isac Nielsen's licenciate thesis "*On Structure Exploiting Numerical Algorithms for Model Predictive Control* at Linköping University. October 23, 2015.

Robertsson, Anders
Member/chair of evaluation committee for the PhD thesis by Sebastian Haner, Dept of Mathematics, Lund University, *View Planning and Refractive Modeling for Structure and Motion,* March 6, 2015.
Member of evaluation committee for the PhD thesis public PhD defence of Niccolo Tosi, KU Leuven, Belgium *Active Sensing for Touch-based Object Localisation*, March 30, 2015.
Member of Thesis committee for PhD defense by Pablo Cano Marchal, Univ Jaen, Spain *Contribution to the Modeling and Automatic Control of the Virgin Olive Oil Elaboration Process*, June 3, 2015.
PhD-thesis opponent Øyvind Berg Magnussen, University of Agder *Multirotor Design Optimization: The Mechatronic Approach*, August 11, 2015.

Member of Thesis committee (chairman). PhD thesis *Robust Observer Design for a Class of Nonlinear Systems: Linear Matrix Inequality Approach*, Saleh Sayyaddelshad, Control Engineering Group, Department of Computer Science, Electrical and Space Engineering, Luleå University of Technology, September 29, 2015.

Member of PhD Thesis committee for Johan Markdahl, Optimization and Systems Theory, KTH, Sweden, PhD thesis *Rigid-Body Attitude Control and Related Topics*, November 6, 2015.

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.

Member of the Royal Swedish Academy of Engineering Sciences (IVA).

Chairman of IVA Syd.

Eker, Johan

Member of IEEE Design and Implementation of Signal Processing Systems Technical Committee.

Johansson, Rolf

Member of IEEE EMBS Technical Committee (TC) for Biomedical Robotics.

Member of Joint EMBS/RAS Advisory Committee on Biorobotics.

Johnsson, Charlotta

Voting member in the standardisation committee ISA95 and an information member in the standardization committees ISA88 and ISA99.

Member in SIS and SEK and serves as the Swedish expert in the international IEC 62264 and ISO 22400 standards.

Member in SIS's Strategic Advisory Group for Industry 4.0/Smart Manufacturing.

Papadopoulos, Alessandro Vittorio

Member of the Standard Performance Evaluation Corporation (SPEC) and of the SPEC RG Cloud WG - Elasticity Controller Benchmarking working group.

Rantzer, Anders
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.
Member of the organizing committeee for the IMA Thematic Program 2015/16 on "Control Theory and its Applications".

OTHER ASSIGNMENTS

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

Johansson, Rolf
Editor, Mathematical Biosciences, (Elsevier).
Editor, Intelligent Service Robotics (ISR).
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
Serves as the IFAC Liaison with IEC 65A
Editor of ISO 22400 Part 1.

Hägglund, Tore
Editor for Control Engineering Practice.

Maggio, Martina
Journal Editor: Associate Editor for the ACM Transaction on Embedded Systems, in the specific area of Self-Aware/Self-Adaptive Computing.

Robertsson, Anders
Member of evaluation board for signals and systems in the Swedish Research Council.

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

LONGER VISITS ABROAD

Antonsson, Jacob
Pasteur Institute, Paris, France during January-April, 2015.

Nilsson, Gustav
Institute for Mathematics and its Applications, UCLA, Los Angeles, USA, during September-October, 2015.

Soltész, Kristian
Lecturer of Automatic Control Basic Course at Zheijang University, Hangzhou, China, during November-December, 2015.
Visiting postdoc at Dept. Chemical Engineering, NTNU, Norway.

Xu, Yang
Zheijang University, Hangzhou, China for two months during the fall.

Economy

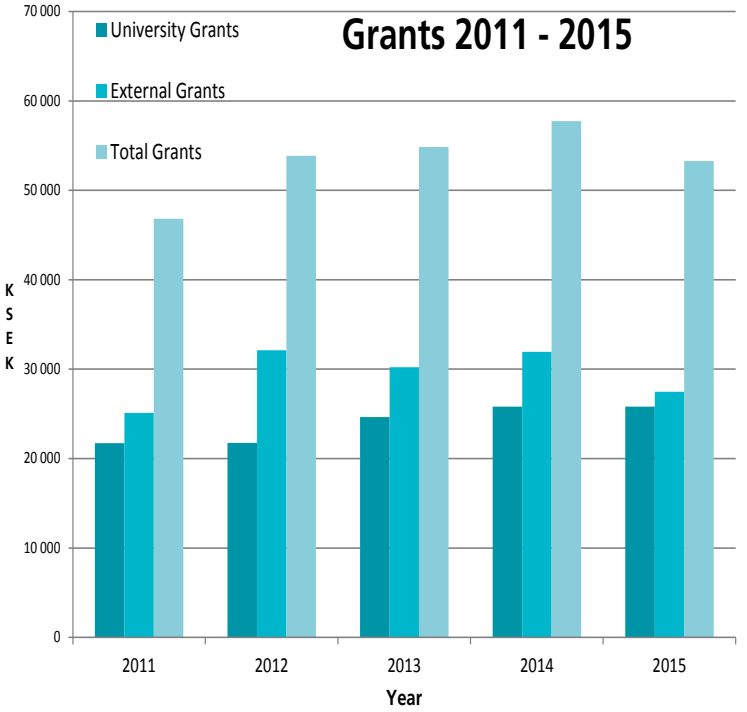
This chapter contains an overall view of the economy and funding

ECONOMY

The turnover for 2015 was 53 MSEK, a decrease by 5 MSEK since 2014. About half of the income, 48%, comes from Lund University, and the rest, 52%, from external grants. The distribution is shown below.

The activity and the number or employees seems to have stabilized during the last years, the number of employees is about the same 2015 as 2010. The department participated in 3 projects funded by the European Union, EU, during 2015 and The Swedish Foundation for Strategic Research, VR, has also provided substantial support of the activities.

The block grants from VR and some of the SSF (Swedish Foundation for Strategic Research) 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.



FUNDING

During 2015 we had the following grants:

VR – Linnaeus grant Lund Center for Control of Complex Engineering Systems LCCC
VR – Resource Allocation and Control of Distributed Service Management Systems
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 – Event-based control components with performance bounds
VR – Active Control of Compressor Systems Based on New Methods of Nonlinear Dynamic Feedback Stabilization
VR – Scalable and Resource-Constrained Control Systems
VR – Cloud Control
VR – Remuneration for Anders Rantzers´ function as a Member of the Scientific Council for Natural and Engineering Sciences within the Swedish Research Council 2013-2015
VR – Power and temperature control for large-scale computing infrastructures
VR – Methods for control of large-scale dynamical systems
VR – Stokastisk reglering för optimal drift av elkraftsystem
VR – Reglering i cyberfysiska system
Energimyndigheten - Predictive Control and System Optimisation of Wheel Loaders
Vinnova – Line Information System Architecture, LISA
Vinnova-Saab – Adaptiv Control in Flying Vehicles
Vinnova- Control of batch processes in biotechnology and biopharma industry
Vinnova – PiiAbio
Vinnova – PiiA-Nyckeltal i svensk processintustri
Vinnova – Nästa generations automatinställare för PID-regulator
Vinnova – FFI Informationssystemarkitektur 2 – Smarta händelsestyrda tjänster – LISA2
Vinnova – Automatinställande Industriell Reglering - PiiAuto
SSF – Process Industrial Centre at Lund University, PICLU
SSF – Enabling GROwing Software Systems, ENGROSS
SSF – ICT platform for lasting infrastructure, ICT-PSI
SSF – Process Industrial Centre at Lund University, PICLU 2
SSF /ICA – Algoritmer och verktyg för realtidsoptimering
EU – FP7 287787 The European Robotics Initiative for Strengthening the Competitiveness of SMEs in Manufacturing by integrating aspects of cognitive systems, SMErobotics
EU – FP7–SME-2013-606156-FlexiFab – Flexible fabrication of lightweight aluminium transport structures, FlexiFab
EU – FP7 285380 The Productive Robot Apprentice, PRACE
EU – Horizon 2020, GA 644938, Smart Assembly Robot with Advanced FUNctionalities – SARAFun
KAW – Wallenberg Autonomous Systems Program – WASP
ESS – Temperature Control of Phase Reference Line
The Linköping–Lund Initiative on IT and Mobile Communication, ELLIIT
SKB - Control of Stirwelding Process for Sealing
Novozymes – Agreement on Co-financed PhD study
Emissions Control for Low Climate Impact, KCFP3
PGS Americas Inc. – Marine Vibrators

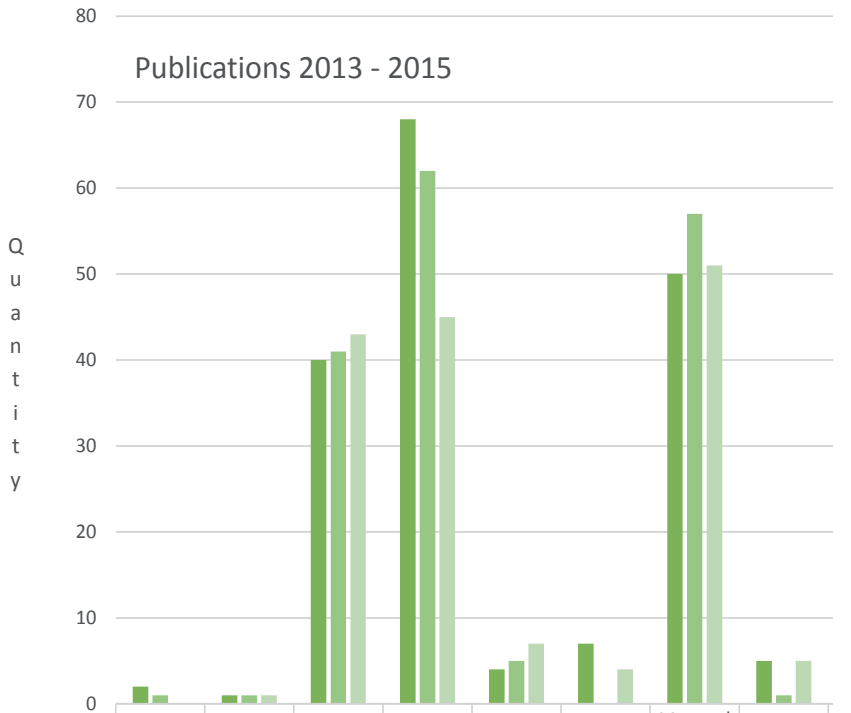
Appendix

This chapter contains a list of publications,seminars and lectures given outside the department during 2015

PUBLICATIONS 2015

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:

- Linköpings Universitetsbibliotek, Svensktrycket, SE-581 83 Linköping.
- Universitetsbiblioteket Lund, Svenska Tryckavdelningen, Box 1010, SE-221 03 Lund.
- Stockholms Universitetsbibliotek, Box 5039, SE 102 41 Stockholm.
- Umeå Universitetsbibliotek, Box 718, SE-901 01 Umeå.
- Uppsala Universitetsbibliotek, Box 510, SE-751 20 Uppsala.



	Books	Book contr	Articles	Conf contr	PhD theses	Lic theses	Masters' theses + TM	Techn reports
2013	2	1	40	68	4	7	50	5
2014	1	1	41	62	5	0	57	1
2015	0	1	43	45	7	4	51	5

BOOK CONTRIBUTIONS

Johansson, Rolf; Nilsson, Klas; Robertsson, Anders: *Force Control;* In Andrew Y. C. Nee (Ed.): Handbook of Manufacturing Engineering and Technology, Springer-Verlag, London, 2015.

JOURNAL ARTICLES

Berntorp, Karl: *Joint Wheel-Slip and Vehicle-Motion Estimation Based on Inertial, GPS, and Wheel-Speed Sensors*; IEEE Transactions on Control Systems Technology, 2015.

Bini, Enrico: *The Quadratic Utilization Upper Bound for Arbitrary Deadline Real-Time Tasks*; IEEE Transactions on Computers, 64:2, pp. 593–599, 2015.

Boyd, Stephen; Hast, Martin; Åström, Karl Johan: *MIMO PID Tuning via Iterated LMI Restriction*; International Journal of Robust and Nonlinear Control, 2015.

Ceriani, Nicola Maria; Zanchettin, Andrea Maria; Rocco, Paolo; Stolt, Andreas; Robertsson, Anders: *Reactive Task Adaptation Based on Hierarchical Constraints Classification for Safe Industrial Robots;* IEEE-ASME Transactions on Mechatronics, 20:6, pp. 2935–2949, 2015.

Cescon, Marzia; Johansson, Rolf; Renard, Eric: *Subspace-based linear multi-step predictors in type 1 diabetes mellitus;* Biomedical Signal Processing and Control, 22, pp. 99–110, 2015.

Chasparis, Georgios C.; Shamma, Jeff S.; Rantzer, Anders*: Nonconvergence to saddle boundary points under perturbed reinforcement learning;* International Journal of Game Theory, 44:3, pp. 667–699, 2015.

Como, Giacomo; Lovisari, Enrico; Savla, Ketan: *Throughput optimality and overload behavior of dynamical flow networks under monotone distributed routing*; IEEE Transactions on Control of Network Systems, 2:1, pp. 57–67, 2015.

De Coninck, Roel; Magnusson, Fredrik; Åkesson, Johan; Helsen, Lieve: *Toolbox for development and validation of grey-box building models for forecasting and control;* Journal of Building Performance Simulation, 2015.

Dirr, Gunther; Ito, Hiroshi; Rantzer, Anders; Rüffer, Björn: *Separable Lyapunov functions for monotone systems: Constructions and limitations*; Discrete and Continuous Dynamical Systems Series B, 20:8, pp. 2497–2526, 2015.

Epperlein, Jonathan P.; Bamieh, Bassam; Åström, Karl Johan: *Thermoacoustics and the Rijke Tube: Experiments, Identification, and Modeling*; IEEE Control Systems Magazine, 35:2, pp. 57–77, 2015.

Fabri, Simon G.; Wittenmark, Björn; Bugeja, Marvin K.: *Dual adaptive extremum control of Hammerstein models*; International Journal of Control, 88:6, pp. 1271–1286, 2015.

Garpinger, Olof; Hägglund, Tore: *Software-based optimal PID design with robustness and noise sensitivity constraints*; Journal of Process Control, 33:9, pp. 90–101, 2015.

Giselsson, Pontus; Boyd, Stephen: *Metric selection in fast dual forward-backward splitting;* Automatica, 62, pp. 1–10, 2015

Guzmán, José Luis; Hägglund, Tore; Veronesi, Max; Visioli, Antonio: *Performance indices for feedforward control*; Journal of Process Control, 26, pp. 26–34, 2015.

Hamon, Camille; Perninge, Magnus; Söder, Lennart: *A computational framework for risk-based power system operations under uncertainty. Part I: Theory;* Electric Power Systems Research, 119, pp. 45–53, 2015.

Hamon, Camille; Perninge, Magnus; Söder, Lennart: *A computational framework for risk-based power system operations under uncertainty. Part II: Case studies;* Electric Power Systems Research, 119, pp. 66–75, 2015.

Hast, Martin; Hägglund, Tore: *Optimal proportional–integral–derivative set-point weighting and tuning rules for proportional set-point weights*; IET Control Theory & Applications, 9:15, pp. 2266–2272, 2015.

Holmqvist, Anders; Andersson, Christian; Magnusson, Fredrik; Åkesson, Johan: *Methods and Tools for Robust Optimal Control of Batch Chromatographic Separation Processes*; Processes, 3:3, pp. 568–606, 2015.

Ingesson, Gabriel; Yin, Lianhao; Johansson, Rolf; Tunestål*; Per: A Model-Based Injection-Timing Strategy for Combustion-Timing Control;* SAE International Journal of Engines, 8:June 2015; 8 (3), pp. 1012–1020, 2015.

Ingesson, Gabriel; Yin, Lianhao; Johansson, Rolf; Tunestål, Per: *Simultaneous Control of Combustion Timing and Ignition Delay in Multi-Cylinder Partially Premixed Combustion; S*AE International Journal of Engines, 8:5, 2015.

Johnsson, Charlotta; Nilsson, Carl-Henric: *Mixing Engineering, Business and Design Students in an International Cross-Disciplinary Course on Innovation*; Applied Innovation Review, 1:1, pp. 66–75, 2015.

Johnsson, Ola; Sahlin, D.; Linde, J.; Lidén, Gunnar; Hägglund, Tore*: A mid-ranging control strategy for non-stationary processes and its application to dissolved oxygen control in a bioprocess;* Control Engineering Practice, 42, pp. 89–94, 2015.

Johnsson, Ola; Andersson, Jonas; Lidén, Gunnar; Johnsson, Charlotta; Hägglund, Tore: *Modelling of the oxygen level response to feed rate perturbations in an industrial scale fermentation process*; Process Biochemistry, 50:4, pp. 507–516, 2015.

Khong, Sei Zhen; Tan, Ying; Manzie, Chris; Nesic, Dragan: *Extremum seeking of dynamical systems via gradient descent and stochastic approximation methods*; Automatica, 56, pp. 44–52, 2015.

Kortier, Henk; Antonsson, Jacob; Schepers, Martin; Gustafsson, Fredrik; Veltink, Peter: *Hand pose estimation by fusion of inertial and magnetic sensing aided by a permanent magnet*; IEEE Transactions on Neural Systems and Rehabilitation Engineering, 23:5, pp. 796–806, 2015.

Lee, Kuan; Moase, Will; Khong, Sei Zhen; Ooi, Andrew; Manzie, Chris: *Aerodynamic Shape Optimization via Global Extremum Seeking*; IEEE Transactions on Control Systems Technology, 23:6, pp. 2336–2343, 2015.

Lee, Sang Hyoung; Suh, Il Hong; Calinon, Sylvain; Johansson, Rolf: *Autonomous framework for segmenting robot trajectories of manipulation task*; Autonomous Robots, 38:2, pp. 107–141, 2015.

Li, Yuling; Johansson, Rolf; Yin, Yixin: *Acceleration feedback control for nonlinear teleoperation systems with time delays*; International Journal of Control, 88:3, pp. 507–516, 2015.

Li, Yuling, Johansson, Rolf; Liu, Kun; Yin, Yixin: *Guaranteed cost control design for delayed teleoperation systems;* Journal of the Franklin Institute, 352:11, pp. 5085–5105, 2015.

Lovisari, Enrico; Kao, Chung-Yao: *Synchronization of Networks of Heterogeneous Agents With Common Nominal Behavior*; IEEE Transactions on Automatic Control, 60:3, pp. 671–683, 2015.

Lu, Shan; Su, Hongye; Johnsson, Charlotta; Wang, Yue; Xie, Lei: *Modelling and Optimization Methods of Integrated Production Planning for Steel Plate Mill with Flexible Customization*; Chinese Journal of Chemical Engineering, 2015.

Magnusson, Fredrik; Åkesson, Johan: *Dynamic Optimization in JModelica.org*; Processes, 3:2, pp. 471–496, 2015.

Papadopoulos, Alessandro Vittorio; Maggio, Martina; Terraneo, Federico; Leva, Alberto: *A Dynamic Modelling Framework for Control-based Computing System Design*; Mathematical and Computer Modelling of Dynamical Systems, 21:3, pp. 251–271, 2015.

Papadopoulos, Alessandro Vittorio; Leva, Alberto: *A model partitioning method based on dynamic decoupling for the efficient simulation of multibody systems*; Multibody System Dynamics, 34:2, pp. 163–190, 2015.

Papadopoulos, Alessandro Vittorio; Maggio, Martina; Leva, Alberto; Bini, Enrico: *Hard real-time guarantees in feedback-based resource reservations*; Real-Time Systems, 51:3, pp. 221–246, 2015.

Perninge, Magnus: *Approximating the parameter-space stability boundary considering post-contingency corrective controls*; Electric Power Systems Research, 121, pp. 313–324, 2015.

Rantzer, Anders: *Scalable Control of Positive Systems*; European Journal of Control, 24, pp. 72–80, 2015.

Rantzer, Anders: *On the Kalman-Yakubovich-Popov Lemma for Positive Systems;* IEEE Transactions on Automatic Control, 2015.

Sidhu, Ikhlaq; Johnsson, Charlotta; Singer, Ken; Suoranta, Mari: *A Game-Based Method for Teaching Entrepreneurship*; Applied Innovation Review, 1:1, pp. 51–65, 2015.

Sörnmo, Olof; Bernhardsson, Bo; Kröling, Olle; Gunnarsson, Per; Tenghamn, Rune: *Frequency-Domain Iterative Learning Control of a Marine Vibrator;* Control Engineering Practice, 2015.

Sörnmo, Olof; Olofsson, Björn; Robertsson, Anders; Johansson; Rolf: *Learning Approach to Cycle-Time-Minimization of Wood Milling Using Adaptive Force Control;* Journal of Manufacturing Science and Engineering, 2015.

Stenmark, Maj; Malec, Jacek; Nilsson, Klas; Robertsson, Anders: *On Distributed Knowledge Bases for Robotized Small-Batch Assembly*; IEEE Transactions on Automation Science and Engineering, 12:2, pp. 519–528, 2015.

Teixeira, Andre; Sou, Kin Cheong; Sandberg, Henrik; Johansson, Karl Henrik: *Secure control systems a quantitative risk management approach*; IEEE Control Systems Magazine, 35:1, pp. 24–45, 2015.

Theorin, Alfred; Hägglund, Tore: *Derivative backoff: The other saturation problem for PID controllers;* Journal of Process Control, 33, pp. 155–160, 2015.

CONFERENCE CONTRIBUTION

Axelsson, Magdalena; Magnusson, Fredrik; Henningsson, Toivo: *A Framework for Nonlinear Model Predictive Control in JModelica.org;* In 11th International Modelica Conference, Paris, France, September 2015.

Bagge Carlson, Fredrik; Johansson, Rolf; Robertsson, Anders: *Six DOF Eye-to-Hand Calibration from 2D Measurements Using Planar Constraints*; In IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2015), Hamburg, Germany, September 2015.

Bagge Carlson, Fredrik; Robertsson, Anders; Johansson, Rolf: *Modeling and Identification of Position and Temperature Dependent Friction Phenomena without Temperature Sensing*; In IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2015), Hamburg, Germany, September 2015.

Berntorp, Karl: *Particle Filter for Combined Wheel-Slip and Vehicle-Motion Estimation*; In 2015 American Control Conference, Chicago, IL, July 2015.

Berntorp, Karl; Magnusson, Fredrik: *Hierarchical Predictive Control for Ground-Vehicle Maneuvering*; In 2015 American Control Conference, Chicago, IL, July 2015.

Cederqvist, Lars; Garpinger, Olof; Cervin, ANton; Nielsen, Isak: *Improved Temperature and Depth Control During FSW of Copper Canisters Using Feedforward Compensation*; In Friction Stir Welding and Processing VIII, 2015

Dellkrantz, Manfred; Dürango, Jonas; Robertsson, Anders; Kihl, Maria: *Model-Based Deadtime Compensation of Virtual Machine Startup Times*; In 10th International Workshop on Feedback Computing, Seattle, WA, April 2015.

Desmeurs, David; Klein, Cristian; Papadopoulos, Alessandro Vittorio; Tordsson, Johan: *Event-Driven Application Brownout: Reconciling High Utilization and Low Tail Response Times*; In 2015 IEEE International Conference on Cloud and Autonomic Computing (ICCAC), Cambridge, MA, USA, September 2015.

Fält, Mattias; Raman, Vasumathi; Murray, Richard M.: *Variable Elimination for Scalable Receding Horizon Temporal Logic Planning;* In American Control Conference, Chicago, July 2015.

Far, Behrouz Afzali; Lidström, Per: *A Class of Generalized Gough-Stewart Platforms Used for Effectively Obtaining Dynamic Isotropy - an Analytical Study*; 2015.

Farias, Felix; Johnsson, Charlotta; Ramminger, Guilherme; Lima, Luiz: *Key Performance Indicators for Monitoring and Evaluation of PID and APC Strategies at Manufacturing Operations Management Level in a Natural Gas Processing Unit*; In 12th International Symposium on Process Systems Engineering and 25th European Symposium on Computer Aided Process Engineering, Copenhagen, Denmark, June 2015.

Filieri, Antonio; Maggio, Martina; Angelopoulos, Konstantinos; D'Ippolito, Nicolas; Gerostathopoulos, Ilias; Hempel, Andreas Berndt; Hoffmann, Henry; Jamshidi, Pooyan; Kalyvianaki, Evangelia; Klein, Cristian; Krikava, Filip; Misailovic, Sasa; Papadopoulos, Alessandro Vittorio; Ray, Suprio; Sharifloo,Amir M.; Shevtsov, Stepan; Ujma, Mateusz; Vogel, Thomas: *Software Engineering Meets Control Theory*; In 10th International Symposium on Software Engineering for Adaptive and Self-Managing Systems, Florence, May 2015.

Filieri, Antonio; Hoffmann, Hank; Maggio, Martina: *Automated Multi-Objective Control for Self-Adaptive Software Design*; In 10th Joint Meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering, Bergamo, Italy, August 2015.

Ghazaei, Mahdi; Stemmann, Meike; Robertsson, Anders; Johansson, Rolf: *An Analytic Solution to Fixed-Time Point-to-Point Trajectory Planning*; In 2015 IEEE Conference on Control Applications (CCA), Sydney, Australia, September 2015.

Ghazaei, Mahdi; Robertsson, Anders; Johansson, Rolf: *Online Minimum-Jerk Trajectory Generation*; In 2015 IMA Conference on Mathematics of Robotics, Oxford, UK, September 2015.

Ghazaei, Mahdi; Olofsson,Björn; Robertsson, Anders; Johansson, Rolf: *Real-Time Trajectory Generation using Model Predictive Control*; In IEEE International Conference on Automation Science and Engineering (IEEE CASE 2015), Gothenburg, August 2015.

Holmqvist, Anders; Magnusson, Fredrik; Nilsson, Bernt: *Dynamic Multi-Objective Optimization of Batch Chromatographic Separation Processes;* In 12th International Symposium on Process Systems Engineering and 25th European Symposium on Computer Aided Process Engineering, Copenhagen, Denmark, May 2015

Imes, Connor; Kim, David H. K.; Maggio, Martina; Hoffmann, Henry: *POET: A Portable Approach to Minimizing Energy Under Soft Real-time Constraints*; In 21st IEEE Real-Time and Embedded Technology and Applications Symposium, Seattle, Washington, USA, April 2015.

Karlsson, Fredrik; Karlsson, Martin; Bernhardsson, Bo; Tufvesson, Fredrik; Persson, Magnus: *Sensor Fused Indoor Positioning Using Dual Band WiFi Signal Measurements*; In 2015 European Control Conference, Linz, Austria, July 2015.

Khong, Sei Zhen; Briat, Corentin; Rantzer, Anders: *Positive Systems Analysis Via Integral Linear Constraints*; In 54th IEEE Conference on Decision and Control, Osaka, Japan, December 2015.

Khong, Sei Zhen; Petersen, Ian; Rantzer, Anders: *Robust Feedback Stability of Negative Imaginary Systems: An Integral Quadratic Constraint Approach*; In 2015 European Control Conference, Linz, Austria, July 2015.

Khong, Sei Zhen; Rantzer, Anders: *Distributed Robustness Analysis of Heterogeneous Networks Via Integral Quadratic Constraints*; In 2015 American Control Conference, Chicago, USA, July 2015.

Khong, Sei Zhen; Lovisari, Enrico; Kao, Chung-Yao: *Robust synchronisation of unstable linear time-invariant systems*; In 2015 Asian Control Conference, Kota Kinabalu, Malaysia, May 2015.

Konstantinos, Angelopoulos; Papadopoulos, Alessandro Vittorio; Mylopoulos, John: *Adaptive predictive control for software systems*; In 1st International Workshop on Control Theory for Software Engineering, Bergamo, Italy, August 2015.

Leva, Alberto; Papadopoulos, Alessandro: *Disturbance rejection in autotuners: an assessment method and a rule proposal*; In 2015 American Control Conference, Chicago, IL, USA, July 2015.

Li, Zheng; Kihl, Maria; Robertsson, Anders: *On a Feedback Control-based Mechanism of Bidding for Cloud Spot Service*; In 7th IEEE International Conference on Cloud Computing Technology and Science, Vancouver, Canada, November 2015.

Magnusson, Fredrik; Palmer, Kyle; Han, Lu; Bollas, George: *Dynamic Parametric Sensitivity Optimization Using Simultaneous Discretization in JModelica.org*; In 2015 International Conference on Complex Systems Engineering, Storrs, CT, November 2015.

Mehta, Amardeep; Dürango, Jonas; Tordsson, Johan; Elmroth, Erik: *Online Spike Detection in Cloud Workloads*; In 2nd IEEE Workshop on Cloud Analytics, Tempe, AZ, USA, March 2015.

Nilsson, Gustav; Hosseini, Pouyan; Como, Giacomo; Savla, Ketan: *Entropy-like Lyapunov Functions for the Stability Analysis of Adaptive Traffic Signal Controls*; In The 54th IEEE Conference on Decision and Control, Osaka, Japan, December 2015.

Papadopoulos, Alessandro Vittorio: *Design and Performance Guarantees in Cloud Computing: Challenges and Opportunities*; In 10th International Workshop on Feedback Computing, Seattle, WA, USA, April 2015.

Papadopoulos, Alessandro Vittorio; Carone, Roberto; Maggio, Martina; Leva, Alberto: *A control-theoretical approach to thread scheduling for multicore processors*; In 2015 IEEE Conference on Control Applications (CCA), Sydney, Australia, September 2015.

Papadopoulos, Alessandro Vittorio; Maggio, Martina: *Virtual Machine Migration in Cloud Infrastructures: Problem Formalization and Policies Proposal*; In 54th IEEE Conference on Decision and Control, Osaka, Japan, December 2015.

Raman, Vasumathi; Fält, Mattias; Wongpiromsarn, Tichakorn; Murray, Richard M.: *Online Horizon Selection in Receding Horizon Temporal Logic Planning*; In IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2015), Hamburg, August 2015.

Shiriaev, Anton; Freidovich, Leonid; Robertsson, Anders; Andersson, Alina; Johansson, Rolf: *Sufficient Conditions for Dynamic Stabilization of 3-State Moore-Greitzer Compressor Model*; In IEEE 54th Annual Conference on Decision and Control (CDC), Osaka, Japan, December 2015.

Sidhu, Ikhlaq; Singer, Ken; Johnsson, Charlotta; Mari, Suoranta: *Introducing the Berkeley Method of Entrepreneurship - a game-based teaching approach*; In American Society of Engineering Education Annual Conference 2015, Seattle, WA, USA, June 2015.

Ståhl, Fredrik; Johansson, Rolf; Landin-Olsson, Mona: *Predicting Nocturnal Hypoglycemia Using a Non-Parametric Insulin Action Model*; In IEEE International Conference on Systems, Man, and Cybernetics (SMC), City University of Hong Kong, China, October 2015.

Stenmark, Maj; Malec, Jacek; Stolt, Andreas: *From High-Level Task Descriptions to Executable Robot Code*; In Intelligent Systems, IS'14, Warsaw, Poland, September 2015.

Stolt, Andreas; Bagge Carlson, Fredrik; Ghazaei, Mahdi; Lundberg, Ivan; Robertsson, Anders; Johansson, Rolf: *Sensorless Friction-Compensated Passive Lead-Through Programming for Industrial Robots*; In IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2015), Hamburg, Germany, September 2015.

Stolt, Andreas; Linderoth, Magnus; Robertsson, Anders; Johansson, Rolf: *Detection of Contact Force Transients in Robotic Assembly*; In 2015 IEEE International Conference on Robotics and Automation, Seattle, WA, USA, May 2015.

Stolt, Andreas; Robertsson, Anders; Johansson, Rolf: *Robotic Force Estimation using Dithering to Decrease the Low Velocity Friction Uncertainties*; In 2015 IEEE International Conference on Robotics and Automation, Seattle, WA, USA, May 2015.

Terraneo, Federico; Leva, Alberto; Seva, Silvano; Maggio, Martina; Papadopoulos, Alessandro Vittorio: *Reverse Flooding: exploiting radio interference for efficient propagation delay compensation in WSN clock synchronization*; In 36th IEEE Real-Time Systems Symposium (RTSS), San Antonio, TX, USA, December 2015.

Theorin, Alfred; Berner, Josefin: *Implementation of an Asymmetric Relay Autotuner in a Sequential Control Language*; In IEEE International Conference on Automation Science and Engineering (IEEE CASE 2015), Gothenburg, Sweden, August 2015.

Theorin, Alfred; Bengtsson, Kristoffer; Provost, Julien; Lieder, Michael; Johnsson, Charlotta; Lundholm, Thomas; Lennartsson, Bengt: *An Event-Driven Manufacturing Information System Architecture*; In IFAC/IEEE Symposium on Information Control Problems in Manufacturing (INCOM2015), Ottawa, Canada, May 2015.

Warell, Anders; Johnsson, Charlotta; Nilsson, Carl-Henric: *Design as an integrating factor in an international cross-disciplinary innovation course*; In American Society for Engineering Education Annual Conference 2015, Seattle, WA, USA, June 2015.

Xu, Yang; Årzén, Karl-Erik; Cervin, Anton; Bini, Enrico; Tanasa, Bogdan: *Exploiting Job Response-Time Information in the Co-Design of Real-Time Control Systems*; In 21th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, Hong Kong, China, August 2015.

Yaqoob, Muhammad Atif; Mannesson, Anders; Butt, Naveed R.; Tufvesson, Fredrik: *Source Localization Using Virtual Antenna Arrays*; In 2015 International Conference on Localization and GNSS (ICL-GNSS), Gothenburg, June 2015.

PHD THESES

Garpinger, Olof: *Analysis and Design of Software-Based Optimal PID Controllers*; PhD Thesis ISRN LUTFD2/TFRT--1105--SE, Department of Automatic Control, Lund University, Sweden, April 2015.

Hast, Martin: *Design of Low-Order Controllers using Optimization Techniques*; PhD Thesis ISRN LUTFD2/TFRT--1106--SE, Department of Automatic Control, Lund University, Sweden, May 2015

Johnsson, Ola: *Perturbation-based Control of Industrial Fed-batch Bioprocesses*; PhD Thesis Department of Automatic Control, Lund University, Sweden, December 2015. To be defended in January 2016.

Nordh, Jerker: *Bayesian Inference for Nonlinear Dynamical Systems — Applications and Software Implementation*; PhD Thesis LUTFD2/TFRT--1107--SE, Department of Automatic Control, Lund University, Sweden, May 2015.

Olofsson, Björn: *Topics in Machining with Industrial Robot Manipulators and Optimal Motion Control*; PhD Thesis ISRN LUTFD2/TFRT--1108--SE, Department of Automatic Control, Lund University, Sweden, August 2015.

Sörnmo, Olof: *Adaptation and Learning for Manipulators and Machining*; PhD Thesis ISRN LUTFD2/TFRT--1110--SE, Department of Automatic Control, Lund University, Sweden, October 2015

Ståhl, Fredrik: *Towards Defence In Depth In Diabetes Glucose Self-Management*; PhD Thesis Department of Automatic Control, Lund University, Sweden, November 2015.

Stolt, Andreas: *On Robotic Assembly using Contact Force Control and Estimation*; PhD Thesis ISRN LUTFD2/TFRT--1109--SE, Department of Automatic Control, Lund University, Sweden, September 2015.

LICENTIATE THESES

Andersson, Alina: *Analytic Parameterization of Stabilizing Controllers for the Moore-Greitzer Compressor Model*; Licentiate Thesis ISRN LUTFD2 TFRT--3266--SE, Department of Automatic Control, Lund University, Sweden, May 2015.

Berner, Josefin: *Automatic Tuning of PID Controllers based on Asymmetric Relay Feedback*; Licentiate Thesis ISRN LUTFD2/TFRT--3267--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Ghazaei, Mahdi: *Topics in Trajectory Generation for Robots*; Licentiate Thesis ISRN LUTFD2/TFRT--3265--SE, Department of Automatic Control, Lund University, Sweden, March 2015.

Ingesson, Gabriel: *Model-Based Control of Gasoline Partially Premixed Combustion*; Licentiate Thesis ISRN LUTFD2/TFRT--3268--SE, Department of Automatic Control, Lund University, Sweden, December 2015.

TECHNICAL REPORTS

Como, Giacomo; Rasmusson, Monika (Eds.); *Activity Report 2014;* Technical Report ISRN LUTFD2/TFRT--4042--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Como, Giacomo; Rantzer, Anders; Westin, Eva: *LCCC focus period and workshop on Dynamics and Control in Networks*; Technical Report ISRN LUTFD2/TFRT--7640--SE, Department of Automatic Control, Lund University, Sweden, August 2015.

Garpinger, Olof: *Optimal PI and PID Parameters for a Batch of Benchmark Process Models Representative for the Process Industry;* Technical Report ISRN LUTFD2/TFRT--7645--SE, Department of Automatic Control, Lund University, Sweden, August 2015. no.

Kristensen, Fredrik; Troeng, Olof; Safavi, Mohammadhassan; Narayanan, Prakash: *Competition in higher education – good or bad?*; Technical Report Department of Automatic Control, Lund University, Sweden, January 2015.

Olofsson, Björn; Berntorp, Karl; Robertsson, Anders: *A Convex Approach to Path Tracking with Obstacle Avoidance for Pseudo-Omnidirectional Vehicles*; Technical Report ISRN LUTFD2/TFRT--7643--SE, Department of Automatic Control, Lund University, Sweden, November 2015.

MASTERS' THESES

Axelsson, Magdalena: *Nonlinear Model Predictive Control in JModelica.org*; Master's Thesis ISRN LUTFD2/TFRT--5987--SE, Department of Automatic Control, Lund University, Sweden, August 2015.

Dahlin Rodin, Christopher: *Radar Based Estimation of Ditches in the Vicinity of the Road*; Master's Thesis ISRN LUTFD2/TFRT--5970--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Davidsson, Emil; Hedenberg, Hampus: *Modelling and Control of an Evaporation Process*; Master's Thesis ISRN LUTFD2/TFRT--5977--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Djup, Martin; Allar, Elias: *Sensorless Control of Brushless DC Motor in Hydraulic Application*; Master's Thesis ISRN LUTFD2/TFRT--5979--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Ed, Olof; Rasmusson, Jonas; Rhodin, Jimmy: *The Applicability of Competitive Battles in Scenario Planning*; TM.

Ek, Britta; Skoghagen, Elin; Eliasson, Filip: P*roduct portfolio management - the key future growth within AAES*; TM.

Ek, Malin; Karlsson Streijffert, Amanda: *Optimization of sales in fashion retail by warehouse integration in multichannels*; TM.

Ekström, Sebastian: *Real Time Model Predictive Control in JModelica.org*; Master's Thesis ISRN LUTFD2/TFRT--5986--SE, Department of Automatic Control, Lund University, Sweden, August 2015.

Elf, John; Andersson, Kajsa: *One step towards creating value from Big Data*; TM.

Ericsson, Martin: *Visual Tracking and Control of a Quadrocopter*; Master's Thesis Department of Automatic Control, Lund University, Sweden, February 2015.

Fält, Mattias; Jimbergsson, Lucas: *Using ADMM for Hybrid System MPC*; Master's Thesis ISRN LUTFD2/TFRT--5981--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Finnved, Sofia; Nöbbelin, Sebastian: *Temperature Estimation in Trailer Disc Brake*; Master's Thesis ISRN LUTFD2/TFRT--5966--SE, Department of Automatic Control, Lund University, Sweden, June 2015

Guijarro, Sonia; Andjelkovic, Alexander: *Developing a strategic controller with haptic and audio feedback for autonomous driving*; Master's Thesis ISRN LUTFD2/TFRT--5969--SE, Department of Automatic Control, Lund University, Sweden, August 2015.

Gustafzelius, Sara: *Dynamic path planning of initially unknown environments using an RGB-D camera*; Master's Thesis ISRN LUTFD2/TFRT--5980--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Hameed, Waqar: *Multi-Objective Optimization of Voyage Plans for Ships*; Master's Thesis ISRN LUTFD2/TFRT--5994--SE, Department of Automatic Control, Lund University, Sweden, December 2015.

Horney, Paulina; Gustafsson, Johanna: *Leadership Driving Successful Implementation of Continuous Improvement Programs - A case Study Using the path Goal Model*; TM.

Johansson, Simon; Persson, Viking: *Tire/road friction estimation for front wheel driven vehicle*; Master's Thesis ISRN LUTFD2/TFRT--5985--SE, Department of Automatic Control, Lund University, Sweden, August 2015.

Johnsson, Per: *Automatisk reglering av färgnyans på pappret i en pappersmaskin*; Master's Thesis ISRN LUTFD2/TFRT--5962--SE, Department of Automatic Control, Lund University, Sweden, February 2015.

Jöndell, Alexander; Bill, Oskar: *The loyalty effect - Predicting customer loyalty using the American Customer Satisfaction Index and the Net Promoter Score*; TM.

Jönsson, Erik: *Stepless fault injection for electrohydraulic actuator*; Master's Thesis ISRN LUTFD2/TFRT--5983--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Kokaia, Givi; Alm, Elin: *Attracting Early Stage and Cross Border Venture Capital in the Biotechnology Sector: Showcase Your Value to Investors*; TM.

Kroon, John: *Automated Event Control of Vehicles for Drivability Testing*; Master's Thesis ISRN LUTFD2/TFRT--5989--SE, Department of Automatic Control, Lund University, Sweden, September 2015.

Larsson, Henning: *District Heating Network Models for Production Planning*; Master's Thesis ISRN LUTFD2/TFRT--5975--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Larsson, Joakim: *Implementation of smooth interpolation for optimization*; Master's Thesis ISRN LUTFD2/TFRT--59964--SE, Department of Automatic Control, Lund University, Sweden, December 2015.

Larsson, Sebastian; Grundén, Eric: *Evaluation of a batch process by means of batch statistical process control and system identification*; Master's Thesis ISRN LUTFD2/TFRT--5974--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Larsson, Tor: *Moving Horizon Estimation for JModelica.org*; Master's Thesis ISRN LUTFD2/TFRT--5982--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Levin, Carl; Håkansson, Christropher: *Clustering driver's destinations - using internal evaluation to adaptively set parameters*; Master's Thesis Department of Automatic Control, Lund University, Sweden, January 2015.

Lilja, Patrik; Sola Merino, Jorge: *Calibration of Gantry-Tau Robot and Prototyping of Extruder for 3D Printing*; Master's Thesis ISRN LUTFD2/TFRT--5978--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Lindgren, Alexander; Bodin, Victor: *Unveiling the power of selling spare-parts as a happy-meal - a study of how spare-part-kits can improve supplier attractiveness*; TM.

Lindgren, Simon: *Detektering, målföljning och identifiering med robotsystem 90*; Master's Thesis ISRN LUTFD2/TFRT--5973--SE, Department of Automatic Control, Lund University, Sweden, June 2015

Melin Lundström, Elin; Ferriera, Emmy-Lou; Widegran, Kristina: *Att orientera i motvind*; TM.

Nakano, Tomohiro: *Recognition of Surfaces Based on Haptic Information*; Master's Thesis ISRN LUTFD2/TFRT--5957--SE, Department of Automatic Control, Lund University, Sweden, March 2015.

Nordenson, Martina; Andersson, Malin: *Exploring the latest paradigm shift in organizational consciousness development, by using the framework from Reinventing Organizations - a qualitative case study at Kvadrat*; TM.

Norell, Anton; Linde, Oscar: *Event Correlated Usage Mapping in an Embedded Linux System - A Data Mining Approach*; Master's Thesis ISRN LUTFD2/TFRT--5988--SE, Department of Automatic Control, Lund University, Sweden, September 2015.

Nylén, Anders: *Control design for diesel engines using a Modelica model*; Master's Thesis ISRN LUTFD2/TFRT--5990--SE, Department of Automatic Control, Lund University, Sweden, January 2015.

Olsson, Stefan: *Pathfinding and positioning in a labyrinth game using a wide-angle camera*; Master's Thesis ISRN LUTFD2/TFRT--5964--SE, Department of Automatic Control, Lund University, Sweden, September 2015.

Önnheim, Patrik; Isaksson, Hampus: *High Precision Positioning and Very Low Velocity Control of a Permanent Magnet Synchronous Motor*; Master's Thesis ISRN LUTFD2/TFRT--5963--SE, Department of Automatic Control, Lund University, Sweden, September 2015.

Oros, Stefan: A Friction Model for Laminator Nips; Master's Thesis ISRN LUTFD2/TFRT--5968--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Österström, Karin; Winbaldh, Paulina: *Moving into the unknown: -A study of how a Newly Established FEI Department within a structured and linear envirement can manage venture prioritisation*; TM.

Skäremo, Julia; Bildt, Gunnel; Bengtsson, Lovisa: *Development of innovative functional pet food products - a compilation of relevant knowledge for industry actors*; TM.

Söder-Hoorn, Anders: *Prediction of position errors for an industrial robot, using a model of the robot with parameters acquired from the clamping procedure*; Master's Thesis ISRN LUTFD2/TFRT--5991--SE, Department of Automatic Control, Lund University, Sweden, December 2015.

Sundberg, Gustav; Olivensjö, Anton: *Mobile Display Advertising and its effect on the consumer*; TM.

Synnøve Jönsson, Ida: *System identification for control of temperature and humidity in buildings*; Master's Thesis ISRN LUTFD2/TFRT--5976--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Thelander Andrén, Marcus; Wedding, Christoffer: *Development of a Solution for Start-up Optimization of a Thermal Power Plant*; Master's Thesis ISRN LUTFD2/TFRT--5972--SE, Department of Automatic Control, Lund University, Sweden, August 2015.

Thilderkvist, Dan; Svensson, Sebastian: *Motion Control of Hexapod Robot Using Model-Based Design*; Master's Thesis ISRN LUTFD2/TFRT--5971--SE, Department of Automatic Control, Lund University, Sweden, June 2015.

Thörn, Therese; Carlberg, Susanne: *Hållbara städer som Komplexa Adaptiva System*; TM.

Tollstadius, Andrea; Sandin, Emma: *Data Sharing Within Connected Business Ecosystems*; TM.

Turesson, Elin; Witting, Marcus; von Essen, Nils: *På rätt spår: återkoppling för lärande i kontrollrumsmiljö - En fallstudie på en svensk järnvägsoperatör*; TM.

Wahnström, John: *Energy Optimization for Platooning through Utilizing the Road Topography*; Master's Thesis ISRN LUTFD2/TFRT--5984--SE, Department of Automatic Control, Lund University, Sweden, July 2015.

Wernersson, Ragnar: *Robot Control and Computer Vision for Automated Test System on Touch Display Products*; Master's Thesis ISRN LUTFD2/TFRT--5967--SE, Department of Automatic Control, Lund University, Sweden, May 2015.

Wessman, Mattias; Eng Stensson, Jonathan: *Key Success Factors for Collaborative Innovation in Silicon Valley*; TM.

SEMINARS AT THE DEPARTMENT

January

16 *To communicate research through media - what, how and why?;* Fredrik Hedenus, Physical Resource Theory, Chalmers.

23 *Meetings in innovative environments*; Liza Nydén, Ideon Meetings.

February

02 Master's Thesis Presentation. *High Precision Positioning and Very Low Velocity Control of a Permanent Magnet Synchronous Motor;* Patrik Önnheim, Hampus Isaksson.

05 *Vägar till jobb* (*making work work*); Jill Carlberg Söderlund (Riksförbundet Attention, National Association for Neuropsychological diagnosis).

26 *Visiting research results and education system and life style differences;* Takayoshi YAMADA, Gifu University.

March

03 Presentation of LGBTQ-network for employees at Lund University; Camilla Lekebjer, Computer Science.

06 Licentiate seminar. *Topics in Trajectory Generation for Robots;* Mahdi Ghazaei Ardakani, Dept. of Automatic Control, LTH, Lund University.

16 *On the Development of an Industrial Mobile Manipulator for a Logistic Task at PSA Peugeot Citroen;* Volker Krüger, Aalborg University.

27 Master's Thesis Presentation. *Nonlinear model predictive control in JModelica.org;* Magdalena Axelsson.

31 Master's Thesis Presentation. *Pathfinding and positioning in labyrinth game with wide-angle camera;* Stefan Olsson.

April

15 *How Borealis is using process control and MPC to stabilize production and earn more money every day;* Staffan Skalen, Borealis.
22 Talk about a gender equality survey performed by Lund University, within the Gender Course at the Faculty of Engineering; Christina Isaxon, Ergonomics and Aerosoltechnology.
22 *FMI: What is it and what can it do for you?;* Maria Henningsson, Modelon.
29 Master's Thesis Presentation. *Detektering, målföljning och identifiering med robotsystem 90;* Simon Lindgren.

May

08 Defence Of Doctoral Dissertation. *Analysis and Design of Software-based Optimal PID Controllers*; Olof Rännbäck Garpinger, Dept. of Automatic Control, LTH, Lund University.
11 Licentiate seminar. *Analytic Parameterization of Stabilizing Controllers for the Moore-Greitzer Compressor Model;* Alina Andersson (Rubanova), Dept. of Automatic Control, LTH, Lund University.
12 Master's Thesis Presentation. *Moving Horizon Estimation for JModelica.org;* Tor Larsson.
13 Licentiate seminar. *Automatic Tuning of PID Controllers based on Asymmetric Relay Feedback;* Josefin Berner, Dept. of Automatic Control, LTH, Lund University.
18 Master's Thesis Presentation. *A Friction Model for Laminator Nips;* Stefan Oros.
19 Master's Thesis Presentation. *Radar Based Estimation of Ditches in the Vicinity of the Road;* Christopher Dahlin Rodin.
19 *Forward-Backward L-BFGS for large-scale nonsmooth optimization;* Panagiotis Patrinos, IMT Lucca.
26 Master's Thesis Presentation. S*ystem Identification for control of temperature and humidity in buildings;* Ida Synnøve Jönsson.

June

03 *ELLIIT distinguished lecture seminar: Adaptive real-time resource management;* Gerhard Fohler, TU Kaiserslautern.
05 Master's Thesis Presentation. *Using ADMM for Hybrid System MPC;* Mattias Fält, Lucas Jimbergsson.
05 Master's Thesis Presentation. *Temperature Estimation in Trailer Disc Brake;* Sofia Finnved, Sebastian Nöbbelin.
05 Defence Of Doctoral Dissertation. *Design of Low-order Controllers using Optimization Techniques;* Martin Hast, Dept. of Automatic Control, LTH, Lund University.
08 Master's Thesis Presentation. *Stepless fault injection for electro-hydraulic actuator;* Erik Jönsson.
08 Master's Thesis Presentation. *Motion control of hexapod robot using Model-Based Design;* Sebastian Svensson, Dan Thilderkvist.
10 Master's Thesis Presentation. *District heating network models for production planning;* Henning Larsson.
11 Master's Thesis Presentation. *Development of a solution for start-up optimization of a thermal power plant;* Marcus Thelander Andrén, Christoffer Wedding.
11 Master's Thesis Presentation. *Numerical modelling of cold helium safety discharges into a non-insulated vent line;* Jonathan Persson.
11 Master's Thesis Presentation. *Modelling and control of an evaporation process;* Emil Davidsson, Hampus Hedenberg.

11 Master's Thesis Presentation. *Evaluation of a batch process by means of batch statistical process control and system identification;* Sebastian Larsson, Eric Grundén.
12 Master's Thesis Presentation. *Calibration and control of Gantry-Tau robot for 3D printing;* Patrik Lilja, Jorge Sola Merino.
12 Master's Thesis Presentation. *Pathplanning and mapping using a RGB-D camera and a hexacopter;* Sara Gustafzelius.
12 Master's Thesis Presentation. *Energy Optimization for Platooning through utilizing the Road Topography;* John Wahnström.
12 Master's Thesis Presentation. *Sensorless Control of Brushless DC Motor in Hydraulic Application;* Elias Allar, Martin Djup.
12 Master's Thesis Presentation. *Tire/road friction estimation for front wheel driven vehicle;* Simon Johansson, Viking Persson.
12 Master's Thesis Presentation. *Developing a "strategic controller" with haptic and audio feedback for autonomous driving;* Sonia Guijarro Carcelén.
15 Defence Of Doctoral Dissertation. *Bayesian Inference for Nonlinear Dynamical Systems — Applications and Software Implementation;* Jerker Nordh, Dept. of Automatic Control, LTH, Lund University.
15 Master's Thesis Presentation. *Real-time NMPC Based on Code Generation with JModelica.org;* Sebastian Ekström.
24 *Schroedinger bridges and the steering of stochastic and deterministic systems;* Yongxin Chen, University of Minnesota, USA.

July

13 *Stochastic Estimation for Vector Linear Systems with Additive Cauchy Noise;* Jason L. Speyer, Mechanical and Aerospace Engineering Department, UCLA

August

17 *On some optimization problems for systems with uncertainties using μ and ν;* Masako Kishida, University of Canterbury, New Zealand.
21 Master's Thesis Presentation. *Event Correlated Usage Mapping in a Embedded Linux System - A Data Mining Approach;* Anton Norell, Oscar Linde.
25 *Distributed hybrid control of multi-agent systems under high level specifications;* Dimos Dimarogonas, Royal Institute of Technology (KTH).
26 *Direct design of LPV controllers from data;* Simone Formentin, Politecnico di Milan.
26 *Critical behaviour in charging of electric vehicles;* Rui Carvalho, Durham University (UK).
31 Master's Thesis Presentation. *Numerical modelling of cold helium safety discharges into a non-insulated vent line;* Jonathan Persson.
31 Master's Thesis Presentation. *Prediction of position errors for an industrial robot, using a model of the robot with parameters acquired from the clamping procedure;* Anders Söder-Hoorns.
31 Master's Thesis Presentation. *Numerical modelling of cold helium safety discharges into a non-insulated vent line;* Jonathan Persson.

September

11 Master's Thesis Presentation. *Kinematic Robot Calibration Using a Double Ball-Bar;* Sandra Collin, Lund University
14 Master's Thesis Presentation. *Automated event control of vehicles for drivability testing;* John Kroon.

15 *Security for control systems: the observability of linear systems under adversarial attacks;* Michelle Chong, Lund University.
24 *May Robotic production systems: Model-based particle filter for vision-based tracking of a moving paint-line;* Olav Egeland, NTNU, Trondheim, Norway.
24 *Plans and initial results for sensor-based control of an industrial robot on a 6-DOF moving base;* Geir Hovland, Univ of Agder, Norway
25 Defence Of Doctoral Dissertation. T*opics in Machining with Industrial Robot Manipulators and Optimal Motion Control;* Björn Olofsson, Lund University.
25 *Optimization of Hybrid Systems Applied to Energy Reduction of Robot Cells;* Bengt Lennartson, Chalmers.
29 *Feedback and Time for Computer Design;* Eric Kerrigan, Imperial College, UK.

October

09 Master's Thesis Presentation. *Automated Curtailment of Wind Turbines during critical transmission periods;* Maid Delic
15 Bachelor's Thesis Presentation. *Machine-readable protocols and rapid-prototyping for synthetic biology research: Implementation of a liquid handling robot;* Marcus Greiff.
15 Master's Thesis Presentation. *Control design for diesel Engines through Design-of-Experiments analysis of Modelica model;* Anders Nylén, Lund University.
23 Defence Of Doctoral Dissertation. *On Robotic Assembly using Contact Force Control and Estimation;* Andreas Stolt, Dept. of Automatic Control, Lund University.
23 *Autonomous underwater robotic operations;* Ingrid Schjølberg.
23 *Industrial Human-Robot Collaboration - Economics, Standardization, Technology and Open Issues;* Björn Matthias.
23 *Hybrid Control of Robot Arms in Task Space Using Real-time Trajectory Generation Algorithms;* Torsten Kröger.
23 *Control tools for safe physical robot interaction;* Luigi Villani.
27 *Constructing Customized Harmonic Periods for Real-Time Tasks with Period Ranges;* Mitra Nasri, Technische Universität Kaiserslautern, Germany.
29 *Biomedical modeling and computation;* Magnus Fontes.

November

02 Master's Thesis Presentation. *Implementation of smooth interpolation for optimization;* Joakim Larsson.
03 *Control design for an Optical Image Stabilization (OIS) system;* Mikael Lindberg, Axis.
11 *A scalable approach to controller design in networks;* Richard Pates, Lund University.
11 Presented ongoing work at the Faculty regarding equality issues; Jeffrey Armstrong, HR and equality strategist at the Faculty of Engineering central office.
12 Bachelor's Thesis Presentation. *Formal synthesis of switching protocols for estimation and control of aircraft electric power systems;* Charlie Erwall.
12 *A constraint-based approach for multi-modal servo-control;* Joris De Schutter, KU Leuven - Department of Mechanical Engineering Division of Production Engineering, Machine Design and Automation (PMA).
13 Defence Of Doctoral Dissertation. *Adaptation and Learning for Manipulators and Machining;* Olof Sörnmo.

December

01 Licentiate seminar. *Model-Based Control of Gasoline Partially Premixed Combustion;* Gabriel Ingesson, Dept. of Automatic Control, Lund University.
01 *Accomplishing Ground Moving Innovations through Modeling, Simulation, and Optimal Control;* Lars Eriksson, Vehicular Systems, Dept. of Electrical Engineering, Linköping University.
02 *On Behaviour Trees;* Petter Ögren, KTH.
09 Master's Thesis Presentation. *Multi-Objective Optimization of Voyage Plans for Ships;* Waqar Hameed, Dept. of Automatic Control, Lund University.
09 Master's Thesis Presentation. *Clustering driver's destinations using adaptive methods;* Carl Levin, Lund University.
10 *The Type 1 Diabetes Simulator and Its Use in In Silico Clinical Trials;* Chiara Dalla Man, University of Padova.
11 Defence Of Doctoral Dissertation. *Towards Defence in Depth in Diabetes Glucose Self-Management;* Fredrik Ståhl, Dept. of Automatic Control, Lund University.
16 Master's Thesis Presentation. *Analysis of ways to import FMUs in automation studio;* Sara Gunnarsson, Lund University.

LECTURES BY STAFF OUTSIDE THE DEPARTMENT

Årzén, Karl-Erik

Det autonoma molnet, Kungliga Ingenjörsvetenskapsakademin (IVA), Stockholm, February 21, 2015

Control of Computer Systems: From Embedded to the Cloud, Keynote at the CTSE: 1st Workshop on Control Theory for Software Engineering, Bergamo, Italy, August 31, 2015.

Dynamic Resource Management for Multicore Linux Platforms, EMSIG Autumn School, Lungby, Denmark, November 11, 2015.

Åström, Karl Johan

Den dolda reglertekniken (Control - the Hidden Technology) Royal Physiographical Society, Lund Sweden, February 11, 2015

PID Control and Tuning, UTC Aerospace Systems and University of Connecticut, Windsor Locks, CT, April 14, 2015.

Diagnostics of Control Loops, UTC Aerospace Systems and University of Connecticut, Windsor Locks, CT, April 15, 2015.

Looking Forward, Automatic Control 50 year Anniversary, Lund University, May 29, 2015.

Control - A Perspective. Invited plenary lecture Workshop in the Honor, of Laszlo Keviczky on his 70th Birthday. Budapest, Hungary, June 3, 2015.

Relay-autotuning. Invited plenary lecture MICNON 2015 1st IFAC Conference on Modelling, Identification and Control of Noninear Systems. Saint-Petersburg, Russia. June 24, 2015.

Control and Automation System. Banquet Speech. 11th annual IEEE International Conference on Automation Science and Engineering (IEEE CASE 2015), Gothenburg, Sweden, August 26, 2015.

Como, Giacomo

Department of Mathematics, Royal Institute of Technology (KTH), (Stockholm, Sweden), November 19, 2015.

Institute for Pure and Applied Mathematics, University of California (Los Angeles, CA, USA), October 27, 2015.

Institute for Mathematics and its Applications, University of Minnesota, (Minneapolis, MN, USA), October 21, 2015.
Lagrange Department of Mathematical Sciences, Politecnico di Torino (Torino, Italy), October 9, 2015.
Lund Mathematical Society, (Lund, Sweden), May 12, 2015.
School of Electrical Engineering, Royal Institute of Technology (KTH), (Stockholm, Sweden), March 19, 2015.
Department of Civil and Environmental Engineering. Massachusetts Institute of Technology, (Cambridge, MA, USA), March 2, 2015.
Los Alamos National Laboratories, (Los Alamos, NM, USA), February 9, 2015.
ITA Workshop, University of California, (San Diego, CA, USA), February 5, 2015.

Eker, Johan

Invited talk *Distributed Cloud & Internet of Things* at the Halmstad University, May 2015.
Invited talk *Distributed Cloud & Internet of Things* at Technische Universität Kaiserslautern, March 2015.

Dellkrantz, Manfred

Model-Based Deadtime Compensation of Virtual Machine Startup Times, 10th International Workshop on Feedback Computing, Seattle, WA, April 13, 2015.
Model-Based Deadtime Compensation of Virtual Machine Startup Times, 7th Cloud Control Workshop, Nässlingen, Sweden, June 10, 2015.

Giselsson, Pontus

British-French-German conference on optimization in June 15-17, 2015. Title: *QPgen: A C Code Generator for Quadratic Optimization Problems*.
Modelon AB. Title: *QPgen: A C Code Generator for Quadratic Optimization Problems*. Apr. 2, 2015.

Johansson, Rolf

Robotic Work-Space Sensor Fusion and Control, Nanjing University of Science & Technology (NJUST), Automation Institute, Nanjing, China, May 13, 2015. Invited Lecture.
Medical Robot Technology and Industrialization, Sonicmed, Inc., Qing Long Qiao, Beijing, China, May 15, 2015. Invited Lecture.
Robotic Work-Space Sensor Fusion and Control, Tsinghua University, Dept. Computer Science and Technology, Beijing, China, May 15, 2015. Invited Lecture.
Industrial Robots, Skills and Work-Space Sensing, 3rd IFToMM Symposium on Mechanism Design for Robotics (MEDER 2015), Aalborg University, Aalborg, Denmark, 2-4 June 2015, Keynote Lecture, June 4, 2015. Invited Lecture.

Johnsson, Charlotta

From zero to prototype in six weeks - results from an international cross-disciplinary course on Innovation, Presentation (abstract) at Global Venture Lab Meeting at UC Berkeley, CA, USA, January 15, 2015.
Advances and Opportunities in MOM-level manufacturing research and standards, NIST, Cleveland, USA, January, 2015.
Key Performance Indicators for Manufacturing Operations Management (ISO 22400), Presentation at ÅF Consulting, Malmö, Sweden, March 2015.

Entrepreneurship/Innovation and Cross-disciplinary collaboration for control students, Presentations at Automatic Control 50 years symposium, Lund, Sweden, May 2015.
Industry 4.0 and Smart Manufacturing, Presentation at AguilaNet, Malmö, Sweden, August 2015.
Manufacturing Operations Management, Wonderware, Malmö, Sweden, October 2015.

Hägglund, Tore
PID: Past, present and perspectives. Plenary lecture. 34th Benelux Meeting on Systems and Control. Lommel. Belgium, March 24.
The art of tuning a PID controller Plenary lecture. 23rd Mediterranean Conference on Control and Automation. Torremolinos. Spain, June 17.

Maggio, Martina
Invited Keynote Speaker at VALUETOOLS 2015, Berlin, Germany. Title: *Cloud Control: using control theory to optimize cloud applications performance*. Invited by William Knottenbelt and Katinka Wolter. December 2015.
Invited to the NII-Shonan Meeting on "Engineering Adaptive Software Systems (EASSy)". Title: *Discrete Time Adaptive Linear Control for Software Systems*. Invited by Tetsuo Tamai, Hausi Müller and Bashar Nuseibeh. September 2015.
Invited to the Charles University in Prague, Czech Republic, Department of Distributed and Dependable Systems. Title: *Control Theory for Computing Systems*. Invited by Ilias Gerostathopoulos. June 2015.
Invited to the University of Chicago, Department of Computer Science, Chicago, USA. Title: *Control Theory for Computing Systems*. Invited by Henry Hoffmann. April 2015
Invited to the Dagstuhl Seminar "Model-driven Algorithms and Architectures for Self-Aware Computing Systems". Title: *Control Theory for Model-based Software Engineering*. Invited by Jeffrey O. Kephart, Samuel Kounev, Marta Kwiatkowska and Xiaoyun Zhu. January 2015.

Papadopoulos, Alessandro Vittorio
Control-based Design of Computing Systems in Presence of Uncertainty, at MDH, Västerås, Sweden, invited by Prof. Hans A. Hansson, Dec 2015.
Control and Performance Evaluation of Computing Systems in Presence of Uncertainty, at INRIA Grenoble Rhône-Alpes, France, invited by Prof. Eric Rutten, Jan 2016.
Invited seminar, at the NII Shonan Meeting entitled *Controlled Adaptation of Self-adaptive Systems (CASaS)*, Shonan Village Center (SVC), Japan, invited by Prof. Paola Inverardi, Dr. Nicolás D'Ippolito, Dr. Kenji Tei.

Rantzer, Anders
Scalable Control of Positive Systems, 6th Chinese-Swedish Control Conference, Chengdu, March 25, 2015.
Scalable Robustness Analysis Using Integral Quadratic Constraints, Seminar at National Space Studies Center, Toulouse, May 13, 2015.
An Extended Kalman-Yakubovich-Popov Lemma for Positive Systems, Invited lecture at 1st IFAC Conference on Modelling, Identification andControl of Nonlinear Systems (MICNON 2015), Saint Petersburg, Russia, June 25, 2015.
Scalable Control of Positive Systems, Plenary lecture at the 14th annual European Control Conference, Linz, July 17, 2015.

Design of network flow dynamics — control or economics?, Invited lecture at IMA Workshop on Analysis and Control of Network Dynamics, University of Minnesota, October 19, 2015.
Exploiting monotonicity in control synthesis for traffic networks, Invited lecture at IPAM Workshop on Traffic Control, UC Los Angeles, October 27, 2015.

Robertsson, Anders
Presentation at Embedded Conference Syd, Malmö, *On Distributed Cloud-Based Knowledge Bases for Small-Batch Assembly*, March 11, 2015.
NMT-dag, *Robotar, cyklar och andra svårstyrda saker,* March 17-18
Presentation at 6th Chinese-Swedish Control Conference, Chengdu, China, title: *Force Estimation and Control for Robotic Assembly Operations*, March 24, 2015.
Seminar *Friction stir welding and small part assembly - two applications of force control in robotics*, Jaen University, June 4, 2015.

Westin, Eva
Varför så många kvinnor på LTH?, presentation av rapport från kursen "Män, kvinnor och teknik - genuspsykologiska aspekter i undervisningen", Matematikcentrum LTH, January 14.

POPULAR SIENCE PRESENTATIONS

Anders Robertsson showing the RoboticsLab
April 15; Group 1: Studenterna på Ingenjörshögskolan för Elektroteknik och Automation, Mats och Henriette; Group 2: RJ-kontakt
September 4; Visning robotlab LTHs närinslivsråd
September 7; Visning robotlab Loeb, Anton Spanne, Martin Nilsson
November 11; Robotlabdemo for persons from MM-workshop
November 23; Visning Robotlab for IEEE standardisering meeting participants
November 23; Visning Robotlab, extra Vattenhallen
November 26; Seminar presentation: *Flexibla robotar - på gott och ont* + LabDemo

Department of Automatic Control
P O Box 118, 221 00 Lund, Sweden
www.control.lth.se

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