Activity Report: Automatic Control 2006

Rantzer, Anders; Tuszynski, Agneta

2007

Document Version:
Publisher's PDF, also known as Version of record

Automatic Control 2006

Activity Report

Automatic Control 2006

Activity Report

Automatic Control 2006

Department of Automatic Control
Lund University
Lund

Mailing address
Department of Automatic Control
Lund University
Box 118
SE–221 00 LUND SWEDEN

Visiting address
Institutionen för Reglerteknik
Lunds Universitet
Ole Römers väg 1, Lund

Telephone
Nat 046–222 87 80
Int +46 46 222 87 80

Fax
Nat 046–13 81 18
Int +46 46 13 81 18

Generic email address
control@control.lth.se

WWW and Anonymous FTP
http://www.control.lth.se
ftp://ftp.control.lth.se/pub

The report was edited by Agneta Tuszyński and Anders Rantzer

Printed in Sweden
Universitetstryckeriet, Lund, April 2007

ISSN 0280–5316
ISRN LUTFD2/TFRT--4034--SE

Contents

1

Introduction

This report covers the activities at the Department of Automatic Control, at Lund University from January 1 to December 31, 2006. The budget for 2006 was 27 MSEK. The proportion coming from the university was 57%.

Three PhD theses were defended this year, by Dan Henriksson, Ola Slätteke, and Lena de Maré. This brings the total number of PhDs graduating from our department to 76. Three Licentiate theses were completed, by Martin Ohlin, Bradford Schofield, and Oskar Nilsson. Six new PhD students have been admitted during the year: Per-Ola Larsson, Erik Johannesson, Aivar Sootla, Pontus Giselsson, Karl Mårtensson, and Anders Widd. During the year three persons with doctor's degree left the department: Ola Slätteke started to work for ABB in Ireland, Dan Henriksson started to work at the University of Illinois at Urbana-Champaign, USA, and Lena de Maré for Tetra Pak Processing Systems AB, Lund, Sweden.

In the civilingenjör (engineering) program we have 13 courses. The total number of students who finished the courses were 863, and 20 students completed their master theses. The total teaching effort corresponds to 128 full-year equivalents.

Research at the department is presented under the following headlines:

Modeling and Control of Complex Systems, Control and Real-Time Computing, Process Control, Robotics, Automotive Systems, Biomedical Systems.

Today the department has seven professors and one professor emeritus.

Some statistics from five years is given in the table on next page.

	02	03	04	05	06	Sum
Books	1	4	0	1	1	7
Papers	21	13	17	15	17	83
Conference papers	44	31	39	27	53	194
PhD theses	1	5	3	2	3	14
Licentiate theses	3	4	2	3	3	15
Master theses	18	19	17	27	20	101
Internal reports	7	2	7	2	3	21

Acknowledgements

We want to thank our main sponsors: ABB, CECOST, EU Commission, Swedish Energy Agency (STEM), Swedish Foundation for Strategic Research (SSF), The Swedish Agency for Innovation Systems (VINNOVA), The Swedish Research Council (VR), Toyota Motor Company, Volvo Powertrain.

2

Internet Services

World Wide Web

Visit our home-page at this address:

```
http://www.control.lth.se
```

Our web site contains information about personnel, research, publications, seminars, education, etc. It also contains fairly complete lecture notes for many courses, and in some cases software tools such as Matlab tool-boxes developed at the department. Our home-page first appeared on the World Wide Web (WWW) in April 1994.

Electronic Mail

All personnel can be contacted by electronic mail. A personal email address consists of the full name and the department address, written in the form `FirstName.LastName@control.lth.se`. Double names are separated by underline, hyphens are treated as ordinary characters, and accents are ignored. Examples:

```
anders.rantzer@control.lth.se
karl-erik.arzen@control.lth.se
```

Our web page `http://www.control.lth.se/people/telemail.html` contains a complete list of email addresses and phone numbers. The department also has a generic email address:

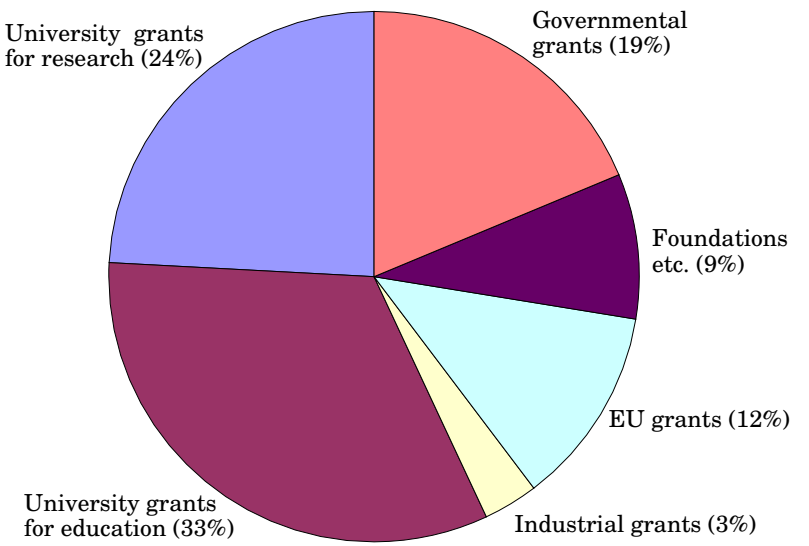
```
control@control.lth.se
```

Emails to this address are continuously read by the postmaster and forwarded to the appropriate receiver.

3

Economy and Facilities

The turnover for 2006 was 27 MSEK. The income comes from Lund University (57%) and from external grants; the distribution is shown below.



Funding

Lund University provides most of the support for graduate students and also our research is externally funded from governmental agencies and industry. During 2006 we had the following contracts:

- VR – Control of Complex and Nonlinear Systems (block grant)

- VR – Decentralized Structures for Industrial Control
- VR – Control and Verification of Systems with State Constraints
- VR – Periodic and Event-based Control over Networks
- VINNOVA – Diesel-HCCI in Multi Cylinder Motor, together with Volvo Powertrain Corporation
- VINNOVA – Lund Center for Applied Software Research (LUCAS)
- VINNOVA-Ericsson – Feedback Based Resource Management and Code Generation for Soft Real-Time Systems
- SSF – Center for Chemical Process Design and Control (CPDC)
- SSF – Flexible Embedded Control Systems (FLEXCON)
- SSF – Decentralized Control of Complex Systems, Senior Individual Grant, SIG Anders Rantzer
- EU IST-004536 – Reconfigurable Ubiquitous Networked Embedded Systems (RUNES)
- EU IST-004175 – Complex Embedded Automotive Control Systems (CEmACS)
- EU IST-004527 – Embedded Systems Design (ARTIST2)
- EU IST-511368 HYbridCONtrol – Taming Heterogeneity and Complexity of Networked Embedded Systems (HYCON)
- EU IST-507728 EURON II NoE, Member Agreement
- EU NMP2-CT-2005-011838 – The European Robot Initiative for Strengthening the Competitiveness of SMES in Manufacturing (SMErobot)
- ABB Automation Technology Products/Business Unit Robotics (Research Collaboration)
- Mid Sweden University – PhD Research Project
- Haldex Brake Products AB – PhD Research Projects
- Toyota Motor Corporation – Project on Linear Model Reduction
- Tetra Pak Processing Systems AB – PhD Research Project
- Swedish Energy Agency (STEM) – Active Control of Combustion Oscillations in Gas Turbines (CECOST)
- Swedish Energy Agency (STEM) – Competence Centre Combustion Processes, KCFP
- Royal Physiographic Society – Scholarship
- Jacob Letterstedt - Scholarship
- Knut and Alice Wallenberg – Scholarship

- Foundation of Per Westlings – Scholarship
- Foundation Sigfrid and Walborg Nordkvist – Scholarship
- Foundation Aeryleanska Traveling Scholarship – Scholarship

The block grant from VR and the CPDC grant from SSF are long range and also some of the VINNOVA projects are long range. Several projects do, however, have a duration of only two years. To match these with the duration of a PhD, which is much longer, we have an internal research planning that is much more long range and we are careful to bid on projects that fit our long range research plan. This has proven an effective way to match short-term funding to long-term planning.

Facilities

Teaching Laboratory

The teaching laboratories are based on desktop processes and personal computers. These laboratories are used in all our courses. The introductory courses give a heavy load on the teaching laboratories because of the large number of students. There are about 900 students, and on the average they spend about 15 hours each in the lab.

Inverted Pendulum on Two Wheels Robot

An inverted pendulum on two wheels robot, entitled YAIP, was constructed during 2006. The robot is intended to be used in advanced undergraduate courses and for research purposes. The problem of devising a stabilizing control system is challenging, since several aspects such as control design, controller implementation, real-time behavior and communication must be considered. The robot is equipped with two independent DC-motors for actuation, and several sensors which are used for state estimation. Further, the robot has three on-board micro controllers which are used to implement the control system, See Figure 3.1.

Linear Servo

The linear servo uses the developed control- and sensor interface units based on the ATMEL processor for embedded control and can also be connected to Matlab/Simulink for real-time control [1]. The servo can be configured and used for a variety of different processes. In Figure 3.2 it

[1] `http://www.control.lth.se/user/anders.blomdell/linux_in_control/`

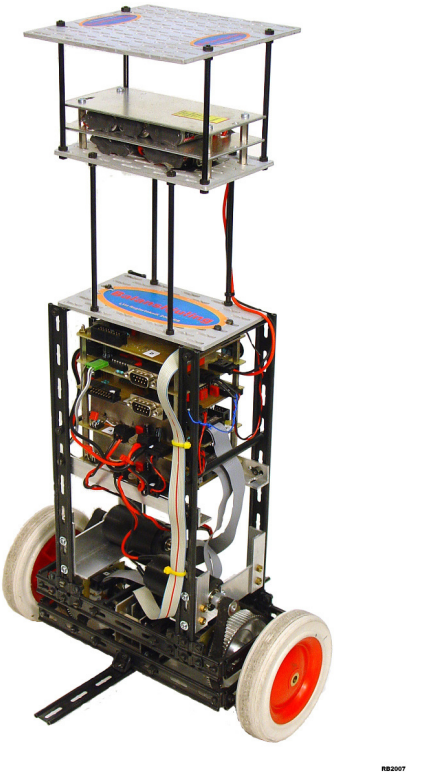


Figure 3.1 Inverted Pendulum.

has been configured as a pendulum on a cart, which was used in the project course (FRT090).

Control over Wireless Sensor Networks

The RBbot, see Figure 3.3, was developed as a experimental platform for wireless networked control using sensor networks. The RBbot is a dual-drive unicycle robot. The hardware consists of a Tmote Sky wireless sensor node for local control and radio communication, and a number of ATMEL AVR micro-controllers, impelementing, e,g, the local motor control. All the hardware units communicate over the I2C bus. The RBbots are also equipped with an ultrasound transmitter, and an movable IR range sensor. The ultrasound is used for localization of the robot. A

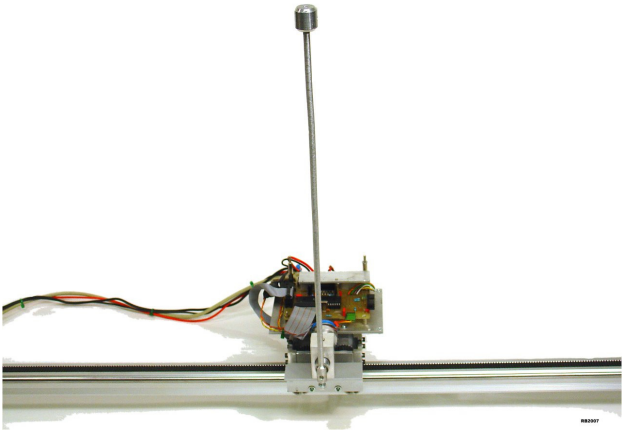


Figure 3.2 Linear Servo.

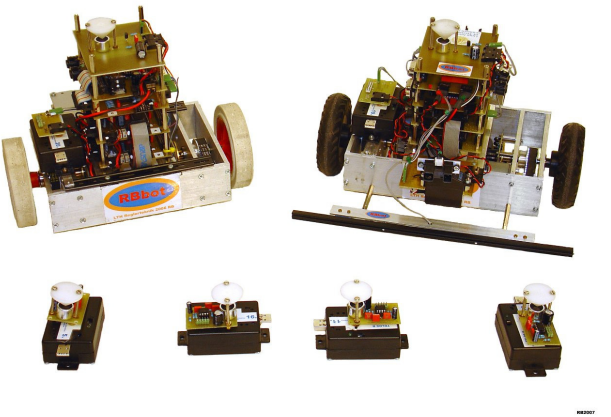


Figure 3.3 RBbot

number of stationary sensor nodes, see the front of the figure, at known locations and equipped with ultrasound receivers, are used to determine the position and orientation of the robot. The RBbots are used in the RUNES project in a mobile robot demonstrator. They were also used in the course Project in Automatic Control.

4

Education

Engineering Program

The engineering education follows the central European systems with a 4.5 year program leading up to the degree "civilingenjör" (civ.ing.), which corresponds to an MSc in the US and British systems.

Automatic control courses are taught as part of the engineering curricula in Engineering Physics (F), Electrical Engineering (E), Computer Engineering (D), Mechanical Engineering (M), Industrial Management and Engineering (I), Chemical Engineering (K), Environmental Engineering (W), Information & Communication Engineering (C), Engineering Mathematics (Pi), and Engineering Nanoscience (N). Our courses are listed in Table 4.1. During 2006, 863 students passed our courses and 20 students completed their master's thesis projects. The number of registered students corresponded to 128 full-year equivalents during the year. The numbers for 2005 were 916, 34, and 130 respectively.

Information on WWW

Many students have access to Internet via Lund University. Therefore we have made a great effort to present the education on web pages. Each course in the engineering program has its own home-page, documentation, manuals, old exams, etc.

We have also information sheets about the engineering courses and the doctorate program. You find the education links at `http://www.control.lth.se/education/`.

Table 4.1 Courses and the number of students who passed.

Reglerteknik AK(FEDIMPi) *FRT010* (Automatic Control, basic course)	444
Reglerteknik (C) *FRT065* (Control)	31
Processreglering (K) *FRT081* (Automatic Process Control)	23
Systemteknik (WN) *FRT110* (Systems Engineering)	90
Digital Reglering *FRT020* (Computer-Controlled Systems)	46
Realtidssystem *FRT031* (Real-Time Systems)	24
Systemidentifiering *FRT041* (System Identification)	33
Adaptiv reglering *FRT050* (Adaptive Control)	29
Olinjär reglering och Servosystem *FRT075* (Nonlinear Control and Servo Systems)	49
Internationell projektkurs i reglerteknik *FRT100* (International Project Course in Automatic Control)	11
Projekt i reglerteknik *FRT090* (Project in Automatic Control)	16
Reglerteori *FRT130* (Control Theory)	12
Matematisk modellering, FK *FRT095* (Mathematical Modelling, Advanced Course)	55
Examensarbete 20 poäng *FRT820* (Master-thesis project, 5 months)	20

Doctorate Program

Three PhD theses were defended, by Dan Henriksson, Ola Slätteke, and Lena de Maré. This brings the total number of PhDs graduating from our department to 76. Three licentiate theses were completed, by Martin Ohlin, Bradford Schofield, and Oskar Nilsson. Abstracts of the theses are given in Chapter 7.

We have admitted six new PhD students during the year, Per-Ola Larsson, Erik Johannesson, Aivar Sootla, Pontus Giselsson, Karl Mårtensson, and Anders Widd.

The following PhD courses were given:

- Nonlinear Control Theory (Anders Robertsson) 5 points

- Advanced Digital Control (Björn Wittenmark) 4 points
- Game Theory (Bo Bernhardsson) 4 points
- Robotics – Kinematics, Dynamics and Control (Rolf Johansson and Anders Robertsson) 5 points

5

Research

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 major research areas are:

- Modeling and Control of Complex Systems
- Control and Real-Time Computing
- Process Control
- Robotics
- Automotive Systems
- Biomedical Systems

In the following presentation the research is in most cases broken down to the granularity of a PhD thesis. There are of course strong relations between the different projects.

Modeling and Control of Complex Systems

Theory and computer tools are developed to deal with fundamental complexity issues appearing in for example vehicles, power systems and communications.

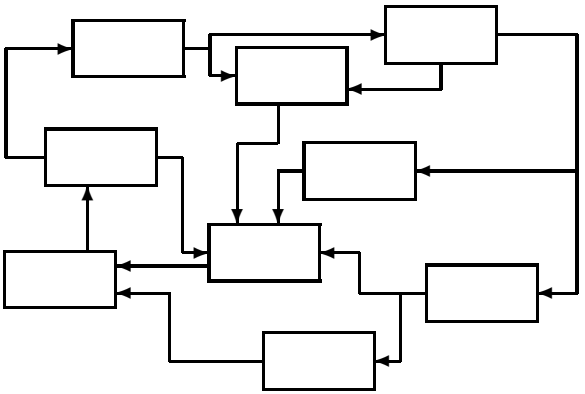


Figure 5.1 A distributed control system.

Distributed Control of Complex Systems

Researchers: Peter Alriksson, Ather Gattami, Toivo Henningsson Perby, Anders Rantzer

How should control equipment distributed across the power grid in southern Scandinavia cooperate to quickly find new transmission routes when a power line is broken? How should the electronic stabilization programme (ESP) of a car gather measurements from wheels and suspensions and decide how to use available brakes and engine power to recover from a dangerous situation? How can a large number of sensors and actuators be coordinated to control the dynamics of a flexible mechanical structure?

All these questions are examples of distributed control problems, where several controllers need to cooperate with access to different information and with bounds on the communication between them. Most of traditional control theory was developed with a centralized viewpoint. However, recently important steps were taken in the new direction of distributed control theory, building on a historical development dating back to economic game theory and statistical decision theory from the 1960s.

We are currently addressing these problems from a general system theoretic viewpoint, but with particular attention to the following three applications:

- Control of power networks

- Dynamic positioning of laboratory vehicles using sensor networks
- Control of a flexible mirror for an astronomic telescope

Relaxed Dynamic Programming

Researchers: Peter Alriksson, Anders Rantzer, Andreas Wernrud

A new approach to synthesis of nonlinear and hybrid observers and controllers is currently developed by extending the classical idea of dynamic programming. This method was introduced by Bellman in the 1950's and has found many important applications since then. The idea is general and very simple, but the "curse of dimensionality" is often prohibitive and has previously restricted most applications to a discrete state space of moderate size. Our idea is to use a relaxed version of dynamic programming to find approximations of the cost function. It turns out that finding a solution which is guaranteed to be within 10% from the optimum can be much less expensive than finding one within 1%.

Our current research on this topic includes performance analysis in model-predictive control, optimal estimation using sensor switching and control synthesis for DC-DC converters.

Figure 5.2 illustrates an example where the cost to go is computed backwards in time, starting at T=200. The three parameter values 1.01, 1.1 and 1.5 correspond to accuracies of 1%, 10% and 50% respectively. Notice that the size of the search tree first grows exponentially for time steps down to about T=180, then the size starts to shrink and finally stabilizes at a lower level that depends on the requested optimization accuracy.

Modeling and Validation of Nonlinear Systems

Researchers: Oskar Nilsson, Anders Rantzer, Andreas Wernrud, Aivar Sootla, and Karl Johan Åström

Large complex mathematical models are regularly used for simulation and prediction. However, in control design it is common practice to work with as simple process models as possible. This makes it easier to analyze and evaluate the model, or to use it inside the controller for on-line estimation of important variables. One objective of this project is to develop methods and tools that can take a complex model and deduce simple models for various purposes and also to derive bounds on the approximation error.

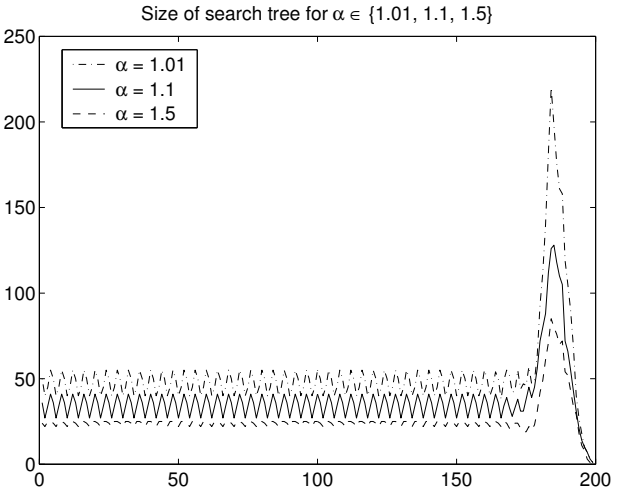


Figure 5.2 The figure illustrates an example where the cost to go is computed backwards in time, starting at T=200. The three parameter values 1.01, 1.1 and 1.5 correspond to accuracies of 1%, 10% and 50% respectively. Notice that the size of the search tree first grows exponentially for time steps down to about T=180, then the size starts to shrink and finally stabilizes at a lower level that depends on the requested optimization accuracy.

Current work is based on the method of balanced truncation and its extension to nonlinear systems. Analysis is done based on linearization around simulated trajectories. Engine models from Toyota Motor Corporation are used as test cases. Figure 5.3 shows a schematic picture of an engine model.

Language Support for Dynamic Optimization

Researchers: Johan Åkesson and Karl-Erik Årzén

Overview The primary area of research in this project is languages for dynamic, model based optimization. The research problem is to investigate the possibility to create a language offering a higher level of abstraction for formulating dynamic optimization problems for a certain class of dynamic models. The research opportunity stems from the observation that there seems to be no strong initiative in this direction applicable to dynamic optimization, as is the case in the field of dynamic modeling and simulation.

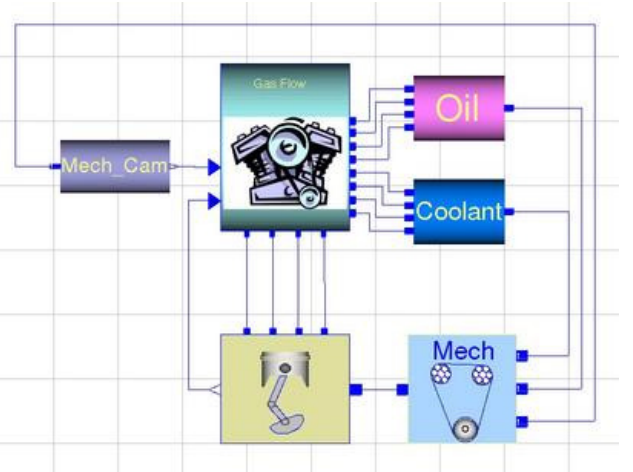


Figure 5.3 Schematic picture of an engine model

An integral part of formulating a dynamic optimization problem is the description of the system dynamics. Modelica, being a language for modelling of dynamical systems, will be considered for this purpose. The language for dynamic optimization to be developed can be viewed as an extension or a complement to Modelica, where Modelica is used to expressing the system dynamics and the new optimization language is used to express optimization quantities as cost function, constraints, control variable discretization etc.

The primary aim of the research is to create a language for dynamic optimization problems which builds on Modelicas capabilities to express dynamical models. A secondary aim is to create a prototype implementation which implements a subset of the language and enables solution of a certain class of optimization problems by means of a sequential method and to perform one or more case studies.

Isn't Modelica Enough? Although being a very rich language in terms of expressive power for describing complex (hybrid) dynamical systems, Modelica lacks important features desirable for expressing optimization problems. This is quite natural since the scope of Modelica does not include optimization. However, Modelica may well be used to describe an important component of the dynamic optimization problem, namely the dynamics. Further, much effort has been put into developing libraries for many application fields using Modelica which enables rapid development

of component based models.

The new language for dynamic optimization should be thought of as a complement to Modelica, which is used to express optimization specific quantities other than the dynamics.

Application Example: Grade Changes Typically, chemical processes are designed and optimized for steady state operation. Also, processes are often controlled by local controllers. This setup leaves, in many cases, to the operators to manage situations as start ups, state transitions (grade changes) and shut downs. Efficient handling of production transitions is critical in a competitive business environment, where the demand is turning to diversification and tailored products. Operator support for grade changes is therefore of interest. This projects addresses the grade change problem by combining optimization techniques and sequential control.

By using an optimization formulation, many critical issues of process state transitions may be expressed. For example, by formulating a minimum time optimization problem, the performance of a grade change may be improved. Also, by imposing constraints on critical process and control variables, safety issues can be dealt with. The aim of the optimization procedure is to generate sequences of reference commands for the process. Normally, the process is equipped with a Digital Control System (DCS), that implements local control loops. In this case the interaction between the process and the DCS will have to be taken into consideration.

For sequential control, the graphical sequence control language Grafchart, and in particular, the Java based Grafchart implementation JGrafchart will be used. Grafchart offers primitives for designing event driven control schemes, and fits nicely into the framework of grade changes. For example, generation of reference command sequences expressed as Grafcharts would be of interest.

Hybrid Control – HYCON Network of Excellence

Researchers: Peter Alriksson, Per Hagander, Staffan Haugwitz, Toivo Henningsson Perby, Rolf Johansson, Oskar Nilsson, Anders Rantzer, Anders Robertsson and Andreas Wernrud in collaboration with the other partners of the HYCON NoE.

HYCON is an EU/IST FP6 Network of Excellence on hybrid control systems. The objective of the NoE HYCON is establishing a durable community of leading researchers and practitioners who develop and apply hybrid systems theory to the design of networked embedded

control systems as found in industrial production, transportation systems, generation and distribution of energy, communication systems.

HYCON has four research work-packages. Lund is active in all of them:

- Energy management
- Industrial control
- Automotive control
- Networked control

In June 1-2, 2006 all HYCON work packages gather for the first time in one meeting. This will be in Lund and our department serves as host.

Inducing Stable Oscillations in Nonlinear Systems by Feedback
Researchers: Rolf Johansson, Anders Robertsson in cooperation with Prof. A. Shiriaev, Umeå University, Swedish Research Council 2006-2008, Ref. 2005-4182

This aim of this project is to develop feedback control laws for nonlinear dynamical systems represented by the classical Euler-Lagrange equations. We consider the systems with the number of actuators being less than the number of its degrees of freedom (DOF) by one. Examples of such dynamical systems are ubiquitous, for instance, a cart-pendulum system (2 DOF correspond to position of the cart and angle of the pendulum, 1 actuator produces the force applied to the cart) and a model of a ship on a plane (3 DOF; 2 actuators).

The two problems, approached in the project, are: how to derive a simple and efficient algorithm of motion planning for such under-actuated systems and how to make a pre-planned motion orbitally stable in the closed loop. It is well known that feedback control design for under-actuated systems is inherently difficult task since not every desired motion is feasible for a system with not actuated DOF. Our controller design approach is based on the idea of virtual holonomic constraint: geometrical relations imposed between generalized coordinates, which are made invariant for the closed loop system.

Exploiting this idea, we have obtained series of preliminary results, in particular, on reducibility of dynamics, integrability of zero dynamics, extension of the famous Lyapunov lemma on presence of center in a nonlinear system, constructive procedure for exponential orbital stabilization of pre-planned motions, extensions to hybrid dynamical systems.

Active Control of Compressor Systems Based on New Methods of Nonlinear Dynamic Feedback Stabilization

Researchers: Rolf Johansson, Anders Robertsson in cooperation with Prof. A. Shiriaev, Umeå University, Swedish Research Council 2007-2009, Ref. 2006-5243)

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.

Control and Real-Time Computing

Projects on networked embedded control, real-time techniques in control system implementation, and control of real-time computing systems.

Flexible Embedded Control Systems (FLEXCON)

Researchers: Dan Henriksson, Anders Blomdell, Anton Cervin, and Karl-Erik Årzén, in collaboration with the Department of Computer Science at Lund University, DAMEK at KTH, MRTC at Mälardalen University, and DRTS at University of Skövde

Control and automation systems constitute an important subclass of embedded real-time systems. Control systems have traditionally been relatively static systems. However, technology advances and market demands are rapidly changing the situation. The increased connectivity implied by Internet and mobile device technology will have a major impact on control system architectures. Products are often based on commercial-off-the-shelf (COTS) components. The rapid development of component-based technologies and languages like Java and C# increases portability and safety, and makes heterogeneous distributed control-system platforms possible. The evolution from static systems towards dynamic systems makes flexibility a key design attribute for future systems.

The key challenge of FLEXCON is how to provide flexibility and reliability in embedded control systems implemented with COTS component-based computing and communications technology. Research will be performed on design and implementation techniques that support dynamic run-time flexibility with respect to, e.g., changes in workload and resource utilization patterns. The use of control-theoretical approaches for modeling, analysis, and design of embedded systems is a promising approach to control uncertainty and to provide flexibility, which will be investigated within FLEXCON. Other focal points are quality-of-service (QoS) issues in control systems, and testing-based verification and monitoring of flexible embedded control systems. The main application area is adaptive industrial automation systems. An industrial robotics-based demonstrator will serve as the carrier of the project results.

The project ended in June 2006. The last six months of the project were devoted to finishing the project and finalizing the software development that were done in the project.

Reconfigurable Ubiquitous Networked Embedded Systems (RUNES)

Researchers: Martin Ohlin, Peter Alriksson, Dan Henriksson, Anton Cervin, and Karl-Erik Årzén in collaboration with the other partners in the Runes project.

RUNES is an EU/IST FP6 integrated project on networked embedded systems with special focus on sensor/actuator networks, that started September 1, 2004. RUNES is coordinated by Ericsson and consists of 23 industrial or academic partners.

Our participation in RUNES is focused on three areas:

- Control over sensor networks
- Control of network resources
- Simulation tools for sensor/actuator network

Within the project we are extending the TrueTime toolbox with support for simulation of wireless battery-powered nodes. We are also extending the control server model to networked control loops.

Partly within RUNES and partly in a student project course we have developed a sensor-network based mobile inverted pendulum robot. The objectives of the project were to develop a test case for control over sensor networks and investigate the performance that can be achieved using state of the art sensor network technology such as TelosB motes with ZigBee radio communication. An inverted pendulum is mounted on the robot. The task is to stabilize the pendulum while driving around in an environment where sensor network nodes are located. The robot contains two ATMEL AVR Mega8 processors (for the wheel motor control), one ATMEL AVR Mega16 processor (for the pendulum angle sensor interface) and one TelosB mote. The control of the pendulums is either done locally on the robot mote or remotely on some other mote. See Figure 5.4

During 2006 the work in RUNES has focused on a tunnel disaster scenario. Within WP6, the work package about control in RUNES, a mobile robot-based sub-scenario is being developed in which autonomous mobile robots are sent into the tunnel acting as mobile radio gateways that are used to ensure connectivity within the tunnel network. In Lund an ultrasound-based localization system has been developed. Each mobile robot is equipped with an ultrasound transmitter and each stationary tunnel-network sensor node is equipped with an ultrasound receiver. By periodically emitting a radio packet and an ultrasound pulse from the robot, it is possible for each sensor node that receives this, to calculate its distance to the robot. When this is done the distance measurements are sent back to the robot and used to calculate its position and orientation using an Extended Kalman filter, in which also dead reckoning from the wheel encoder sensors is included. In order to handle localization of multiple robots a CSMA scheme is used to avoid contention.

Lund is also active in WP7 of RUNES. Here we are developing the TrueTime simulation tool for wireless sensor network and MANET applications. During 2006 version 1.4 of TrueTime was released.

Design of Embedded Systems (ARTIST2)

Researchers: Martin Ohlin, Dan Henriksson, Anders Robertsson, Anton Cervin, and Karl-Erik Årzén in collaboration with the other partners of the ARTIST2 NoE.

ARTIST2 is an EU/IST FP6 network of excellence on design of embedded systems. The objective of ARTIST2 is to strengthen European research in Embedded Systems Design, and promote the emergence of this new multi-disciplinary area. ARTIST2 gathers together the best European

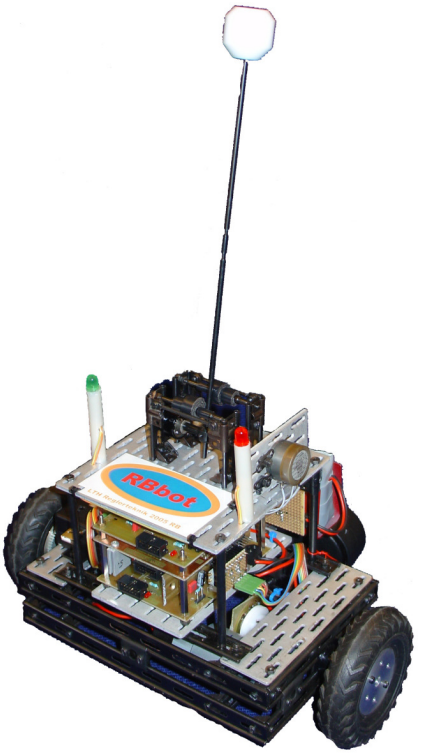


Figure 5.4 RBbot

teams from the composing disciplines, and will work to forge a scientific community.

Internally ARTIST2 is divided into seven clusters (Modelling and Components, Hard Real-Time, Adaptive Real-Time, Compilers and Timing Analysis, Execution Platforms, Control for Embedded Systems, Testing and Verification). Lund is a member of the cluster Control for Embedded Systems with Karl-Erik Årzén as the cluster leader. The other nodes is this cluster are KTH, Czech Technical University, and the Polytechnical University of Valencia. The work within the cluster is focused on three areas:

- Control of Real-Time Computing Systems,
- Real-Time Techniques in Control System Implementation, and

- Co-Design Tools for Control, Computing, and Communication

During 2006 the following events were organized by the cluster:

- Graduate course on Embedded Control, Prague, 3-7 April
- Invited session on co-design tools at the IEEE CACSD conference, Munich, Oct 5
- Co-organized the First European Laboratory on Real-Time and Control for Embedded Systems, July 10-14th, 2006, Pisa, Italy
- The workshop Interaction between control and embedded electronics in the automotive industry was jointly organized in Innsbruck, March 23
- The Scandinavian ARTIST2 Day in Stockholm, 21 August 2006.

LUCAS Center for Applied Software Research

Researchers: Karl-Erik Årzén, Rolf Johansson, Anders Robertsson, Anton Cervin, Dan Henriksson, Martin Ohlin, Anders Blomdell, and Leif Andersson in collaboration with Department of Computer Science, Department of Communication Systems, and industry.

The Center for Applied Software Research (LUCAS) is a collaboration between the software-oriented parts of three departments at LTH:

- Computer Science
- Communication Systems, and
- Automatic Control

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. The work is organized along three thematic areas:

- Software Engineering Environments
- Methods in Software Engineering
- Real-Time Systems Software

The first thematic area focuses on the core areas of integrated environments (tools and methods), object-oriented languages in the tradition of Simula, Beta, and Java, and embedded systems. The research method is focused on experimental implementation and development of relevant theory. Examples of issues that are studied are configuration management, collaboration support, domain-specific languages, frameworks and patterns and Java for embedded systems. The second thematic area is focused on software development processes, methods and architectural issues for development and maintenance of complex software systems. More specifically, the research is directed towards the following key areas: software quality, verification and validation, requirements engineering, and software process architectures. The research is approached through empirical studies to understand, assess, and improve software development. The third thematic area is focused on the software aspects of real-time systems, in particular embedded system, networked systems, and control systems. Some examples of topics within the area are real-time kernels and run-time systems for embedded systems, system architectures for real-time control systems in e.g., industrial automation and robotics, integrated approaches to control design and CPU and communication bandwidth scheduling, and verification and validation of real-time systems.

The activities within LUCAS consist of research projects in collaboration with industry, center activities, and teaching activities. The projects can span the full range of LUCAS or be focused on one of the thematic areas. The aim of the center activities is to maintain the infrastructure of LUCAS and to disseminate information among the partners. The teaching activities include both graduate-level courses and continued education courses.

Industries can join LUCAS at three levels of participation. A gold member is involved in projects over the full range of LUCAS and has a long-term strategic interest in the activities of LUCAS. Silver participants are involved in a single research project, whereas bronze members have access to the LUCAS network in terms of seminars, tutorials, courses, and workshops.

Control of Computer Server Systems

Researchers: Anders Robertsson, Martin Ansbjerg Kjær, Karl-Erik Årzén, and Björn Wittenmark, in cooperation with Maria Kihl and Mikael Andersson, Department of Telecommunications, Lund University. Dan Henriksson graduated during 2006 and is since September 2006 postdoc at UIUC, working in cooperation with Lui Sha and Tarek Abdelzaher, Department of Computer Science, University of Illinois Urbana Champaign.

Admission Control In a collaboration with the Dept of Telecommunication at Lund University we study admission control schemes. In this project we consider modeling of network service control nodes and the use of nonlinear control theory for analysis and design of admission control schemes.

In the last couple of years "Communication and Control" has gained large attention and a lot of new research has focused on control of and over networks. However, the admission control problem, which is important for the utilization and the robustness of the network still remains as an rather unexplored area. Here, we believe the interaction of queuing theory and nonlinear control play a major role.

During the project a discrete-time model of server nodes has been found which aligns well with the properties of the discrete-event models from the queuing theory. The different control algorithms and the effect of different arrival and service process distributions are evaluated experimentally on an Apache web server in a laboratory network. A traffic generator is used to represent client requests. The control of the Apache server has been re-written to implement our algorithms. We show that the control theoretic model aligns well with the experiments on the web-server. Stability analysis and controller design for both continuous and discrete-time models are considered.

Service Rate Control In a collaboration with Tarek Abdelzaher at Univ of Illinois we study service rate control of web-servers. An control scheme based on feedforward using an instantaneous queue model together with event-based PI feedback has been developed.

Periodic and Event-Based Control over Networks

Researchers: Anton Cervin, Toivo Henningsson, Erik Johannesson

Existing communication networks have not been designed with networked control loops in mind. Delays, jitter, and transmission errors limit the applications. To achieve flexible, cheap networked embedded systems with good control performance, it is necessary to do co-design of the control, the communication, and the computations.

In this project, we investigate the timing aspects of networked control and focus on the interplay between network scheduling and control performance. We study the fundamental trade-offs that exist between sampling rates, delays, and jitter in networked control. We want to be able to answer questions such as "What level of control performance can be achieved using time-triggered vs priority-based communication protocols?", "How can impact of network-induced jitter be handled in control design?", and "How can primitives suitable for control be included in existing and new communication protocols?"

A very promising approach to more efficient usage of the network bandwidth is event-based control. The idea is to communicate measurement and control signals only when something unexpected and significant has happened in the system. We are investigating how this approach compares to ordinary, periodic control, and how event-based sampling and control can be incorporated in network scheduling algorithms.

During 2006, we have looked into sporadic event-based control, that is, event-based control with a specified minimum inter-event time. Such an inter-event time is needed to implement the controller in a real-time system. We have studied two sporadic control schemes (with continuous-time and discrete-time measurements) for first-order linear stochastic systems and compared the achievable performance to both periodic and aperiodic control. The results indicate that sporadic control can give better performance than periodic control in terms of both reduced process state variance and reduced control action frequency.

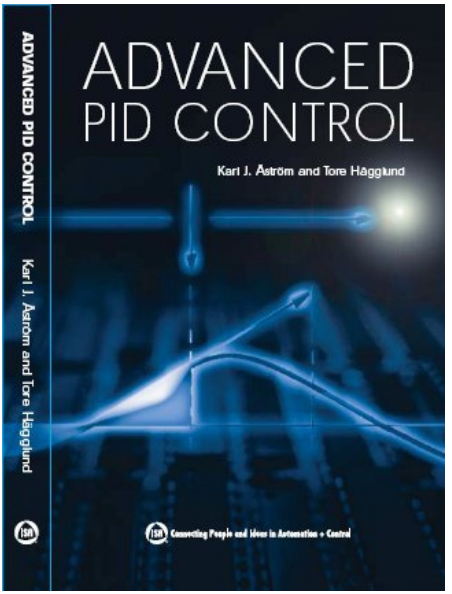


Figure 5.5 The book “Advanced PID Control”.

Process Control

Research is done in cooperation with pharmaceutic, pulp and paper as well as chemical process industry.

PID Control

Researchers: Karl Johan Åström, Olof Garpinger, Tore Hägglund, and Per-Ola Larsson

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.

A new project has been initiated where a PID controller combined with a simple dead-time compensator is investigated. The motivation for the project is that this new controller structure may be as easy to tune as a PID controller, provided that model-based tuning rules are used. The performance of the new controller will be compared with the performance of the PID controller, and simple tuning rules will be derived.

Figure 5.6 Steam cylinder temperature measuring.

Software tools for design of PID controllers are also under development. The tools are based on Matlab, and the goal is to obtain robust procedures that provide PID controller parameters based on IAE optimization and robustness specifications in terms of M circles.

We have also started to develop 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.

New Control Strategies in the Dryer Section of the Paper Machine

Researchers: Jenny Ekvall and Tore Hägglund

This is a joint project between the Network for Process Intelligence (NPI) at the Mid Sweden University and Lund University.

In a first phase, a model of a drying cylinder, describing the relation between the steam pressure and the cylinder temperature, has been developed and implemented in Matlab-Simulink. The model has been validated through experiments performed at the M-real Husum mill.

After validation, the model has been used to derive optimal control strategies of the steam pressure during web breaks. The goal of the strategy is to control the steam pressure so that the production is restarted with the same drying properties of the cylinder as before the break. The new control strategy has been tested and is currently in use at the M-real Husum mill. This phase of the project has resulted in a licentiate thesis by Jenny Ekvall.

In the second phase of the project, a Modelica model of the whole drying section is developed. This model will be used to investigate new control strategies for control of the moisture content in the paper web.

Decentralized Structures for Industrial Control
Researchers: Olof Garpinger and Tore Hägglund

There is an unfortunate gap between the centralized computational approaches of multi-variable 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. By increasing the performance of the modules, the usefulness of present MIMO control functions such as MPC will increase. In this way, we will try to decrease the gap between MIMO control functions and the state of the art of process control. 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.

In a first stage, we will develop a new module building on experiences from PID control: a TITO controller, i.e. a controller with two inputs and two outputs. To be accepted in process control, the TITO controller will be fully automatic without any parameters to be set by the user. It means that an automatic tuning procedure has to be developed.

In a first phase, a decoupling procedure and a new PID design method have been developed. The decoupler is dynamic, but the goal has been to introduce as little dynamics in the decoupler as possible. Traditional PID design methods are not suitable for decoupled systems. For this reason, a new design method based on exhaustive search has been derived. The work in this first phase has resulted in a licentiate thesis by Pontus Nordfeldt.

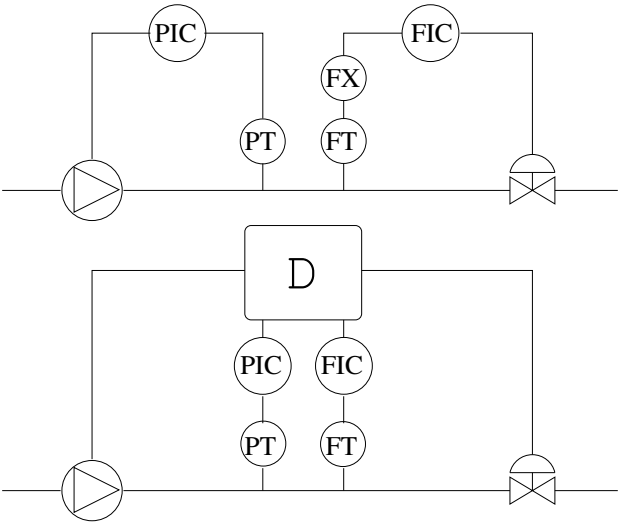


Figure 5.7 Conventional control of coupled systems (upper) and control with decoupling.

During 2006, the ”cost of decoupling” has been analysed. The goal is to provide the decoupler with a mechanism to adjust the amount of decoupling depending on the cost. Collaboration with ABB has also been extended through a master-thesis project dealing with implementation aspects.

Control of Biotechnology Processes

Researchers: Lena de Maré, Stéphane Velut, and Per Hagander in cooperation with Jan Peter Axelsson, Pfizer AB, Christian Cimander Novozymes Biopharma AB, Eva Nordberg Karlsson and Olle Holst, Department of Biotechnology, Lund University.

Large-scale production of many enzymes and pharmaceuticals can today be made using genetically modified microorganisms. In so called bioreactors, living cells are grown to large numbers and then made to produce the desired substance. Fed-batch operation, where additional substrate is fed to the culture, is often the preferred way of production. To achieve reproducible cultivations with high cell densities and high productivity, it is important to design good strategies for the substrate-dosage control. A characteristic feature of biological processes is that many important process variables are not easily measured on-line, which complicates the design and realization of feedback strategies.

A project on substrate-dosage control of fed-batch units with genetically modified *E. coli* is performed together with Pfizer. Information of how to change the substrate feed rate is obtained from standard dissolved oxygen measurements by introducing controlled process perturbations. Tuning rules are derived for the control strategy that assume a minimum of process specific information, and the system is analysed for stability using the theory for piecewise linear systems.

The strategy is implemented at many industries and research laboratories, and it is tested with different *E. coli* strains and also other organisms like bakers yeast and cholera bacteria. Good cultivation conditions and high production levels are in general obtained from the first experiments.

For the case when the oxygen transfer capacity of the reactor is reached, we have designed a method that combines the use of stirrer speed and temperature in a mid-ranging fashion instead of feed reduction to maintain the oxygen concentration at desired levels also during the production phase.

Sometimes it is not enough to add a carbon nutrient feed in order to obtain a satisfactory growth and production, e.g. due to auxotrophic production strains. In some cases additions of supplementary amino acids or complex media containing for example yeast extract are needed. We have investigated how the pulsing technique can be used to control two feeds simultaneously. The strategies work well, and as almost no process knowledge is required they can be used to shorten the process development phase considerably.

In large scale it is hard to obtain well-mixed conditions, and we have together with Pfizer investigated if gradients might influence the applicability of the probing controllers. There was also a time-varying demand in glucose related to the consumption of complex components present in the broth. It required some more care and experience, but we obtained remarkable results that indicate that the process development phase can be reduced considerably. Even though the performance of the probing strategy was affected by scale and complex media, the methodology rapidly identified a glucose feed protocol similar to an experimentally derived feed regime.

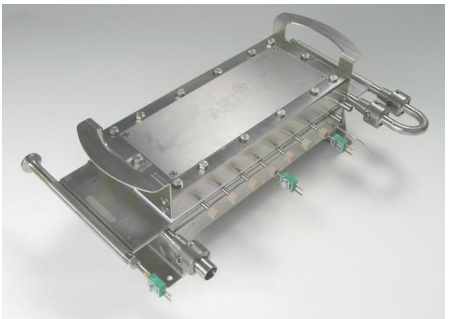


Figure 5.8 The laboratory version of the Plate Reactor

New Control Strategies for a Novel Heat Exchange Reactor

Researchers: Staffan Haugwitz and Per Hagander

Abstract The project is aiming at improving process control of chemical reactors, especially the new Alfa Laval Plate Reactor. Innovative process design leads to vastly improved control capabilities, allowing increased productivity, efficiency and safety.

Background and process description In the chemical industry of today, the batch reactor is the most common reactor type. However is it unsuitable for highly exothermic reactions due to its limited heat transfer capacity. The reactant solutions have to be diluted with water to reduce the amount of energy released during the reaction. After the reaction, separation is necessary to remove the excess water of the product solution. Alfa Laval AB is currently developing a new kind of reactor technology, a plate heat exchanger of new design, where one side is used as a chemical continuous reactor and the other side is filled with a cooling/heating medium. See Figure 5.8

A typical reaction can be stated as: A + B -> C + D. The primary reactant A enters the main inlet of the reactor. The secondary reactant B is then added in multiple inlet ports along the reactor, to distribute the heat from the exothermic reaction. See Figure 5.9.

The process has a much higher heat transfer capacity, so solutions of higher concentrations can be used leading to less separation need. The process will also have higher productivity, more efficient reaction and a safer process.

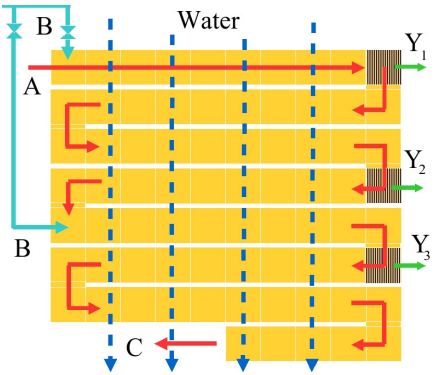


Figure 5.9 A sketch of the first rows inside the plate reactor.

Realize the full potentials with advanced process control The Plate Reactor is very interesting from a control point of view. It has internal sensors enabling accurate information about the reactor temperature and also indirectly concentrations inside the reactor. With multiple injection points the heat from the exothermic reactions can be re-distributed for an improved safety and performance. The primary control objective is to guarantee safety in terms of the temperature inside the reactor. In addition the plate reactor should be controlled so that the reaction yield, that is, the chemical efficiency is maximized. The control system should be robust towards process uncertainties, disturbances and variations in inlet feed conditions. One crucial part of the control system will be the start-up procedure. The objectives of the control system can be summarized as:

- Utilize the reactor maximally in a safe way
- Achieve and maintain desired operating conditions
- Robustness towards uncertainties and disturbances in the process
- Fast and safe start-up/shut-down

The start-up procedure can be challenging, especially when there are strongly exothermic reactions. This has been studied within the HYCON project “Large transitions in processing plants”. A process control system for the reactor has been designed and tested in simulations. Model Predictive Control (MPC) is used to calculate suitable injection flows and cooling temperatures. Reactant injection and cooling temperature controllers are designed separately to be placed in a cascade with the MPC.

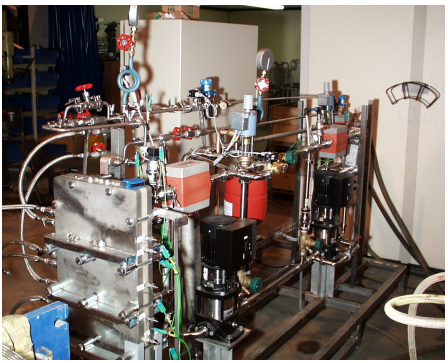


Figure 5.10 The laboratory set-up.

A utility system has been designed, which delivers cooling water with desired temperature and flow rate. A temperature controller using a mid-ranging control structure has been developed. The utility system has been assembled at Alfa Laval facilities in Lund. Experiments to investigate the control properties of the plate reactor and to test the temperature control system have been conducted successfully. A photo of the laboratory set up, see Figure 5.10. The designed process control system increases the safety of operations by reducing the impact from external disturbances. This will also decrease the risk of unnecessary shutdowns of the process operation.

Current activities The main focus is now on dynamic optimization to generate start-up trajectories and designing a mid-ranging feedback structure to improve the robustness towards process uncertainties. In parallel, work is being done on nonlinear model predictive control of the plate reactor. This will allow on-line dynamic optimization of the productivity, the conversion and the temperature of the reactor.

Active Control of Combustion Oscillations in Gas Turbines

Researchers: Rolf Johansson, Martin A. Kjær in cooperation with CECOST (Prof. Rolf Gabrielsson, Dr. Jens Klingmann, Prof. Tord Torisson) and Siemens.

Today's strict environmental regulations are resulting in increasingly higher demands for more efficient gas turbines that provide ever lower emissions levels. This has lead to a continuous development of methods and concepts for competitive and robust combustors. In LPP (Lean Premixed Prevaporised) combustion the incoming fuel is mixed prior to combustion with the air stream delivered by the compressor. The fuel is

diluted by the air and hence the heat release is distributed in a bigger volume which results in lower local flame temperatures and thus less formation of NOx. The lower temperatures in the primary combustion zone make it more difficult to sustain a stable combustion during transients and part load operation. It is therefore desirable to control the combustion process during operation actively with respect to certain characteristic stability parameters. Acoustic waves can be described by the wave equation arising from modeling of pressure and mass flow dynamics. It is well known that the operating range of pressure and flow divides into a dynamically stable part (with fairly high mass flow) and an unstable region. Depending on the configuration of the system, different types of instability can arise, and two of such has been studied; surge and rotating stall. Using nonlinear, low order models, these types of instabilities have been generated and studied. Expanding the model with actuation (valve control of the output flow and pressure adding device) and assuming measurements of flow and pressure, controllers have been designed to stabilize the system in the low flow region. Nonlinear control methods have proved satisfactory in performance and robustness, and attempts to include adaptation to parameter variations have also been successful.

A classic experiment for demonstration and experiments of flame behavior in a resonant cavity was proposed by P. L. Rijke in 1858. In the currently used modification, the Rijke tube is equipped with microphone and load speaker for experiments with active control and suppression of the thermoacoustic oscillations. A simplified dynamical model has been derived, describing the dynamical relationship between the loudspeaker-generated pressure and the pressure near the microphone. The model includes the coupling between the acoustic properties of the tube and the properties of the flame, and predicts oscillations with constant amplitude. Using control design and analysis methods, the oscillations are suppressed using acoustic feedback. This experiment shows the potential of active control in a combustion chamber.

Robotics

Robotics offer both theoretical and practical challenges. Our main research are in motion and compliance control, control system architectures and different sensor fusion problems.

SMErobot

Researchers: Isolde Dressler, Rolf Johansson, Anders Robertsson in cooperation with Klas Nilsson, Dept. Computer Science; Karl Åström, Rikard Bertilsson, Fredrik Kahl, Dept. Mathematics, Lund University, and Dr. Torgny Brogårdh, ABB Robotics.

The project SMErobot is lead by Fraunhofer – Institut für Produktionstechnik und Automatisierung (IPA) and other project partners include GPS Gesellschaft für Produktionssysteme GmbH, Pro-Support B.V., ABB Automated Technologies Robotics, COMAU S.p.A., KUKA Roboter GmbH, Reis Robotics GmbH & Co. Maschinenfabrik, Güdel AG, Casting technology International LTD by Gurantee, Visual Components Oy, Rinas ApS, SMEEIG EESV, Prospektiv Gesellschaft f. betriebliche Zukunftsgestaltung GmbH, Fraunhofer - Institut f. Produktionstechnik und Automatisierung (IPA), German Aerospace Center - Institute of Robotics and Mechatronics, University of Coimbra / ADDF, Istituto di Tecnologie Industriali e Automazione, Fraunhofer - Institut f. Systemtechnik und Innovationsforschung (ISI) SMErobot is an Integrated Project within the 6th Framework Programme of the EC to create a new family of SME-suitable robots and to exploit its potentials for competitive SME manufacturing.

The need More than 228 000 manufacturing SMEs in the EU are a crucial factor in Europe's competitiveness, wealth creation, quality of life and employment. To enable the EU to become the most competitive region in the world, the Commission has emphasized research efforts aimed at strengthening knowledge-based manufacturing in SMEs as agreed at the Lisbon Summit and as pointed out at MANUFUTURE-2003. However, existing automation technologies have been developed for capital-intensive large-volume manufacturing, resulting in costly and complex systems, which typically cannot be used in an SME context. Therefore, manufacturing SMEs are today caught in an 'automation trap': they must either opt for current and inappropriate automation solutions or compete on the basis of lowest wages. A new paradigm of affordable and flexible robot automation technology, which meets the requirements of SMEs, is called for.

Breakthrough This initiative is intended to exploit the potentials of industrial robots, because they constitute the most flexible existing automation technology. The consortium is set to create a radically new type of robot system – a whole family of SME-suitable robots.

Objectives The SMErobot initiative offers an escape out of the automation trap through:

- Technology development of SME robot systems adaptable to varying degrees of automation, at a third of today's automation life-cycle costs;
- New business models creating options for financing and operating robot automation given uncertainties in product volumes and life-times and to varying workforce qualification.
- Empowering the supply chain of robot automation by focusing on the needs and culture of SME manufacturing with regard to planning, operation and maintenance.

Innovations Research and development in SMErobot is geared towards creating the following technical innovations:

1. Robot capable of understanding human-like instructions (by voice, gesture, graphics)
2. Safe and productive human-aware space-sharing robot (cooperative, no fences)
3. Three-day-deploy-able integrated robot system (modular plug-and-produce components).

Partners Five major European robot manufacturers have joined forces in SMErobot, in close cooperation with key component manufacturers, five leading research institutes and universities, and consultants for multidisciplinary RTD, dissemination and training efforts.

Implementation Demonstrations of fully functional prototypes will be set up in different SME manufacturing branches (plastics & rubber, small-batch foundry, metal parts fabrication, etc.), together with SME end users and SME system integrators, partly from the new Member States. Training and education will be conducted at all levels from researcher to end-users.

Integration SMEs and society benefit from the combined integration of knowledge along the supply chain of robotic automation, from component manufacturers to end users, from multidisciplinary activities to business/financing models, and from fundamental technical research when confronted with SME scenarios. Management includes dedicated support for SME integration.

ProViking FlexAA – Flexible and Accurate Manufacturing Operations Using Robot Systems

Researchers: Anders Blomdell, Mathias Haage, Rolf Johansson, Klas Nilsson, Tomas Olsson, Anders Robertsson, Lund University in cooperation with Mats Björkman, Henrik Kihlman, Gilbert Ossbahr, IKP, Linköping University.

This projects deals with a feasibility study is of flexible and accurate manufacturing operations using robot systems with interactions sensors such as work-space force sensing. The goal of the project is to develop methodology and hardware support for improved high-precision operations and functionality for fast off-line programming based upon computer-aided design.

The need for flexibility today often motivates the use of robots within manufacturing, which works well for many standard applications. However, both deficient absolute precision (for non-compliant motions) and lack of control of the applied contact force (between tool and work-piece for compliant motions) severely limits the applicability today. Another key problem within flexible manipulation is that fixtures are needed but they are not flexible. In total, considering cost and productivity, the experienced implication is that robots do not really help short-series production in Swedish industry today.

Based on standard industrial robots, enhanced with new types of sensing and control interfaces, we propose an interdisciplinary research effort to improve the flexibility of flexible automation. Based on recent scientific advances and industrial results within ongoing European research projects, we have found opportunities to create robot systems with capabilities that go well beyond what is available and affordable today.

One of the basic ideas is to make use of the latest developments in industrial metrology and manufacturing simulation techniques, to drastically improve precision. A second basic idea is to combine the robot with the unique low-cost flexible fixture technology of the Adfast (EU FP5) project, providing automatic fixture set-up for precision assembly/machining/measurements and avoiding today's large investments in product specific equipment. A third idea is to make use of end-effector

force/torque sensing for force-controlled motions, maintaining accurate position control in some directions but accepting compliance and deviations in other directions as required for the task at hand.

An enabling factor for our ideas is the availability of an industrial robot system that has superior capabilities in terms of feedback from external sensors to the built-in motion control system. Based on the last ten years of research within open control systems for industrial robots at LTH, the core of such a system has been developed within the Autofett (EU FP5) project as a joint effort between ABB and LTH, and the resulting system is successfully being tested in Holland and in the USA.

More specifically the objective of this project is to deliver: A standard industrial robot that via an embedded metrology system will achieve a high absolute accuracy (<0.1 mm) in several applications. A standard industrial robot that via force sensing and feedback control will achieve compliant motion in certain directions as required within typical applications like grinding and deburring. A robotic research platform enabling other groups/projects to explore the possibilities of low-cost sensing to improve flexibility within a larger variety of applications, packaged as a research kit to be installed into new ABB robots. A task-oriented generic programming method that will increase the agility/flexibility of the robot and other flexible manufacturing equipment. The method will shorten the lead-time in the operation planning for the total manufacturing robot cell. Two functional demonstrators of end-user applications comprising improved robot system, simulation based operational planning and programming, flexible fixture application with robot-based machining

Automotive Systems

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

Complex Embedded Automotive Control Systems (CEmACS)

Researchers: Brad Schofield, Tore Hägglund, Anders Rantzer in cooperation with DaimlerChrysler AG, University of Glasgow, The Hamilton Institute and SINTEF.

The overall aim of the CEmACS project is the development of active safety systems for road vehicles. Part of the work deals with the development of controllers for rollover prevention. Rollover accidents are a common and deadly form of vehicle accident, particularly for certain vehicle classes such as Sports Utility Vehicles (SUV) and light commercial vans, where

Figure 5.11 DaimlerChrysler test vehicles, an S-500 and an A-class.

the centre of gravity can be high. In the case of commercial vehicles, both the mass and the centre of gravity vary depending on the loading conditions. This complicates the task of finding a controller to mitigate rollover.

Various systems for rollover prevention exist today in certain production vehicles, but they are rather simple. The aim of the project is to develop controllers capable of preventing rollover under all loading conditions without restricting vehicle performance unnecessarily. This requires the development of advanced methods of state estimation, parameter estimation and control design. Testing of controllers can be done in an advanced vehicle simulation environment as well as in various test vehicles maintained by DaimlerChrysler.

During 2006 considerable work towards experimental validation of the controllers has been carried out. A new experimental vehicle intended specifically for research on rollover has been acquired by DaimlerChrysler. Implementation of control allocation algorithms capable of real-time operation has been performed. Experiments are due to be performed in spring 2007. In Figure 5.11 see DaimlerChrysler test vehicles.

Model-Based Road Friction Estimation

Researchers: Jacob Svendenius, Magnus Gäfvert and Björn Wittenmark at Lund University and Haldex and Johan Hultén and Fredrik Bruzelius at Volvo Cars.

Road vehicles rely strongly on friction. Their large masses that often move at high speeds may cause fatal damage if they loose steer-ability. The controlling tire forces are generated by and dependent on a sometimes abruptly changing friction. A large safety margin in the traffic should be compulsory, but is often not sufficiently regarded by the drivers. Modern vehicle control systems can, to some extent, correct for uncautious actions from the driver, but a correct appraisal of the driving circumstances is mandatory for safe driving.

Figure 5.12 Vehicle testing in northern Sweden.

Many investigations show a correlation between the road condition and the accident risk. The output from a road friction estimator might be used as a detecting device that warns the driver about a bad or suddenly changed road condition. Information about the friction can also be used to enhance the functionality of active and adaptive control systems within the vehicle or sent to a global infrastructure that receives and transmits information about the roads.

The model-based road friction estimation project is a subproject within the Road Friction Estimation project, RFE, having members from SAAB, VTI, Volvo Technologies, Volvo Cars, Lund University, Luleå Technical University and Haldex Brake Products. The project is a part in the national research programme Intelligent Vehicle Safety Systems (IVSS).

The aim of the RFE project is to estimate the friction between tire and road surface and to evaluate and optimize the reliability as well as the delay of the estimation. The model-based estimation subproject aims at deriving algorithms for on board estimation of the friction based on measurements from already available sensors in the vehicle. The main focus is on longitudinal tire force excitations.

Preliminary tests and evaluations have been preformed on the test-track Hällered and in Arjeplog, Sweden. The tests show promising results. See Figure 5.12.

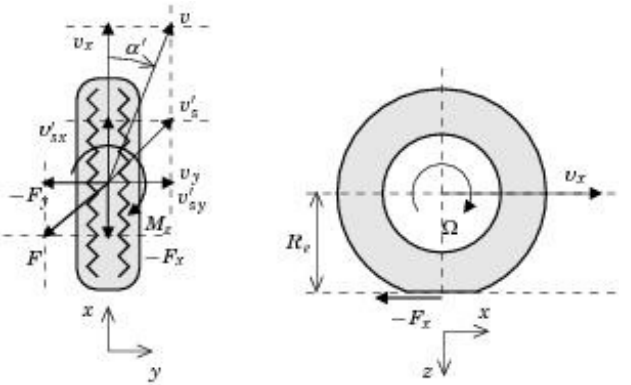


Figure 5.13 Kinematics of a tire during braking and cornering.

Semi-Empirical Tire Model for Combined Slip

Researchers: Jacob Svendenius, Magnus Gäfvert and Björn Wittenmark in cooperation with Haldex.

With new active chassis-control systems that are based on unilateral braking it is increasingly important to correctly describe the effects of combined braking and cornering. Accurate tire models are necessary components of models aimed at analyzing or simulating vehicle motion in real driving conditions. A new easy-to-use tire-force model has been developed for this purpose. The model is based on combining empirical models for pure braking and pure cornering with brush-model tire mechanics. The model can handle effects from wheel camber and from transient changes of the brake and cornering commands. See Figure 5.13

Diesel HCCI in Multi-cylinder Engines

Researchers: Maria Karlsson and Rolf Johansson in cooperation with Prof. Bengt Johansson, Dr. Per Tunestål, Div. Combustion Engines, Lund University, and Johan Bengtsson, Petter Strandh, Stefan Strömberg, Volvo Powertrain, Inc.

Homogeneous Charge Compression Ignition (HCCI) is a hybrid of the spark ignition and compression ignition engine concepts. As in an SI engine, a homogeneous fuel-air mixture is created in the inlet system. During the compression stroke the temperature of the mixture increases and reaches the point of autoignition, just as in a CI engine. One challenge with HCCI engines is the need for good timing control of the combustion. Auto ignition of a homogeneous mixture is very sensitive to operating

condition. Even small variations of the load can change the timing from too early to too late combustion. Thus, a fast combustion timing control is necessary since it sets the performance limitation of the load control. This project deals with various approaches to feedback control of the HCCI engine for optimized fuel economy and low emissions. A 12-liter Volvo Diesel engine has been successfully converted to HCCI operation with feedback systems based upon feedback of measured cylinder pressure or ion current.

Among control methods successfully applied, linear quadratic Gaussian control and model-predictive control have been implemented and tested.

KCFP, Closed-Loop Combustion Control

Researchers: Rolf Johansson, Anders Widd in cooperation with Assoc. Prof. Per Tunestål and Prof. Bengt Johansson, Div. Combustion Engines

Competence Center Combustion Processes at Lund University focuses on research of combustion processes between conventional HCCI (Homogeneous Charge Compression Ignition) and classical Otto and Diesel engines.

Project aims:

- System identification of combustion processes under closed-loop control;
- Development of algorithms hardware implementation suitable for ASICs and FPGA;
- Control-oriented modeling and simulation of combustion processes .

In addition to aspects of modeling related to thermodynamics, chemical combustion kinetics, and engine operation, careful attention is required for control-oriented combustion modeling and the interactions among dynamics, control, thermodynamics and chemical combustion properties. Modeling of engine-load transients as well as thermal transients also belong to this important domain of modeling. Progress in this area is important and necessary for successful and robust control such as model-predictive control.

Biomedical Systems

Cardiologic Analysis and Modeling

Researchers: Rolf Johansson in cooperation with Prof. S. Bertil Olsson, and Dr. Jonas Carlson, Dept. Cardiology, Lund University Hospital, Lund University.

This project is directed towards chronic atrial fibrillation (CAF), one of the most common cardiac arrhythmia's in man and associated with increased morbidity and mortality. Previous studies in animals have shown that experimental atrial fibrillation is based on different types of intraatrial electrical reentry. By exploring the activation of the right atrial free wall during open-heart surgery in patients with CAF and an underlying heart disease, we confirmed the presence of reentry mechanisms. In addition, areas with organised activation were identified. The nature of the organised activation suggested reentry in an anatomical structure, like the right annular bundle surrounding the tricuspid valve. In patients without signs of organised activation, multiple activation waves continuously reenter due to functional properties of the atrial myocardium. An interesting result was that we failed to demonstrate that anisotropy in conduction velocity be a general property of the epicardial right atrial free wall of the intact human heart in patients with stable sinus rhythm as well as in patients with CAF.

On December 9, 2005, Jonas Carlson defended his Ph.D. thesis entitled Exploration of Supraventricular Conduction with Respect to Atrial Fibrillation, PhD Thesis 2005:106, Dept. Clinical Sciences, Cardiology, Lund University Hospital.

Balance Laboratory

Researchers: Rolf Johansson in cooperation with Prof Måns Magnusson, Dr. Per-A. Fransson and Dr. Mikael Karlberg (Department of Clinical Sciences, Div. Otorhinolaryngology, Lund University Hospital).

The project is directed towards assessment of normal and pathological human postural control. System identification and mathematical modeling of the dynamics in postural control are studied with special interest on adaptation, reflexive and anticipatory control. Reflexive and voluntary eye movements are studied in patients with lesions related to balance disorders. Experimental studies, with special reference to the level of alertness, are undertaken to enhance understanding, diagnosis and treatment of dizziness and vertigo. A major complication is that human postural control is characterized by multisensory feedback control (visual, vestibular, proprioceptive feedback) and this fact is reflected both in experiment

design and analysis. Special interest is directed to the importance of cervical and vestibular afferent pathways. To this purpose, stability properties are studied by means of induced perturbations specific to each sensory feedback loop by using system identification methodology.

6

External Contacts

A healthy mix of fundamental and applied work is a cornerstone of our activities. In the applications projects the goal is to solve real control problems together with external partners. In these 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.

Industrial Contacts and Scholarships

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

ABB,
Alfa Laval,
DaimlerChrysler,
ETH,
EPFL,
Gudel,

Haldex AB,
Jaako Pöyry AB,
KPS Rinas,
Modelon AB,
NFO,
Novozymes Biopharma AB,
Perstorp Specialty Chemicals AB,
Pöyry Forest ind.,
Robert Bosch GmbH,
Saab,
Sigbi System AB,
Tetra Pak Processing Systems AB,
Toyota Motor Corporation,
ZF Lenksysteme,
Volvo Powertrain, Enc.,

and we got scholarships from the following foundations:

Royal Physiographic Society,
Jacob Letterstedt,
Knut and Alice Wallenberg,
Foundation of Per Westlings,
Foundation Sigfrid and Walborg Nordkvist,
Foundation Aeryleanska Traveling Scholarship.

European Collaboration

The department is involved in several projects in the 6th Frame Program of the European Commission.

FP6 Projects:

Networks of Excellence (NoE):

- ARTIST2 — Embedded Systems Design
- HYCON — Hybrid Control: Taming heterogeneity and complexity of networked embedded systems
- EURON-II — European Robotics Research Network

Integrated Projects (IP):

- RUNES — Reconfigurable Ubiquitous Networked Embedded Systems
- SMErobot — The European Robot Initiative for Strengthening the Competitiveness of SMEs in Manufacturing

Specific Targeted Research Projects (STREP):

- CEmACS — Complex Embedded Automotive Control systems

7

Dissertations

Three PhD theses were defended by Dan Henriksson, Ola Slätteke, and Lena de Maré; three Licentiate theses were completed by Martin Ohlin, Bradford Schofield, and Oskar Nilsson.

The abstracts are presented here in chronological order. PDF-documents of the theses are available at

http://www.control.lth.se/publications/.

Resource-Constrained Embedded Control and Computing Systems

Dan Henriksson
PhD dissertation, January 13, 2006

Opponent: Prof. Dawn Tilbury, Mechanical Engineering Dept, University of Michigan, Ann Arbor, USA. Committee: Dr. Mikael Johansson, Automatic Control, Royal Institute of Technology, Stockholm, Sweden; Prof. Luigi Palopoli, Dept of Information and Communication, University of Trento, Italy; Prof. Anders P. Ravn, Dept of Computer Science, Allborg University, Allborg, Denmark; Prof. Per Runesson, Dept of Communication Systems, Lund University, Sweden.

This thesis deals with methods for handling resource constraints in embedded control systems and real-time computing systems. By dynamic feedback-based resource scheduling it is possible to achieve adaptability and increased performance for these systems.

A feedback scheduling strategy is presented, which uses feedback from plant states to distribute computing resources optimally among a set of controller tasks. Linear-quadratic controllers are analyzed, and expressions relating the expected cost to the sampling period and the plant state are derived and used for on-line sample-rate adjustments.

A flexible implementation of model predictive control (MPC) tasks is described. A termination criterion is derived that, unlike traditional MPC, takes the effects of computational delay into account in the optimization. A scheduling scheme is also described, where the MPC cost functions being minimized are used as dynamic task priorities for a set of MPC tasks.

A method for optimizing the use of computational resources in a multi-camera-based positioning system is studied. The covariance of the estimation error is minimized, while meeting computation time constraints.

A novel predictor for delay control in server systems is introduced. The predictor uses instantaneous measurements of queue length and arrival times and is continuously updated as new requests arrive according to a receding horizon principle. The predictor is evaluated in simulation and by experiments on an Apache web server.

The MATLAB/Simulink-based simulator TrueTime is presented. TrueTime is a codesign tool that facilitates simulation of distributed real-time control systems. TrueTime also supports simulation of wireless communication and resource constraints associated with wireless sensor/actuator networks.

Modeling and Control of the Paper Machine Drying Section

Ola Slätteke
PhD dissertation, January 28, 2006

Opponent: Prof. Sigurd Skogestad, Department of Chemical Engineering, Norwegian University of Science, Trondheim, Norway. Committee: Prof. Elling Jacobsen, Automatic Control, Royal Institute of Technology, Stockholm, Sweden; Docent Alf Isaksson, Dept of Automation Technologies, ABB Corporate Research, Västerås, Sweden; Dr. Bernt Nilsson, Chemical Engineering, Lund University, Lund, Sweden; Docent Jan Sternby, Treatment Systems Research, Gambro Lundia, Lund, Sweden.

The topic of this thesis is modeling and control of the last part of the paper machine – the drying section. Paper is dried by letting it pass through a series of steam heated cylinders and the evaporation is thus powered by the latent heat of vaporization of the steam. The moisture in the paper is controlled by adjusting the set point of the steam pressure controllers.

There exist several commercial incentives to focus on the performance of the moisture control. The time to perform a grade change is often limited by the moisture and shorter grade change time is directly correlated to economic profit. Studies have shown that the drying section uses 2/3 of the total energy requirement in paper making. Reduced variations in moisture gives opportunity for target shifts (changed set point) which reduces the amount of raw material and steam requirement. It also creates opportunity for increased production rate.

The thesis is divided in two parts. The first part deals with the control of the steam pressure inside the cylinders. Both a black-box model and a physical model are given for the steam pressure process. A tuning rule for both PI and PID control is derived and various other controller structures are investigated. Many of the results are verified by experiments on paper machines at different paper mills. The second part of the thesis treats the moisture controller. The physical model from the first part is expanded with a model for the paper. This gives a complete simulation model for the drying section that is implemented in the object-oriented modeling language Modelica. Two new approaches to control the moisture by feedback are evaluated. The first utilizes the air around the paper in combination with the drying cylinders to improve the controller performance. The second uses only the last part of the drying section to control the moisture, while the first part is put at an appropriate level. Finally, feedforward of a surface temperature signal is examined.

Feeding Strategies Based on Probing Control for E. coli and V. cholerae Cultivations

Lena de Maré
PhD dissertation, June 16, 2006

Opponent: Prof. Elling Jacobsen, Automatic Control, Royal Institute of Technology, Stockholm, Sweden. Committee: Adj. Prof. Christina Skjöldebrand, Dept. of Design Sciences, Lund University, Lund, Sweden; Prof Alexander Medvedev, Department of Automatic Control, Uppsala University, Uppsala, Sweden; Dr. Bernt Nilsson, Chemical Engineering, Lund University, Lund, Sweden; Docent Jan Sternby, Treatment System Research, Gambro Lundia AB, Lund, Sweden.

The recombinant DNA techniques have made it possible to produce many different proteins for a wide range of applications. The vector encoding for the recombinant protein is often inserted in the bacterium E. coli as it is a well studied and a well-known organism. To achieve a high

productivity, it is important to reach a high cell density. This is obtained through fed-batch operation where the nutrient, usually glucose, is added continuously. The feeding strategy should be designed to avoid starvation and overfeeding. This is not an easy task as on-line measurements of key variables are normally not available. A probing feeding strategy using the measurements of the standard dissolved oxygen sensor is developed by M. Åkesson. The key idea is to superimpose pulses on the feed-rate and make use of the responses in the dissolved oxygen in a feedback algorithm. Also, when the maximum transfer capacity of the reactor is reached the feed-rate is decreased in order to keep the reactor working under aerobic conditions. The strategy has been successfully implemented in cultivations with different E. coli strains and on different scales.

The probing feeding strategy is further developed in many aspects in this thesis. Firstly, it is implemented with good results also in V. cholerae cultivations, which shows how general the strategy is. Also, a model of a bio-reactor operating in fed-batch mode is presented and verified. The effect on the tuning rules of the probing controller is investigated. The probing feeding strategy is further improved for a more efficient product synthesis. This new fermentation technique manipulates the temperature when the maximum oxygen transfer capacity of the reactor is reached. The strategy consists of a mid-ranging controller structure and a modified probing controller. It is analysed and evaluated in experiments and simulations. Furthermore, some E. coli production strains need additions of amino acids or complex media besides the carbon nutrient to grow and produce the recombinant protein. The probing control concept is therefore extended in order to handle these situations. Feeding strategies for dual feeding of amino acids or complex media and glucose are developed.

Feedback Linux Scheduling and a Simulation Tool for Wireless Control

Martin Ohlin
Licentiate dissertation, August 25, 2006

Opponent: Lic Tech Patrik Persson, Ericsson Mobile Platforms AB, Research Department, Lund, Sweden.

Computing systems are becoming more and more complex and powerful. It is nowadays not uncommon to run several server applications on the same physical platform. This gives rise to a need for resource reservation techniques, so that administrators may prioritize some tasks, or

customers, over others. This thesis gives an introduction to the Linux kernel 2.6 task scheduler, and scheduling related operating system concepts such as priority, nice value, interactivity and task states. The thesis also presents an implementation of a scheduling mechanism, that in a non-intrusive way introduces per task CPU bandwidth reservations in the Linux operating system.

The MATLAB/Simulink-based simulator TrueTime is given a short introduction, and the wireless capabilities of the tool are described in more detail. TrueTime is a tool for co-simulation of real-time tasks, network communication, and continuous-time plant dynamics. The modeling of the common medium access control (MAC) layers of IEEE 802.11 and IEEE 802.15.4 is described, along with the radio model used. TrueTime's capabilities to simulate local clocks with drift, Dynamic Voltage Scaling, and battery powered devices are also presented.

Vehicle Dynamics Control for Rollover Prevention

Bradford Schofield
Licentiate dissertation, December 8, 2006

Opponent: Dr. Stefan Solyom, Volvo Car Corporation, Gothenburg, Sweden.

Vehicle rollover accidents are a particularly dangerous form of road accident. Existing vehicle dynamics controllers primarily deal with yaw stability, and are of limited use for dealing with problems of roll instability. This thesis deals with the development of a new type of vehicle dynamics control system, capable of preventing rollover accidents caused by extreme maneuvering. A control strategy based on limitation of the roll angle while following a yaw rate reference is presented. Methods for rollover detection are investigated. A new computationally-efficient control allocation strategy based on convex optimization is used to map the controller commands to the individual braking forces, taking into account actuator constraints. Simulations show that the strategy is capable of preventing rollover of a commercial van during various standard test maneuvers.

Modeling and Model Reduction in Automotive Systems

Oskar Nilsson
Licentiate dissertation, December 20, 2006

Opponent: Prof. Anders Helmersson, ISY, Automatic Control, Linköping University, Linköping, Sweden.

The current control design development process in automotive industry and elsewhere involves many expensive experiments and hand-tuning of control parameters. Model based control design is a promising approach to reduce costs and development time. In this process low complexity models are essential. This thesis combines the areas of modeling and model reduction in automotive systems. A model of the exhaust gas oxygen sensor, used for air-fuel ratio control in automotive spark ignition engines, is developed and successfully validated. A model reduction case study is also performed on an engine air path. The heuristic method commonly used when modeling engine dynamics is compared with a more systematic approach based on the balanced truncation method.

Finally, a method for model reduction of nonlinear systems has been derived. The procedure is focused on reducing the number of states using information obtained by linearization around trajectories. The methodology is closely tied to existing theory on error bounds and good results are shown in form of examples and simulation data.

8

Honors and Awards

Karl-Erik Årzén received the *Dr Guido Carlo-Stella Award* from the World Bach Foundation (WBF) for his contribution to process automation and information integration in the manufacturing industries.

Karl Johan Åström received the *2006 IEEE Control Systems Magazine Outstanding Paper Award* for paper coauthored with **R.E. Klein** and **A. Lennartsson** entitled "Bicycle Dynamics and Control: Adapted Bicycles for Education and Research".

Per Hagander was elected member of The Royal Physiographic Society in Lund.

9

Personnel and Visitors

Personnel

During 2006 the following persons have been employed at the department. The list shows the *status of December 2006* if nothing else is mentioned.

Professors

Karl-Erik Årzén
Karl Johan Åström (emeritus)
Bo Bernhardsson *(part time)*
Per Hagander
Tore Hägglund
Rolf Johansson
Anders Rantzer
Björn Wittenmark

Research Associates

Anton Cervin
Charlotta Johnsson
Anders Robertsson

Research Engineers

Leif Andersson
Anders Blomdell
Rolf Braun

PhD Students

Johan Åkesson
Peter Alriksson
Lena de Maré *(until October)*
Isolde Dressler
Jenny Ekvall
Olof Garpinger
Ather Gattami
Pontus Giselsson *(from November)*
Staffan Haugwitz
Dan Henriksson *(until August)*
Erik Johannesson *(from May)*
Maria Karlsson
Martin A. Kjær
Larsson, Per-Ola
Karl Mårtensson *(from November)*
Oskar Nilsson
Martin Ohlin

Tomas Olsson
Toivo Perby Henningsson
Mikael Petersson
Brad Schofield
Ola Slätteke *(until May)*
Aivar Sootla *(from September)*
Jacob Svendenius
Andreas Wernrud
Anders Widd *(from November)*

Secretaries

Britt-Marie Mårtensson
Eva Schildt
Agneta Tuszyński

Visiting Scientists

The following researchers have stayed with the department for a couple of days by the least.

Changming Yin *Dec 1, 2005–August 30, 2006*
Changsha University of Science, Hunan, Chin

Francesco Pierri *March 16–September 15, 2006*
Universita degli Studi della Basilicata, Potenza, Italy

Angel Gaspar Gonzalez Rodgriguez *May 31–September 1, 2006*
Campus Las Lagunillas, Jaén, Spain

Roland Lenain *June 16–December 20, 2006*
Clermont-Ferrand Regional Cenre, France

Leonid Freidovich *June 26–June 30, 2006*
Umeå University, Umeå, Sweden

Richard Murray *July 23–July 26, 2006*
California Institute of Technology, Pasadena, USA

Visiting Students

The following foreign students from the ERASMUS program, have stayed with the department and have made their master's theses.

David Barrio-Vicente *from June*
Universidad de Valladolid, Spain

Benoit Brochier *until October*
Institut National Polytechnique de Grenoble, France

Simone del Favero *until June*
Universitá degli Studi di Padova, Italy

Thomas Dietz *April – July*
Eidgenössische Technische Hochschule, Zürich, Switzerland

Luis Rodriguez Blanco *until June*
Universidad de Valladolid, Spain

Mathieu Gerard *until June*
Université de Liége, Belgium

Jaume Corvera Ripoll *until May*
Universitat de Girona, Spain

10

Staff Activities

This is a short description of the staff (listed in alphabetic order) and their activities during the year. Publications and lectures are listed in separate sections.

Åkesson, Johan

Lic Tech, graduate student since January 2001. Johan's main research interest is in the field of languages for dynamic optimization of large scale systems.

Johan's research interests also include stabilization of unstable systems subject to input saturation. During 2006, Johan has developed a compiler for a subset of the Modelica language. An extension of this compiler can also translate a high level formulation of an optimization problem, along with a Modelica model description, into a format suitable for numerical optimization algorithms. These tools have been used to solve a large scale dynamic optimization formulation, where the problem has been to find optimal start-up trajectories for a plate reactor.

Johan has also been involved in the design and control algorithm implementation of an inverted pendulum on two wheels robot, YAIP. During the year, Johan was a teaching assistant in the courses Computer Controlled Systems and Real-Time Systems.

Alriksson, Peter

MSc graduate student since June 2003. His research interests are in estimation and optimal control of hybrid systems. Also some work have been done in the area of distributed estimation. His teaching responsibilities include being a teaching assistant in the courses Control Theory and Automatic Control (Basic Course). Peter has also been co-supervising a master thesis started in September 2006.

Andersson, Leif

MSc, Research Engineer since 1970. Leif started at the department with a responsibility for the teaching laboratory. He designed some lab equipment, notably an analog computer. In 1976 he started in ernest with digital computers, and has been responsible for the department computing facilities since then. His professional activities, apart from computer system maintenance, have ranged from computer typesetting (TEX and LATEX) via Real Time Programming to using Java as a tool for writing educational software.

Årzén, Karl-Erik

Professor (2000), PhD (1987): Joined the department in 1981. His research interests are real-time control, real-time systems, programming languages for control, Petri nets and Grafcet, and monitoring and diagnosis.

Programme director the SSF/FLEXCON project on flexible embedded control systems. Leader for the cluster on control for embedded systems within the EU/IST FP6 network of excellence ARTIST2 on design of embedded systems. During the year he has primarily been involved in the EU/IST FP6 IP project RUNES (Reconfigurable Ubiquitous Networked Embedded Systems) and in the SSF/FLEXCON project. He has been responsible for and taught the undergraduate course on Real-Time Systems, the Project Course in Automatic Control, and the International Project Course in Automatic Control. He is partly or fully involved in the supervision of three PhD students.

Bernhardsson, Bo

PhD 1992, Docent in 1998, and Professor in December 1999. Since 2001 Bo is on leave working at Ericsson Mobile Platforms in Lund and is working part time at our department.

Blomdell, Anders

Research Engineer since 1988. Responsible for the department network and lab computers for teaching and research. Professional interest includes man-machine interaction, real-time programming, hardware design, network communication protocols, and computer languages for control engineering.

During the previous years, Linux has been deployed on many different systems in hope of replacing the legacy STORK Real Time Kernel, which is now only used in m680x0 and PowerPC systems.

Braun, Rolf

Research Engineer at the department since 1969. Designs and builds equipment for education and research, and handles hardware maintenance of computers and equipment. He also plans and supervises maintenance and rebuilding of offices and labs.

Cervin, Anton

Research associate, PhD (2003); joined the department in 1998. Anton's research interests include real-time systems, networked control, event-based control, and computer tools for analysis and simulation of controller timing. During 2006, he has worked in his research project "Periodic and event-based control over networks", funded by the Swedish Research Council. He has also been involved in various activities within the ARTIST2 Network of Excellence on Embedded Systems Design, including giving lectures at two European graduate courses in real-time control. As Chairman of SNART, he was co-organizer of the Swedish Embedded Systems meeting and the Scandinavian ARTIST2 Seminar on Embedded Systems Design. He has also been a lecturer in the basic control course for the information and communication engineering students.

Dressler, Isolde

Msc, graduate student since September 2004. Isolde is interested in modeling, calibration and control of parallel kinematic robots and works within the SMErobot project. She was teaching assistant in the Computer Controlled Systems and the Systems Engineering course.

Ekvall, Jenny

Lic Tech in November 2004, graduate student since January 2002. The process Jenny studies is the drying section of a paper machine. In collaboration with M-real, Husum, she models the drying section. She also evaluates different control strategies with purpose to improve moisture control.

Jenny is employed by Mid Sweden University and she is part of the research group NPI (Network for Process Intelligence) in Örnsköldsvik, where she also has her office.

Garpinger, Olof

MSc, graduate student since August 2005. This year Olof has started to work within the project "Decentralized Structures for Industrial Control", which is funded by The Swedish Research Council (VR). It is a

continuation of the work Pontus Nordfeldt did until his Licentiate Thesis in December 2005. The research concerns automatic tuning of systems with two inputs and two outputs (TITO systems). Olof has also been teaching assistant twice in the basic automatic control course.

Gattami, Ather

MSc, graduate student since September 2003. Ather Gattami interests include optimization and optimal control, game theory and information theory with applications to distributed control problems over graphs with limited information.

Ather has also been a teaching assistant for the basic course "Automatic control", and the graduate course "Control of Nonlinear Systems".

Giselsson, Pontus

MSc, graduate student since November 2006. Pontus finished his Master Thesis, on Modeling and Control of Large Deformable Mirrors, this autumn. The project was a part of the design development of an Extremely Large Telescope called Euro50. Since the employment at the department started, Pontus has spent his time on courses.

Hagander, Per

Professor, PhD (1973). Per has been with the department since 1968 and works with linear system theory and with applications in biotechnology and medicine. Per is the LTH vice rector of international affairs.

During 2006 he taught the basic course together with the course Control Theory.

He is leading a project with Pfizer AB, on multivariable control of genetically engineered *E. Coli*. The work is also a collaboration with the Department of Biotechnology, Lund University and Novozymes Biopharma.

He leads a project on the control of a special type of continuous chemical reactors together with Alfa Laval AB within the Center for Process Design and Control (CPDC). The project is partially funded by EU-FP6 HYCON, WP4b.

Hägglund, Tore

Professor, PhD (1984). Has been at the department since 1978 except for four years when he worked for Alfa Laval Automation AB (now ABB). He is responsible for two of the basic courses in Automatic Control in the engineering program. His 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, decentralized control structures, and research projects in collaboration with the pulp and paper industry. He has also developed a new method for backlash detection that is patent pending.

Haugwitz, Staffan

Lic Tech, graduate student since August 2002. Staffan is working with Per Hagander on the project "New control strategies for a novel heat exchange reactor". The project aims at improving process control of chemical reactors, especially the new Alfa Laval Plate Reactor, which is being developed by Alfa Laval AB. The focus is to develop new control methods to take advantage of the flexible configuration of the reactor and to be able to use its full potential.

Staffan was teaching assistant in the basic Automatic Control and the Process Control courses during the spring and fall.

Henningsson Perby, Toivo

MSc, graduate student since August 2005. His research interests are in distributed, event based and embedded control and estimation. Toivo is working on distributed control for power systems and lightly damped distributed systems in general. During 2006 he also coauthored two papers on sporadic event based control and was a teaching assistant in the Project Course and the Real-Time Systems course.

Johannesson, Erik

MSc, graduate student since May 2006. Erik is interested in the interconnections between control and economics. He also has an interest in event-based control. During the spring, Erik was a teaching assistant for the basic Automatic Control course for the undergraduate programs in Mathematical Engineering and Environmental Engineering.

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 node leader for the research projects SMErobot, HYCON, SSF ProViking FlexAA, Vinnova PFF Diesel HCCI and CECOST Gas Turbine. He is coordinating director for Robotics Laboratory with cooperation partners from Dept Computer Science, Dept Mechanical Engineering, Dept. Mathematics and industrial partners. He has industrial cooperation with ABB Robotics, Volvo Powertrain, Volvo Car Corporation and Scania CV AB. He is responsible for the two courses

FRT041 System Identification and FRT050 Adaptive Control. Together with Dr. Måns Magnusson he leads research at the Vestibular Laboratory, Dept. Otorhinolaryngology, Lund University Hospital.

Johnsson, Charlotta

Charlotta Johnsson holds a position as a Senior Research Associate. Her research is focused upon Batch Control Systems and Manufacturing Operations System. Charlotta got her Ph.D. degree at the Department, in March 1999, with the thesis "A Graphical Languages for Batch Control". After dissertation, Charlotta joined Orsi Automatzione S.p.A., later part of Siemens A&D, and worked in Genoa, Italy for 4.5 years.

At the department, Charlotta is responsible for two undergraduate courses; Automatic Process Control for Chemical Engineering and Biochemical Engineering, and Systems Engineering for Environmental Engineering and Engineering Nanoscience. Charlotta is also co-responsible for the course "Technology, Strategy and Structure" given for the Technology Management program at Lund University. Charlotta also actively participated in the course "Packaging Logistics" given at LTH.

During the year, Charlotta acted as the examinator for one master thesis project performed in cooperation with Novozymes AB in Lund.

Karlsson, Maria

MSc, graduate student since August 2005. She is working with Professor Rolf Johansson in the project Diesel-HCCI in a Multi-cylinder Engine in cooperation with Volvo Powertrain and the division of of combustion engines at Lund University. She has been a teaching assistant in the courses System Identification, Biological Systems, and the basic course in Automatic Control.

Kjær, Martin Ansberg

Msc, Lic. Tech. Graduate student since August 2003. He is working in the field of active control of web servers together with Anders Robertsson. During the last year he has been focusing on queuing prediction and experimental research. His teaching activities were related to supervision of students in an international project course where Swedish students were cooperating with students of Ecole de Mines, Nantes, France

Larsson, Per-Ola

MSc (2005), graduate student since January 2006. His research interest is within process control, especially in processes with delay dominant

properties. Per-Ola is involved in a project together with Professor Tore Hägglund concerning tuning methods for a dead-time compensating PID controller. He has been a teaching assistant in the basic Automatic control courses during spring and autumn.

Mårtensson, Britt-Marie

Secretary at the department since 1974. She is responsible for the department library, ordering books, handles the mail and office supplies. Assistant Webmaster. She handles the contact with printing offices for dissertations and other publications. Britt-Marie is also the department's service-person.

Mårtensson, Karl

MSc, graduate student since December 2006. He has spent his time finishing the courses that he started this autumn.

Nilsson, Oskar

Lic Tech, graduate student since September 2003. Oskar is working together with Anders Rantzer in a project funded by Toyota Motor Corporation. His research is currently focused on model reduction of automotive models implemented in Dymola.

Ohlin, Martin

Lic. Eng., graduate student since September 2003. Martins research interests concern design and analysis of real time control systems, networked embedded systems, and control of computing systems. He is one of the authors of the TrueTime simulator. He has been involved in ARTES++, RUNES and ARTIST2. Martin has been a teaching assistant at the department in the Real-Time Systems course and in the course Control for InfoCom.

Olsson, Tomas

Lic Tech, graduate student since December 2001. His main research interests are robotic force control and high-speed vision-based tracking and control. He is working with industrial force control and applications of vision-based control in the SSF/ProViking project FlexAA. During the year he has been a teaching assistant in the course Real-Time Systems. Tomas received Travel contributions from Knut and Alice Wallenberg Stiftelse.

Rantzer, Anders

Professor of Automatic Control since 1999 and serves as department prefekt. Joined Lund University in 1993 after a PhD at KTH and postdoctoral positions at KTH and University of Minnesota. The academic year of 2004/05 was spent as visiting associate at Caltech. He has broad interests in modeling, analysis and synthesis of control systems, with particular attention to uncertainty, optimization and distributed control.

Anders Rantzer is the main supervisor for several PhD students. He served on several international scientific committees during the year and was chairman of the evaluation committee in Signals and Systems for the Swedish Research Council.

Robertsson, Anders

"Docent" (2005), Research Associate (May 2003), PhD (1999). His main interest is in nonlinear control and robotics. Currently he is working on sensor-data integration and force control of industrial robots in collaboration with ABB Robotics. The research has been conducted with the LUCAS project and the Robotics Lab. He has also been doing research on admission control systems for server systems in cooperation with the Department of Telecommunications, LTH. He has lectured the course on Nonlinear Control and Servo Systems for engineering students, the PhD course on Nonlinear Control Theory in Lund, lectured in a PhD course on Nonlinear Oscillations in Aalborg, Denmark, and acted as advisor for 3 PhD students and several Master's Thesis projects.

He has held a part-time position (25%) as "Guest lecturer" at the Dept of Applied Physics and Electronics, Umeå University since March 1.

Schildt, Eva

Secretary at the Department since 1970. Eva is mainly responsible for the financial transactions of the department such as bookkeeping and reporting to our sponsors. She handles the personnel administration and takes care of the administration concerning visitors at the department.

Svendenius, Jacob

Lic Tech since November 2003 and MSc in mechanical engineering since 1998. After three years of work in the laboratory at Haldex Brake Products with performance testing of brakes for heavy vehicles he started 2001 as a PhD student at the department. The main research interests concern braking control and tire modeling. His major occupation is in the IVSS-project "Road Friction Estimation", which is a cooperation between, among

others, Haldex, Lund University, and Volvo Cars aiming at developing methods for detection of the road-surface friction during driving.

Tuszyński, Agneta

Secretary at the department since 1981. She is responsible for registration of the student's and PhD student's course entries and exam results. She works with word processing in LaTeX. Agneta is also responsible for Activity Report 2006 together with Anders Rantzer.

During one week she got three grandchildren, Olle, born on January 24, and twin boys, Aksel and Arthur, born on February 1.

Wernrud, Andreas

MSc, graduate student since March 2003. His research interests are in optimal control and hybrid systems, with a focus on computational methods. He is involved in the HyCon-project, control and analysis of hybrid systems. During the year he has been teaching in the courses Adaptive Control and Real-Time Systems and was the supervisor for one Master's Thesis project.

Widd, Anders

MSc, graduate student since December 2006. Anders completed his Master's Thesis, 'Estimation of Side Wind Disturbances in Automotive Vehicles', in November 2006. The work was carried out at one of DaimlerChrysler's research facilities in Sindelfingen, Germany.

Wittenmark, Björn

Professor in Automatic Control since 1989. He joined the department in 1966 and took his PhD in 1973. His main research interests are adaptive control, sampled-data systems, and process control. He is currently working within projects in the area of process design and control and control of communication networks. Since March 1, 2003 he is appointed as Assistant vice-chancellor (Vice president) of Lund University.

External Assignments

Opponent and Member of Examination Committee

Karl-Erik Årzén: Member of the PhD thesis examination board of Anders Nilsson, Dept of Computer Science, Lund University, June 14. External

reviewer of the PhD thesis by Mohamed El Mongi Ben Gaid, Laboratoire COSI–Groupe ESIEE, University d'Evry Val d'Essonne, Paris, France, November 20. Member of the PhD thesis examination board of Frans Lüders, Dept of Computer Science and Electronics, Mälardalen University, December 18.

Anton Cervin: Member of the PhD thesis examination board of Thomas Nolte, May 5, Mälardalen University. External reviewer of the Licentiate thesis by Viacheslav Izosimov, November 15, Linköping University.

Per Hagander: Member of the examination board of Petter Strandh, Heat and Power Engineering, Lund University, Lund, Sweden, May 29.

Tore Hägglund: External reviewer of the Licentiate thesis by Johan Wahlström, Division of Vehicular Systems, Department of Electrical Engineering, Linköping University, October 20.

Charlotta Johnsson: Member of the PhD thesis examination board of Carina Andersson, Dept. of Communication Systems, LTH, May 5.

Anders Rantzer: Member of the PhD thesis examination board of Henrik Mosskull, April 7 at Royal Institute of Technology, Stockholm. Member of the PhD thesis examination board of Ion Necora, October 17 at Technische Universiteit Delft, The Netherlands. Member of the PhD thesis examination board of Ioannis Lestas, November 20 at Cambridge University, United Kingdom.

Anders Robertsson: Member of the PhD thesis examination board of Javier Gamez Garcia, Jaen, Spain, February 17.

Björn Wittenmark: External reviewer for adjunct professorship for Torbjörn Wigren at Uppsala University.

Board Member

Karl-Erik Årzén: Member of the Research Senate, Lund University. Member of the Board of the SSF Graduate School on Chemical Process Design and Control (CPDC).

Anton Cervin: Board Member and Chairman of SNART (the Swedish National Real-Time Association).

Tore Hägglund: Member of the Education Board 2 at Faculty of Engineering, Lund University. Expert member in legal proceedings for patent at Svea Court of Appeal, 2004–2006.

Rolf Johansson: Member of SMErobot Scientific and Technical Advisory Booard.

Charlotta Johnsson: Board member of WBF (the Forum for Automation and Manufacturing Professionals) where she serves as the treasurer and the Director of European Operations.

Anders Rantzer: Chairman of the evaluation committee on Signals and Systems at the Swedish Research Council. Member of the steering committee for the International Symposium on Mathematical Theory of Networks and Systems. Member of the Administrative Council for the European Union Control Association.

Björn Wittenmark: Assistant vice-chancellor (Vice president) for Lund University from March 1, 2003. Chairman of the Board of Campus Helsingborg. Board member of LUCAS. Board member of Gyllenstiernska Krapperupstiftelsen.

Book and Journal Editor

Tore Hägglund: Associate editor for Control Engineering Practice.

Rolf Johansson: Assoc. Editor of Int. J. Adaptive Control & Signal Processing, Assoc. Editor of Chinese Journal of Scientific Instrument, and Guest Assoc. Editor of Int. J. Control.

Anders Rantzer: Member of the editorial board for International Journal of Robust and Nonlinear Control.

Björn Wittenmark: Optimal Control Applications & Methods, Journal of Forecasting, IEE Proceedings Control Theory & Applications, and International Journal of Adaptive Control and Signal Processing.

Advisory Committees and Working Groups

Karl-Erik Årzén: Member of the IFAC Technical Committee on Chemical Process Control. Vice chair of the IFAC Technical Committee on Computers and Control.

Per Hagander: Member of IFAC Technical Committee BIOMED. Member of IFAC Technical Committee Biotechnological Processes. Member of ESBES–Working group M^3C.

Rolf Johansson: Member of IEEE EMBS Technical Committee (TC) for Biomedical Robotics, Member of Joint EMBS/RAS Advisory Committee on Biorobotics; Science Foundation Ireland (SFI), Research Frontiers Programme, October 23-24, Dublin, Ireland.

Charlotta Johnsson: Educational Chair of ISA District 12 (Europe, Middle East, Africa and Russia). Voting member in the standardisation committee ISA 95, and an information member in the standardisation committees ISA 88 and ISA 99. Member in SEK and serves as the Swedish expert in the international IEC and ISO working group JWG15.

Anders Rantzer: 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 Swedish IFAC Committee.

Björn Wittenmark: Expert member in legal proceedings for patent at Svea Court of Appeal, 2004-2006. Member of the Technical Committee for IFAC Adaptive Control and Learning. Member of the IEEE Control System Society International Affairs Committee. Reviewer for research evaluations for the Australian Research Council and Norwegian Research Council. Member of the committee of the IEEE Control Systems Society George S. Axelby Outstanding Paper Award.

Member of International Program Committee (IPC)

Karl-Erik Årzén: Member of the IPC for the 14th International Workshop on Parallel and Distributed Real-Time Systems (WPDRTS 2006), Rhodes, Greece, April 2006. Member of the IPC for the Real-Time Systems Symposium, Rio de Janeiro, Brazil, December 2006. Member of the IPC for the track on Model-Based design for EmbeddedMember of the IPC for the 10th International Conference on Hybrid Systems: Computation and Control (HSCC'07), Pisa, Italy, April 2007. Member of the IPC for the Second IEEE International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks (FeBID), Munich, Germany, May 2007. Member of the IPC for the special track on Computational Modeling and Simulation of Embedded Systems, Summer Computer Simulation Conference (SCSC), San Diego, CA, July 2007.

Anton Cervin: Member of the IPC for the 18th Euromicro Conference on Real-Time Systems (ECRTS'06). Member of the IPC for the 14th International Conference on Real-Time and Network Systems (RTNS'06).

Per Hagander: Member of IPC for the 6th IFAC Symposium on Modelling and Control in Biomedical Systems, September.

Tore Hägglund: Member of the International Program Committees for the conferences Controlo 2006–7th Portuguese Conference on Automatic Control in Lisbon, Portugal. 2006 IEEE Symposium on Computer-Aided Control Systems Design (CACSD6) in Munich, Germany.

Rolf Johansson: Member of the Executive Committee of The First IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob 2006). IPC Member of the International Conference Control 2006, Glasgow, Scotland, August 30-September 1. IPC Member of the 7th Portuguese Conference on Automatic Control (CONTROLO 2006), Instituto Superior Técnico, September 11-13. IPC Member of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2006), Beijing, China, October 9-15. IPC Member of 2nd Workshop on Dynamical Models for Computer Vision, European Conference on Computer Vision (ECCV 2006), Graz, Austria, May 13. IPC Member of IEEE 2006 Conference on Decision and Control (CDC 2006), San Diego, CA, 13-15 December. IPC Member of IEEE Engineering in Medicine and Biology Society Conference (EMBS'06), August 30-September 3, New York City.

Charlotta Johnsson: Serves as a Program committee member for the 3rd International Conference on Interoperability for Enterprise Software and Applications (IESA-07), March 28-30, 2007, Madeira Island, Portugal.

Anders Rantzer: Member of the IPC for European Control Conference 2007 (ECC07). Member of the IPC for 2nd IFAC Conference on Analysis and Design of Hybrid Systems (ADHS06). Member of the IPC for 7th IFAC Symposium on Nonlinear Control Systems (NOLCOS07).

Björn Wittenmark: Member of the International Program Committee IFAC Symposium on "System Identification" in Newcastle, Australia, March 2006 (SYSID2006). Member of the International Program Committee of " Advances in Control Education", Madrid, June.

Other Assignments

Rolf Johansson: Co-Chairman HYCON & CEMaCS Workshop on Automotive Systems and Control, June 1-2. Program Chair Europe of The First IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob 2006).

Charlotta Johnsson: During November 13–15 Charlotta Johnsson was the Conference Chair for the WBF (the Forum for Automation and Manufacturing Professionals) Conference held in Mechelen, Belgium. The conference attracted around 155 people from both academia and industry (vendors and endusers).

11

Publications and Conference Contributions

This year 1 book, 3 book contributions, 14 journal papers, and 53 conference papers have been published.

Many of the publications can be retrieved from:

http://www.control.lth.se/publications.

Books

Åström, Karl Johan: *Introduction to Stochastic Control Theory*. Dover, New York, 2006. Reprint. Originally published by Academic Press 1970.

Book Contributions

Cervin, Anton, and Johan Eker: "The control server model for co-design of real-time control systems." In Hansson, Ed., *ARTES – A network for Real-Time research and graduate Education in Sweden 1997–2006*. Department of Information Technology, Uppsala University, Sweden, March 2006.

Henriksson, Dan, Ola Redell, Jad El-Khoury, Anton Cervin, Martin Törngren, and Karl-Erik Årzén: "Tools for real-time control systems co-design." In Hansson, Ed., *ARTES – A network for Real-Time research and graduate Education in Sweden 1997–2006*. Department of Information Technology, Uppsala University, Sweden, March 2006.

Shiriaev, Anton, Anders Robertsson, Leonid Freidovich, and Rolf Johansson: "Coordinating control for a fleet of underactuated ships." In *Group Coordination and Cooperative Control*, vol. LNCIS 336. Springer-Verlag, Berlin Heidelberg, May 2006. Chap. 14, pp. 233-250.

Journal Papers

Årzén, Karl-Erik, Anders Robertsson, Dan Henriksson, Mikael Johansson, H. Hjalmarsson, and Karl Henrik Johansson: "Conclusions of the ARTIST2 roadmap on control of computing systems." *ACM SIGBED (Special Interest Group on Embedded Systems) Review*, **3:3**, July 2006.

Bengtsson, Johan, Petter Strandh, Rolf Johansson, Per Tunestål, and Bengt Johansson: "Hybrid control of homogeneous charge compression ignition (HCCI) engine dynamics." *International Journal of Control*, **79:5**, pp. 422–448, May 2006.

Bengtsson, Johan, Petter Strandh, Rolf Johansson, Per Tunestål, and Bengt Johansson: "Multi-output control of a heavy-duty HCCI engine using variable valve actuation and model predictive control." *SAE Paper 2006-01-0873*, April 2006.

de Maré, Lena, Christian Cimander, Anders Elfwing, and Per Hagander: "Feeding strategies for *E. coli* cultivations demanding an enriched environment." *Bioprocess and Biosystems Engineering*, 2006. Published online: November 2006, `http://dx.doi.org/10.1007/s00449-006-0090-z`.

García, Pedro, Pedro Albertos, and Tore Hägglund: "Control of unstable non-minimum-phase delayed systems." *Journal of Process Control*, **16**, pp. 1099–1111, 2006.

Haugwitz, Staffan, Per Hagander, and Tommy Norén: "Modeling and control of a novel heat exchange reactor, the open plate reactor." *Control Engineering Practice*, 2006. In press, available online through DOI using doi:10.1016/j.conengprac.2006.02.019.

Johansson, Rolf, and Anders Robertsson: "The Yakubovich-Kalman-Popov lemma and stability analysis of dynamic output feedback systems." *International Journal of Robust and Nonlinear Control*, **16**, January, pp. 45–69, January 2006.

Lincoln, Bo, and Anders Rantzer: "Relaxing dynamic programming." *IEEE Transactions on Automatic Control*, **51:8**, pp. 1249–1260, August 2006.

Nordfeldt, Pontus, and Tore Hägglund: "Decoupler and PID controller design of TITO systems." *Journal of Process Control*, **16**, pp. 923–936, 2006.

Platonov, Pyotr G., Yunlong Xia, Shiwen Yuan, and Rolf Johansson: "Non-fluoroscopic catheter-based mapping systems in cardiac electrophysiology–From approved clinical indications to novel research usage." *The International Journal of Medical Robotics and Computer Assisted Surgery*, **2:1**, pp. 21–27, March 2006.

Rantzer, Anders: "Relaxed dynamic programming in switching systems." *IEE Proceedings - Control Theory and Applications*, **153:5**, pp. 567 – 574, September 2006.

Sandberg, Henrik: "A case study in model reduction of linear time-varying systems." *Automatica*, **42:3**, pp. 467–472, March 2006.

Skoglund, Tomas, Karl-Erik Årzén, and Petr Dejmek: "Dynamic object-oriented heat exchanger models for simulation of fluid property transitions." *Int. J. of Heat and Mass Transfer*, **49:13-14**, pp. 2291–2303, January 2006.

Svendenius, Jacob, and Magnus Gäfvert: "A semi-empirical dynamic tire model for combined-slip forces." *Vehicle System Dynamics*, **44:2**, pp. 189–208, February 2006. Special Issue:AVEC '04: 7th International Symposium on Advanced VEhicle Control 23-27 August 2004 HAN University, Arnhem, The Netherlands.

Conference Papers

Åkesson, Johan, Anders Blomdell, and Rolf Braun: "Design and control of YAIP—An inverted pendulum on two wheels robot." In *Proceedings of the IEEE International Conference on Control Applications*, Munich, Germany, October 2006.

Åkesson, Johan, and Jenny Ekvall: "Parameter optimization of a paper machine model." In *Proceedings of Reglermöte 2006*, Stockholm, Sweden, May 2006.

Åkesson, Johan, and Ola Slätteke: "Modeling, calibration and control of a paper machine dryer section." In *5th International Modelica Conference 2006*, Vienna, Austria, September 2006. Modelica Association.

Alriksson, Peter, and Anders Rantzer: "Distributed Kalman filtering using weighted averaging." In *Proceedings of the 17th International*

Symposium on Mathematical Theory of Networks and Systems, Kyoto, Japan, July 2006.

Alriksson, Peter, and Anders Rantzer: "Observer synthesis for switched discrete-time linear systems using relaxed dynamic programming." In *Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems*, Kyoto, Japan, July 2006.

Andersson, Martin: "Controlling Linux in a nice way." In *Proc. Reglermöte 2006*, Stockholm, Sweden, May 2006.

Årzén, Karl-Erik, Antonio Bicchi, Stephen Hailes, Karl Henrik Johansson, and John Lygeros: "On the design and control of wireless networked embedded systems." In *Proceedings of the 2006 IEEE Computer Aided Control Systems Design Symposium*, October 2006.

Årzén, Karl-Erik, Anders Robertsson, Dan Henriksson, Mikael Johansson, H. Hjalmarsson, and Karl Henrik Johansson: "Conclusions from the european roadmap on control of computing systems." In *First International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks*, Vancouver, Canada, April 2006.

Åström, Karl Johan: "Challenges in control education." In *7th IFAC Symposium on Advances in Control Education (ACE2006)*, Madrid, June 2006.

Bengtsson, Johan, Petter Strandh, Rolf Johansson, Per Tunestål, and Bengt Johansson: "Model predictive control of homogeneous charge compression ignition (HCCI) engine dynamics." In *Proc. 2006 IEEE Int. Conf. Control Applications (CCA 2006)*, Munich, Germany, October 2006. pp. 1675-1680.

Castañé, Rosa, Pau Martí, Manel Velasco, Anton Cervin, and Dan Henriksson: "Resource management for control tasks based on the transient dynamics of closed-loop systems." In *Proceedings of the 18th Euromicro Conference on Real-Time Systems*, Dresden, Germany, July 2006.

Cervin, Anton, and Peter Alriksson: "Optimal on-line scheduling of multiple control tasks: A case study." In *Proceedings of the 18th Euromicro Conference on Real-Time Systems*, Dresden, Germany, July 2006.

Cervin, Anton, Karl-Erik Årzén, Dan Henriksson, Manuel Lluesma Camps, Patricia Balbastre, Ismael Ripoll, and Alfons Crespo: "Control loop timing analysis using TrueTime and Jitterbug." In *Proceedings of*

the 2006 IEEE Computer Aided Control Systems Design Symposium, October 2006.

Cervin, Anton, Charlotta Johnsson, and Anders Robertsson: "Återkoppling mellan lärare och studenter ur ett reglertekniskt perspektiv," (Feedback between teachers and students from a control perspective). In *Proc. 4:e Pedagogiska inspirationskonferensen*, Lunds Tekniska Högskola, June 2006.

Cervin, Anton, Charlotta Johnsson, Anders Robertsson, and Tobias Rydén: "Återkoppling som del i lärandeprocessen," (Feedback as part of the learning process). In *Proc. 4:e Pedagogiska inspirationskonferensen*, Lunds Tekniska Högskola, June 2006.

Chen, DeJiu, Martin Törngren, Jianlin Shi, Henrik Lönn, Sebastien Gerard, Mikael Strömberg, and Karl-Erik Årzén: "Model based integration in the development of embedded control systems—A characterization of current research efforts." In *Proceedings of the 2006 IEEE Computer Aided Control Systems Design Symposium*, October 2006.

de Maré, Lena, and Per Hagander: "Parameter estimation of a model describing the oxygen dynamics in a fed-batch *E. coli* cultivation." In *Reglermöte 2006*, May 2006.

Fernández, Roemi, Anders Robertsson, Rolf Johansson, Teodor Akinfiev, and Manuel Armada: "Observer backstepping for nonlinear drive control." In *Proc. 45th IEEE Conf. Decision & Control, San Diego, CA, December 13-15*, December 2006.

Freidovich, Leonid, Anders Robertsson, Anton Shiriaev, and Rolf Johansson: "Friction compensation based on LuGre model." In *Proceedings of the 45th IEEE Conference on Decision & Control*, San Diego, CA, USA, December 2006.

Freidovich, Leonid, Anders Robertsson, Anton Shiriaev, and Rolf Johansson: "Stable periodic motions of the pendubot via virtual holonomic constraints." In *Proc. 3rd IFAC Workshop on Lagrangian and Hamiltonian Methods for Nonlinear Control*, Nagoya, Japan, July 2006. pp. 111-116.

Gäfvert, Magnus, Jacob Svendenius, and Johan Andreasson: "Implementation and application of a semi-empirical tire-model in multi-body simulation of vehicle handling." In *Proceedings of the 8th International Symposium on Advanced Vehicle Control*, Taipei, Taiwan, August 2006.

Gattami, Ather: "Distributed stochastic control: A team theoretic approach." In *Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems (MTNS), Kyoto, Japan*, July 2006.

Gattami, Ather: "Generalized linear quadratic control theory." In *Proceedings of the 45th IEEE Conference on Decision and Control (CDC), San Diego, USA*, December 2006.

Guzmán, José Luis, Karl Johan Åström, Sebastián Dormido, Tore Hägglund, and Yves Piguet: "Interactive learning modules for PID control." In *7th IFAC Symposium on Advances in Control Education*, Madrid, Spain, June 2006.

Guzmán, José Luis, Pedro García, Tore Hägglund, Sebastián Dormido, Pedro Albertos, and Manuel Berenguel: "Interactive tool for analysis of time-delay dystems with dead-time compensation." In *7th IFAC Symposium on Advances in Control Education*, Madrid, Spain, June 2006.

Gámez García, Javier, Anders Robertsson, Juan Gómez Ortega, and Rolf Johansson: "Estimador de las fuerzas y pares de contacto ejercidos por un robot manipulador sobre su entorno (estimator for contact forces and moments exerted by a robot on its environment)," (Estimator for contact forces and moments exerted by a robot on its environment). In *XXVII Jornadas de Automática*, Almería, Spain, September 6-9, 2006.

Gámez García, Javier, Anders Robertsson, Juan Gómez Ortega, and Rolf Johansson: "Generalized contact force estimator for a robot manipulator." In *Proc. of IEEE Int Conf on Robotics and Automation (ICRA'2006)*, Orlando, Florida, USA, May 2006.

Haugwitz, Staffan, and Per Hagander: "Analysis and selection of control variables and structures for the open plate reactor." In *Proceedings of Nordic Process Control Workshop*, Copenhagen, Denmark, January 2006.

Haugwitz, Staffan, and Per Hagander: "Challenges in start-up control of a heat exchange reactor with exothermic reactions; a hybrid Approach." In *Proceedings of the 2nd IFAC Conference on Analysis and Design of Hybrid Systems*, Alghero, Italy, June 2006.

Haugwitz, Staffan, Per Hagander, and Tommy Norén: "Process and control design for a novel chemical heat exchange reactor." In *Proceedings of Reglermötet*, Stockholm, Sweden, May 2006.

Henningsson, Toivo, and Karl Johan Åström: "Log-concave observers." In *Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems*, Kyoto, Japan, July 2006.

Henningsson, Toivo, and Anton Cervin: "Event-based control over networks: Some research questions and preliminary results." In *Proc. Reglermöte 2006*, Stockholm, Sweden, May 2006.

Henriksson, Dan, Anton Cervin, Martin Andersson, and Karl-Erik Årzén: "TrueTime: Simulation of networked computer control systems." In *Proceedings of the 2nd IFAC Conference on Analysis and Design of Hybrid Systems*, Alghero, Italy, June 2006. Invited extended abstract.

Karlsson, Magnus, Ola Slätteke, Tore Hägglund, and Stig Stenström: "Feedforward control in the paper machine drying section." In *American Control Conference 2006*, Minneapolis, Minnesota, USA, June 2006.

Kjær, Martin Ansbjerg, Rolf Johansson, and Anders Robertsson: "Active control of thermoacoustic oscillation." In *Proceedings of the IEEE International Conference on Control Applications*, Munich, Germany, October 2006.

Kutil, Michal, Zdenek Hanzalek, and Anton Cervin: "Balancing the waiting times in a simple traffic intersection model." In *Proc. 11th IFAC Symposium on Control in Transportation Systems*, Delft, The Netherlands, August 2006.

Larsson, Per-Ola: "Prediction of radio channels for OFDM by autoregressive modeling." In *Proceedings of Reglermöte, Stockholm, Sweden*, September 2006.

Lluesma Camps, Manuel, Anton Cervin, Patricia Balbastre, Ismael Ripoll, and Alfons Crespo: "Jitter evaluation of real-time control systems." In *Proc. 12th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications*, Sydney, Australia, August 2006.

Nilsson, Oskar, Anders Rantzer, and Jonathan Chauvin: "A model reduction case study: Automotive engine air path." In *Proceedings of the IEEE International Conference on Control Applications*, Munich, Germany, October 2006.

Olsson, Tomas, Rolf Johansson, and Anders Robertsson: "High-speed visual robot control using an optimal linearizing intensity-based filtering approach." In *Proc. IEEE/RSJ Int. Conf. Intelligent Robots and Systems, IROS 2006*, Beijing, China, October 2006.

Purvis, K.B., and K.J. Åström: "Estimating radar positions using unmanned air vehicle temas engaged in cooperative deception." In *American Control Conference 2006*, Minneapolis, Minnesota, USA, June 2006.

Rantzer, Anders: "Linear quadratic team theory revisited." In *Proceedings of American Control Conference*, Minneapolis, June 2006.

Rantzer, Anders: "A separation principle for distributed control." In *Proceedings of the 45th IEEE Conference on Decision and Control*, San Diego, December 2006.

Robertsson, Anders, Tomas Olsson, Rolf Johansson, Anders Blomdell, Klas Nilsson, Mathias Haage, B. Lauwers, H. de Baerdemaeker, Torgny Brogårdh, and H. Brantmark: "Implementation of industrial robot force control - case study: High power stub grinding and deburring." In *Proc. 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2006)*, Beijing, China, October 2006. pp. 2743-2748.

Robertz, Sven Gestegård, Dan Henriksson, and Anton Cervin: "Memory-aware feedback scheduling of control tasks." In *Proceedings of the 11th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA06)*, Prague, Czech Republic, September 2006.

Schitter, G., K.J. Åström, B. DeMartini, G.E. Fantner, Ph. J. Thurner, K.J. Turner, and P.K. Hansma: "Designing and modeling of a high-speed scanner for atomic force micropscopy." In *American Control Conference 2006*, Minneapolis, Minnesota, USA, June 2006.

Schofield, Brad, Tore Hägglund, and Anders Rantzer: "Vehicle dynamics control and controller allocation for rollover prevention." In *Proceedings of the IEEE International Conference on Control Applications*, Munich, Germany, October 2006.

Shiriaev, Anton, Leonid Freidovich, Anders Robertsson, and Rolf Johansson: "Virtual-constraints-based design of stable oscillations of Furuta pendulum: Theory and experiments." In *Proceedings of the 45th IEEE Conference on Decision & Control*, San Diego, CA, USA, December 2006.

Shiriaev, Anton, Anders Robertsson, Leonid Freidovich, and Rolf Johansson: "Generating stable propeller motions for devil stick." In *Proc. 3rd IFAC Workshop on Lagrangian and Hamiltonian Methods for Nonlinear Control*, Nagoya, Japan, July 2006. pp. 105-110.

Slätteke, Ola: "Object-oriented modeling and predictive control of the moisture content in paper production." In *American Control Conference 2006*, Minneapolis, Minnesota, USA, June 2006.

Törngren, Martin, Dan Henriksson, Karl-Erik Årzén, Anton Cervin, and Zdenek Hanzalek: "Tools supporting the co-design of control systems and their real-time implementation; current status and future directions." In *Proceedings of the 2006 IEEE Computer Aided Control Systems Design Symposium*, October 2006.

Wernrud, Andreas: "Computation of approximate value functions for constrained control problems." In *Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems, Kyoto, Japan*, July 2006.

Zhang, Geordie Z., G. Nair, R. J. Evans, and Björn Wittenmark: "A data-rate limited view of adaptive control." In *Preprints IFAC Symposium on System Identification*. IFAC, March 2006.

12

Reports

During this year 3 PhD theses and 3 Licentiate theses have been published. The abstracts are presented in Chapter 7. Also 20 Master theses and 5 internal reports have been completed.

Dissertations

de Maré, Lena: *Feeding Strategies Based on Probing Control for E. coli and V. cholerae Cultivations* (Feedstrategier baserade på probing control för *E. coli* och *V. cholerae* odlingar). PhD thesis ISRN LUTFD2/TFRT--1076--SE, Department of Automatic Control, Lund University, Sweden, June 2006.

Henriksson, Dan: *Resource-Constrained Embedded Control and Computing Systems*. PhD thesis ISRN LUTFD2/TFRT--1074--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, January 2006.

Nilsson, Oskar: "Modeling and model reduction in automotive systems." Licentiate Thesis ISRN LUTFD2/TFRT--3242--SE, Department of Automatic Control, Lund University, Sweden, December 2006.

Ohlin, Martin: "Feedback Linux scheduling and a simulation tool for wireless control." Licentiate Thesis ISRN LUTFD2/TFRT--3240--SE, Department of Automatic Control, Lund University, Sweden, June 2006.

Schofield, Brad: "Vehicle dynamics control for rollover prevention." Licentiate Thesis ISRN LUTFD2/TFRT--3241--SE, Department of Automatic Control, Lund University, Sweden, December 2006.

Slätteke, Ola: *Modeling and Control of the Paper Machine Drying Section.* PhD thesis ISRN LUTFD2/TFRT--1075--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, January 2006.

Master's Theses

Andersson, Andreas: "Road-tire friction estimation for AFS vehicle control," (Skattning av friktion mellan däck och vägbana för reglering av fordon med aktiv framhjulsstyrning). Master's Thesis ISRN LUTFD2/TFRT--5774--SE. Advisor: Wolfgang Reinelt and Christian Lundquist. Examiner: Tore Hägglund. Department of Automatic Control, Lund University, Sweden, August 2006.

Blanco, Luis Rodriguez: "Modeling and grey-box identification of a robot manipulator." Master's Thesis 5768. Advisor: Anders Robertsson. Examiner: Rolf Johansson. Department of Automatic Control, Lund University, Sweden, June 2006.

Brochier, Benoit: "Control of a Gantry-Tau structure." Master's Thesis ISRN LUTFD2/TFRT--5777--SE, Department of Automatic Control, Lund University, Sweden, July 2006.

Carlsson, Hampus, and Nils-Petter Nytzén: "Control of heating chamber on packaging machine A1 TFA." Master's Thesis ISRN LUTFD2/TFRT--5766--SE. Advisor: Pär Olanders. Examiner: Tore Hägglund. Department of Automatic Control, Lund University, Sweden, January 2006.

Corvera Ripoll, Jaume: "Engine cooling & model verification." Master's Thesis ISRN LUTFD2/TFRT--5767--SE. Advisor: Hubertus Tummescheit. Examiner: Anders Rantzer. Department of Automatic Control, Lund University, Sweden, January 2006.

Del Favero, Simone: "Linear time periodic analysis of Dc-Dc converter." Master's Thesis ISRN LUTFD2/TFRT--5770--SE. Advisor: Giorgio Picci and Andreas Wernrud. Examiner: Anders Rantzer. Department of Automatic Control, Lund University, Sweden, June 2006.

Dietz, Thomas: "Model-based friction compensation for the Furuta pendelum using the LuGre Model," (Modellbaserad friktionskompensering för furuta-pendel med hjälp av lugre-modellen). Master's Thesis ISRN LUTFD2/TFRT--5773--SE. Advisor: Hans Peter Geering. Examiner: Rolf Johansson. Department of Automatic Control, Lund University, Sweden, July 2006.

Engdahl, Henrik, and Niklas Johansson: "Solving a dead-lock problem of NFO-sinus." Master's Thesis ISRN LUTFD2/TFRT--5780--SE. Advisor: Ragnar Jönsson NFO. Examiner: Rolf Johansson. Department of Automatic Control, Lund University, Sweden, December 2006.

Gerard, Mathieu: "Tire-road friction estimation using slip-based observers." Master's Thesis ISRN LUTFD2/TFRT--5771--SE. Advisor: Rodolphe Sepulchre and Brad Schofield. Examiner: Anders Rantzer. Department of Automatic Control, Lund University, Sweden, June 2006.

Giselsson, Pontus: "Modeling and control of a 1.45 m deformable mirror." Master's Thesis ISRN LUTFD2/TFRT--5775--SE. Advisor: Torben Andersen. Examiner: Anders Rantzer. Department of Automatic Control, Lund University, Sweden, October 2006.

Gunnarsson, Dan: "Safety-critical communication in avionics." Master's Thesis ISRN LUTFD2/TFRT--5782--SE. Advisor: Kristina Forsberg, Saab Avitronics. Examiner: Anton Cervin. Department of Automatic Control, Lund University, Sweden, December 2006.

Ikonen, Tommy: "Bucket and vehicle oscillation damping for a wheel loader." Master's Thesis ISRN LUTFD2/TFRT--5781--SE. Advisor: Amos Albert and Dieter Schwarzmann. Examiner: Karl-Erik Årzén. Department of Automatic Control, Lund University, Sweden, December 2006.

Kurjak, Adis, and Faris Mustajbasic: "Process estimation with relay feedback method." Master's Thesis ISRN LUTFD2/TFRT--5764--SE. Advisor: Tore Hägglund. Examiner: Karl Johan Åström. Department of Automatic Control, Lund University, Sweden, February 2006.

Lewander, Magnus: "Actuator comparison and coordination for integrated vehicle dynamics control." Master's Thesis ISRN LUTFD2/TFRT--5779--SE. Advisor: Daniel Keppler. Examiner: Karl-Erik Årzén. Department of Automatic Control, Lund University, Sweden, November 2006.

Malm, Jennie: "All wheel drive hardware dependant control." Master's Thesis ISRN LUTFD2/TFRT--5772--SE. Advisor: Edo F Drenth. Examiner: Anders Rantzer. Department of Automatic Control, Lund University, Sweden, June 2006.

Razavi, Camran: "Error detection in the active front steering system." Master's Thesis ISRN LUTFD2/TFRT--5765--SE. Advisor: Wolfgang

Reinelt, Samuel Malinen, and Brad Schofield. Examiner: Tore Hägglund. Department of Automatic Control, Lund University, Sweden, February 2006.

Schwerdt, Christian: "Modeling NOx-formation in combustion processes." Master's Thesis ISRN LUTFD2/TFRT--5769--SE. Advisor: Hubertus Tummescheit. Examiner: Anders Rantzer. Department of Automatic Control, Lund University, Sweden, June 2006.

Svärdh, Emil: "Radio frequency identification in library (RFID)." Master's Thesis ISRN LUTFD2/TFRT--5776--SE. Advisor: Patric Englund. Examiner: Karl-Erik Årzén. Department of Automatic Control, Lund University, Sweden, November 2006.

Widd, Anders: "Estimation of side wind disturbances in automotive vechicles." Master's Thesis ISRN LUTFD2/TFRT--5778--SE. Advisor: Jens Kalkkuhl. Examiner: Karl-Erik Årzén. Department of Automatic Control, Lund University, Sweden, November 2006.

Windahl, Johan: "Modelling and parameter estimation of a paper machine drying section using Modelica." Master's Thesis ISRN LUTFD2/TFRT--5783--SE. Advisor: Ola Slätteke, ABB. Examiner: Tore Hägglund. Department of Automatic Control, Lund University, Sweden, December 2006.

Other Reports

Åkesson, Johan: "Mpctools 1.0 - reference manual." Technical Report ISRN LUTFD2/TFRT--7613--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, Department of Automatic Control, Lund University, Sweden, January 2006.

Åkesson, Johan, and Ola Slätteke: "A modelica library for paper machine dryer section modeling - drylib - and applications." Technical Report ISRN LUTFD2/TFRT--7615--SE, Department of Automatic Control, Lund University, Sweden, August 2006.

Cervin, Anton, and Agneta Tuszynski: "Automatic Control 2005. Activity Report." Technical Report ISRN LUTFD2/TFRT--4033--SE, Department of Automatic Control, Lund University, Sweden, June 2006.

Ohlin, Martin, Dan Henriksson, and Anton Cervin: *TrueTime 1.4—Reference Manual*, September 2006.

Svendenius, Jacob: “Examples of scale factors for a semi-empirical tire-model.” Technical Report ISRN LUTFD2/TFRT--7614--SE, Department of Automatic Control, Lund University, Sweden, January 2006.

Reports Available

Only a limited number of copies of our reports are available for sale from the Department. Any of the listed publications may, however, be borrowed through your library service or from the following libraries in Sweden:

- Linköpings Universitetsbibliotek, Svensktrycket, SE-581 83 Linköping
- UB, Svenska Tryckavdelningen, Box 1010, SE-221 03 Lund
- Stockholms Universitetsbibliotek, Svenska Tryckavdelningen, SE-106 91 Stockholm
- Kungliga Biblioteket, Box 5039, SE-102 41 Stockholm
- Umeå Universitetsbibliotek, Box 718, SE-901 10 Umeå
- Uppsala Universitetsbibliotek, Box 510, SE-751 20 Uppsala

Almost all our publications are available in full through our web server http://www.control.lth.se/publications.

The reports in the 1000- and 3000-series may be ordered from the Department, see address on page 4. Please be certain to specify both the report number and report title.

There is a copying and handling charge of between 300 and 500 SEK for each document. Invoice will be sent together with the ordered report(s).

13

Lectures by the Staff Outside the Department

Årzén, Karl-Erik

Jitterbug and TrueTime: Timing Analysis and Simulation of Networked Embedded Control Systems, Caltech, CA, USA, May 10.

TrueTime: A Simulation Tool for Networke Control and Mobile Autonomous Vehicles, 2006 IEEE International Conference on Robotics and Automation, Orlando, Florida, USA, May 15.

Implementering av reglersystem: utmaningar och forskningsriktningar (Implementation of Control Systems: Challenges and Research Directions), Plenary address, Reglermötet 2006, KTH, Stockholm, Sweden, May 30.

On the Design and Control of Wireless Networked Embedded Systems, IEEE International Symposium on Computer-Aided Control Systems Design, Munich, Germany, October 4.

Real-Time Aspects in Control, Plenary address, ANIPLA 2006, Rome, Italy, November 15.

Åström, Karl Johan

Nyquist and His Seminal Papers, Center for Control Dynamical Systems and Computation, University of California, Santa Barbara, USA, February 3.

Relay Systems—The Simplest Hybrid Systems?, Workshop on Topics in Computation and Control HSCC2006, Santa Barbara, CA, USA, March 27.

Qualitative Assessment of Achievable Performance in Loop Shaping Design. Control of Uncertain Systems: Modeling, Approximation, and Design, A workshop on the occasion of Keith Glover's 60th birthday, Cambridge, UK, April 22.

Friction Models and Friction Compensation, Control and Power Research Group, Department of Electrical and Electronic Engineering, Imperial College, London, UK, May 3.

Feedback Fundamentals, IEEE-IAS Advanced Process Control Applications for Industry Workshop, (Invited plenary lecture) Vancouver, Canada, May 9.

Event Based Control, CASY Workshop on Advances in Control Theory and Applications, Bertinoro, Italy, May 24.

Bicycle Dynamics and Control, IFAC-IEEE Workshop: The Power, Beauty and Excitement of the Cross-Boundaries Nature of Control on Advances in Control Education, Madrid, Spain, June 20.

Challenges in Control Education, 7th IFAC Symposium on Advances in Control Education Madrid ACE2006. (Invited plenary lecture), Madrid, Spain, June 21.

Control the Hidden Technology, Laboratory of Decision and Control, MIT, USA, September 8.

Present Developments in Control Applications, International Conference on Present and Future of Automatic Control IFAC 50th Anniversary Celebration. (Invited plenary lecture), Heidelberg, Germany, September 15.

Adventures in System Identification. Forever Ljung, A workshop on the occasion of Lennart Ljung's 60th birthday, Linköping, Sweden, September 22.

Present Developments in Control Applications, First Russian Multiconference on Control Problems. Part 1: Conference on Gyroscopic Devices in Memory of Ostrakov, Part 2: Control and Information Technology, Part 3: Mechatronics Automation and Control, (Invited plenare lecture), St. Petersburg, Russia, October 10.

Cykelåkning från ett reglertekniskt perspektiv (A Control Engineers View of Biking), PAM Seminar. Institutionen för matematik, Uppsala University, Uppsala, Sweden, October 13.

Cykelåkning från ett reglertekniskt perspektiv (A Control Engineers View of Biking), Optimeringslära och Systemteori, KTH, Stockholm, Sweden, October 19.

Anton Cervin

An Overview of Real-Time and Embedded Systems Research in Sweden, Swedish Embedded Systems Meeting, Stockholm, Sweden, March 13.

Tools for Analysis and Simulation of Real-Time Control Systems, Swedish Embedded Systems Meeting, Stockholm, Sweden, March 13.

Integrated Control Design and Implementation; Control of Computing Systems; Jitterbug and TrueTime, ARTIST2 Graduate Course on Embedded Control Systems, Prague, Czech Republic, April 4–5.

Optimal On-Line Sampling Period Assignment Assuming Non-Stationary Noise Processes, Reglermöte 2006, Stockholm, Sweden, May 30.

Återkoppling som del i lärandeprocessen (Feedback as part of the learning process), 4:e Pedagogiska inspirationskonferensen, LTH, Lund, Sweden, June 1.

TrueTime: Simulation of Networked Computer Control Systems, 2nd IFAC Conference on Analysis and Design of Hybrid Systems, Alghero, Italy, June 8.

Optimal On-Line Scheduling of Multiple Control Tasks: A Case Study, 18th Euromicro Conference on Real-Time Systems, Dresden, Germany, July 6.

Real-Time Control, ARTIST2 First European Laboratory on Real-Time Embedded Systems, Pisa, Italy, July 12.

Introduction to SNART and ARTIST2, Scandinavian ARTIST2 Seminar on Embedded Systems Design, KTH, Stockholm, Sweden, August 21.

Control Loop Timing Analysis Using TrueTime and Jitterbug, IEEE Computer Aided Control Systems Design Symposium, Munich, Germany, October 5.

Jitterbug and TrueTime: MATLAB tools for Analysis and Simulation of Controller Timing, Pre-congress graduate course, National Autonomous University of Mexico (UNAM), Mexico City, Mexico, October 17.

Jitterbug and TrueTime: MATLAB tools for Analysis and Simulation of Controller Timing, Plenary lecture at the Mexican National Congress of Automatic Control, Mexico City, Mexico, October 19.

Hägglund, Tore

MIGO and AMIGO design of PID controllers, Invited lecture. Linköping university, Sweden, April 6.

Process Control in Practice, Industrial course. Stockholm, Sweden, May 17–18.

Process Control in Practice, Industrial course. Stockholm, Sweden, November 29–30.

Haugwitz, Staffan

Analysis and Selection of Control Variables and Structures for the Open Plate Reactor, Nordic Process Control Workshop, Copenhagen, Denmark, January 26–27.

Process and Control Design for a Novel Chemical Heat Exchange Reactor, Reglermötet, Stockholm, Sweden, May 29–31.

Start-up Control of a Heat Exchange Reactor with Exothermic Reactions: A Hybrid Approach, Hycon Workshop, Lund, Sweden, June 1–2.

Challenges in Start-up Control of a Heat Exchange Reactor with Exothermic Reactions; A Hybrid Approach, 2nd IFAC Conference on Analysis and Design of Hybrid Systems, Alghero, Italy, June 7–9.

Nonlinear MPC and the Start-up Problem for Open Plate Reactors, Lund-Lyngby-Aalborg Meeting, Lund, Sweden, November 1.

Johansson, Rolf

Prototype of Novel Parallel Kinematic Manipulator, Invited lecture,Third Swedish-Chinese Conference on Control, Linköping University, Linköping, Sweden, May 18, 2006.

Control of Homogeneous Charge Compression Ignition (HCCI) Combustion Engines, Fifth Russian-Swedish Control Conference, Lund University, Lund, August 29, 2006.

Control of Homogeneous Charge Compression Ignition (HCCI) Combustion Engines, Invited lecture, Johannes Kepler Universität, Linz, Austria, November 6, 2006.

Johnsson, Charlotta

Understanding the ISA95 Enterprise/Control System Integration Standard, Invited presentation (tutorial) given at WBF NA'06, Atlanta, USA, March 5-8.

ISA 88, ISA 95, IEC/ISO JWG 15 — Up to the Minute Headlines, Presentation given at WBF NA'06, Atlanta, USA, May 5–8.

Återkoppling som del i lärandeprocessen, Presentation given at LTHs pedagogiska inspirationskonferens, Lund, Sweden, June.

Återkoppling till studenter ur ett reglertekniskt perspektiv, Presentation given at LTHs pedagogiska inspirationskonferens, Lund, Sweden, June.

Engagerande undervisning — en genusfråga?, Presentation given at LTHs pedagogiska inspirationskonferens, Lund, Sweden, June.

ISA 95 Standardisering för framtiden, Presentation given at NFA-dagene (Norsk Förening för Automatisering), October 16–17.

Understanding the ISA95 Enterprise/Control System Integration Standard, Invited presentation (tutorial) given at WBF EU'06, Mechelen, Belgium, November 13–15.

Kjær, Martin Ansbjerg

Active Control of Thermoacoustic Oscillation, IEEE International Conference on Control Applications, Munich, Germany, October 6.

Olsson, Tomas

High-Speed Visual Robot Control using an Optimal Linearizing Intensity-Based Filtering Approach, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2006), Beijing, China, October 13.

Rantzer, Anders

Interview in Regional Television News, TV4 Öresund, Sweden, Feb 13.

On Optimal Linear Quadratic Distributed Control,, Invited lecture, 3rd Swedish-Chinese Conference on Control, Linköping, Sweden, May 18.

On Opportunities in Distributed Control Theory, Invited lecture, Workshop on Advances in Control Theory and Applications, CASY, Center for Research on Complex Automated Systems, Bertinoro, Italy, May 23.

Linear Quadratic Theory for Distributed Control, California Institute of Technology, USA, June 12.

Linear Quadratic Team Theory Revisited, American Control Conference, Minneapolis, USA, June 14.

On Reduction of Dynamical Models, Toyota Motor Company, Higashi-Fuji Technical Center, Japan, July 20.

Linear Quadratic Theory for Distributed Control, Tokyo Denki University, Japan, July 21.

Linear Quadratic Theory for Distributed Control — From telescopes to vehicle formations, Invited Plenary Lecture, 17th International Symposium on Mathematical Theory of Networks and Systems, 17th International Symposium on Mathematical Theory of Networks and Systems, Kyoto International Conference Hall, Kyoto, Japan, July 26.

Absolute Stability Theory — Past and Future, Invited tutorial lecture, Maths for Engineers Summer School, University of Leicester, UK, Distributed Intelligent Networks and Systems, Munich, Oct 3.

On Opportunities in Distributed Control — From Telescopes to Vehicle Formations, Technische Universiteit Delft, Netherlands, Oct 17.

Linear Quadratic Theory for Distributed Control — From Telescopes to Vehicle Formations, Cambridge University, UK, Nov 17.

Att samordna många viljor: Om teleskop-speglar, Internetprotokoll och fordonskolonner, Invited lecture, Lund Matematiska Sällskap, Lund, Sweden, Nov 28.

A Separation Principle for Distributed Control, Conference on Decision and Control, San Diego, USA, Dec 14.

Robertsson, Anders

Course on Nonlinear Oscillations, PhD course given at Aalborg University, Denmark, August.

Conclusions from the European Roadmap on Control of Computing, Invited talk at 1st Workshop on Feedback Control Implementation and Design in Computing Systems and Networks, Vancouver, Canada, April 3.

The SMErobot-project, LUCAS seminar, Lund University, Lund, Sweden, March.

Virtual-Constraints-Based Design of Stable Oscillations of Furuta Pendulum:Theory and Experiments, CDC-presentation, San Diego, California, USA, December.

Wittenmark, Björn

Admission Control in Web-Server Systems, Invited lecture, Xi'an Jiaotong University, Xi'an, China, May 12.

Swedish Research in Science and Engineering, Invited lecture, Tsinghua University, Beijing, China, May 15.

Admission Control in Web-Server Systems, Invited lecture, Tsinghua University, Beijing, China, May 17.

IPZ Models — Tuning and Modeling, Invited lecture, Tsinghua University, Beijing, China, May 18.

14

Seminars at the Department

Seminars presented in order of date. The seminars were given at the department during 2006, both by the staff and by invited lecturers. Dissertations and master's theses presentations are also included.

AC = Department of Automatic Control, Lund Institute of Technology
LU = Lund University

Jan 12: **Johan Åkesson** (AC), *A Language for Dynamic Optimization – Ideas and Preliminary Results.*

Jan 13: **Dan Henriksson** (AC), *Resource-Constrained Embedded Control and Computing Systems.* Doctoral dissertation defence.

Jan 28: **Ola Slätteke** (AC), *Modeling and Control of the Paper Machine Drying Section.* Doctoral dissertation defence.

Feb 2: **Faris Mustajbasic, Adis Kurjak** (LU) *Process Estimation with Relay Feedback Method.* MSc-thesis presentation.

Feb 2: **Ulf Jönsson** (Royal Institute of Technology), *A Popov Criterion for Networked Systems.*

Feb 22: **Per Rutquist** (Chalmer University of Technology), *On Infinite Horizon, State Constrained, Optimal Control.*

Feb 22: **Mike Rotkowitz** (Royal Institute of Technology), *All Stabilizing Controllers for Interconnected Systems.*

Mar 1: **Thomas Schön** (Linköping University), *Solving Estimation Problems for Automotive Applications.* MSc-thesis presentation.

Mar 20: **Daniel Braun** (Universität Freiburg), *Adaptive Control Models in Sensorimotor Learning.*

Mar 30: **Jonas Jansson** (Volvo), *Threat Assessment for Automotive Collision Mitigation.*

Mar 30: **Axel Fagerstedt** (LU), *Web Services on Mobile Terminals.* MSc-thesis presentation.

Apr 7: **Hampus Carlsson, Nils-Petter Nytzén** (Tetra Pak), *Control of Heating Chamber on Packaging Machine A1 TFA.* MSc-thesis presentation.

Apr 12: **Rickard Karlsson** (Linköping University), *Particle Filtering for Positioning and Tracking Applications.*

Apr 28: **Rolf Syding** (Elsensor Roiscan AB), *Från $\dot{x}$ till \$ – om kommersialisering av modern reglerteknik.*

May 4: **Jaume Corvera Ripoll** (Universitat de Girona), *Engine Cooling Model & Verification.* MSc-thesis presentation.

May 11: **Martin Enqvist** (Linköping University), *Linear Models of Nonlinear Systems.*

May 16: **Li Qiu** (Hong Kong University of Science and Technology) *Perturbation Analysis beyond Singular Values – A metric gerometry on the Grassmann manifold.*

Jun 8: **Noboru Sakamoto** (Nagoya University), *Nonlinear Control for Integrable Systems using Hamiltonian Perturbation Theory.*

Jun 9: **Christian Schwerdt** (LU), *Modeling NOx-formation in Combustion Processes.* MSc-thesis presentation.

Jun 15: **Herman Bruyninckx** (Katholieke Universiteit), *The Open Robot Control Software project OROCOS.*

Jun 15: **Jennie Malm** (LU), *All Wheel Drive Hardware Dependant Control.* MSc-thesis presentation.

Jun 15: **Gerulf K. M. Pedersen** (Aalborg University), *Evolutionary Algorithms: An Introduction.*

Jun 16: **Lena de Maré**(AC), *Feeding Strategies Based on Probing Control for E. coli and V. cholerae Cultivations.* Doctoral dissertation defence.

Jun 16: **Luis Rodriguez Blanco** (Universidad de Valladolid), *Modeling and Grey-box Identification of a Robot Manipulator.* MSc-thesis presentation.

Jun 20: **Simone Del Favero** (Universita degli studi di Padova), *Linear Time Periodic Analysis of Dc-Dc converters.* MSc-thesis presentation.

Jun 21: **Mathieu Gerard** (Université de Liege), *Tire-Road Friction Estimation Using Slip-based Observers.* MSc-thesis presentation.

Jun 29: **John Bagterp Jørgensen** (Danmarks Tekniske Universitet), *Numerical Methods for Model Predictive Control.*

Jul 7: **Thomas Dietz** (LU), *Friction Compensation for the Furuta Pendulum using the LuGre Model.* MSc-thesis presentation.

Aug 16: **Mohammad Tabbara** (University of Melbourne), *Input-Output Stability of Networked Control Systems.*

Aug 25: **Martin Ohlin** (AC), *Feedback Linux Scheduling and Simulation Tool for Wireless Control.* Lic Tech dissertation seminar.

Aug 31: **Jette L. Paulsen** (RisøNational Laboratory) *Strategy for Design of Display Systems for Process Plants.*

Sep 9: **Tatsuya Iwase** (Toyota Central R&D Labs), *Netstream – Traffic Simulator for Large-Scale Road Network.*

Sep 28: **Andreas Andersson** (LU), *Road-tire Friction Estimation for AFS Vehicle Control.* MSc-thesis presentation.

Oct 9: **Pontus Giselsson** (LU), *Modeling and Control of 1.45 m Deformable Mirror.* MSc-thesis presentation.

Oct 26: **Emil Svärdh** (LU), *RFID in Libraries.* MSc-thesis presentation.

Oct 31: **Avenir Kobetski** (Chalmers University), *Optimization of Manufacturing Cells Using Discrete Event Models.*

Oct 31: **Rafael Wisniewski** (Aalborg University), *Smooth Realization for Autonomous Switched Systems.*

Nov 17: **Anders Widd** (LU), *Estimation of Side Wind Disturbances in Automotive Vehicle.* MSc-thesis presentation.

Nov 17: **Magnus Lewander** (LU), *Actuator Comparison and Coordination for Integrated Vehicle Dynamics Control.* MSc-thesis presentation.

Nov 24: **Karl Johan Åström** (AC), *Present Developments in Control Applications (Repris av plenarföreläsning vid IFACs 50-årsjubileum i Heidelberg 15 Sept 2006).*

Nov 28: **Tommy Ikonen** (LU), *Bucket and Vehicle Oscillation Damping for a Wheel Loader.* MSc-thesis presentation.

Dec 12: **Brad Schofield** (AC), *Vehicle Dynamics Control for Rollover Prevention.* Lic Tech dissertation seminar.

Dec 20: **Oskar Nilsson** (AC) *Modeling and Model Reduction in Automotive Systems.* Lic Tech dissertation seminar.

Dec 20: **Anders Helmersson** (Linköping University), *LTV Model Reduction with Error Bounds.*

Dec 20: **Johan Windahl** (LU), *Modelling and Parameter Estimation of a Paper Machine Drying Section Using Modelica.* MSc-thesis presentation.

Dec 21: **Niklas Johansson, Henrik Engdahl** (LU), *Solving a Dead-lock Problem of NFO Sinus.* MSc-thesis presentation.

Dec 21: **Dan Gunnarsson** (LU), *Safety-Critical Communication in Avionics.* MSc-thesis presentation.

LUND UNIVERSITY

Department of Automatic Control

ISSN 0280–5316
ISRN LUTFD2/TFRT––4034––SE