Activity Report: Automatic Control 2002

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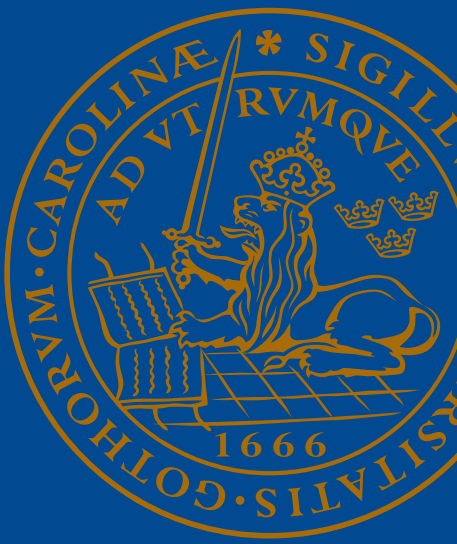
Activity Report



Activity Report

Automatic Control

2002

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Contents

1. Introduction

This report covers the activities at the Department of Automatic Control at Lund Institute of Technology (LTH) from January 1 to December 31, 2002.

The budget for 2002 was 23 MSEK. The proportion coming from the University was 51%.

One PhD thesis was defended this year by Hubertus Tummescheit. This brings the total number of PhDs graduating from our department to 63. Three Lic Tech theses were completed, by Stefan Solyom, Henrik Sandberg, and Rasmus Olsson. Three new PhD students have been admitted during the year: Ove Glenberg, Staffan Haugwitz, and Jenny Ekvall. Bo Bernhardsson, one of our professors, is on temporary leave working for Ericsson Mobile Platforms AB, Lund, and one person with doctor's degree left the department: Hubertus Tummescheit who started to work for United Technology Research Center in Hartford, CT in USA.

In the civilingenjör (master) program we have 11 courses. The total number of students who finished the courses were 787, and 21 students completed their master theses. The total teaching effort corresponds to 130 full-year equivalents.

Research at the department is presented under the following headlines: nonlinear and uncertain systems, modeling and simulation, process control, biotechnology processes, robotics, real-time control, and automotive systems.

Today the department has seven professors and one professor emeritus.

During the year we have formed a Scientific Advisory Board consisting of Professor Graham Goodwin, University of Newcastle, Australia, Professor Richard Murray, Caltech, USA, and Professor Lui Sha, University of Illinois, USA.

The department participates in LUCAS - Center for Applied Software Research at Lund Institute of Technology. The center is a collaboration between the software related activities at three departments: Automatic Control, Computer Science, and Communication systems. The center is funded by VINNOVA, Swedish industry, and Lund University.

Some statistics from five years is given in the table below.

	98	99	00	01	02	Sum
Books	1	2	0	0	1	4
Papers	24	24	18	16	21	105
Conference papers	37	45	37	20	44	184
PhD theses	2	7	3	2	1	15
Licentiate theses	6	1	1	1	3	12
Master theses	20	25	24	23	18	110
Internal reports	11	8	5	5	7	36

Acknowledgments

We want to thank our sponsors, The Swedish Agency for Innovation Systems (VINNOVA), The Swedish Research Council (VR), European Commission, The European Council, Foundation for Strategic Research (SSF), The Swedish Foundation for International Cooperation in Research and Higher Education (STINT), ABB, ABB Robotics, Active Biotech, Lund Research Center AB, Alfa Laval Lund AB, BlueCell, ConnectBlue, C-Technology, Ericsson Microwave, Ericsson Mobile Communications AB, Ericsson Mobile Platforms, Haldex Brake Products AB, Håkan Hansson Stiftelse, Hörjel Foundation, IAR Systems, Knut and Alice Wallenberg Foundation, LM Ericsson Foundation, LU Kompetensutvecklingsfond, NFO Control AB, Pharmacia AB, Q-labs, SBL Vaccine AB, Sony Ericsson Mobile, Sydkraft AB, Swedish Medical Research Council (MFR), TAC, Telelogic, Tetra Pak Research & Development AB, The Royal Physiographic Society, Toyota Motor Company, and Volvo Technical Development Corporation, for their support to our projects.

2. Internet Services

World Wide Web

Our home-page first appeared on the World Wide Web (WWW) in April 1994. Visit our home-page at this address:

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

Our web site contains information about personnel, 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.

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:

```
karl_johan.astrom@control.lth.se
bjorn.wittenmark@control.lth.se
karl-erik.arzen@control.lth.se
```

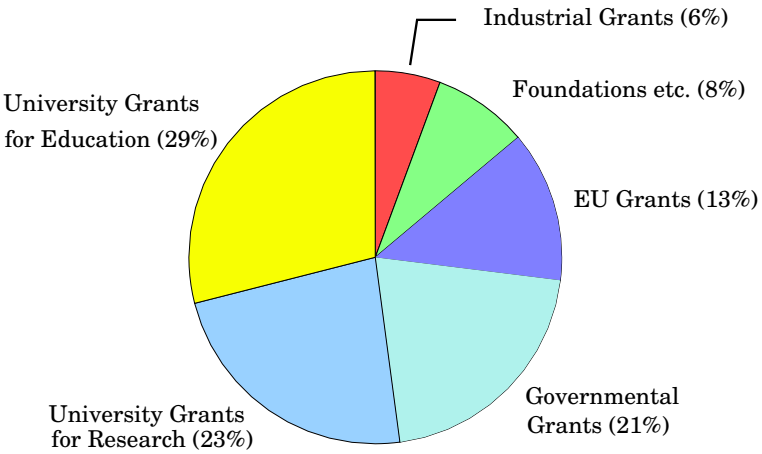
Our web page `http://www.control.lth.se/people/telemail.html` contains a complete list of email addresses. The department also has a generic email address:

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

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

3. Economy and Facilities

The turnover for 2002 was 23 MSEK. The income comes from Lund University (51%) and from external grants; the distribution is shown below.



Funding

Lund University provides partial support for graduate students. The majority of our research is, however, externally funded from governmental agencies and industry. During 2002 we had the following contracts:

- VR – Control of Complex and Nonlinear Systems (block grant)
- VR – Industrial Aspects of on-line Monitoring and Diagnosis
- VR – Theory for Modeling, Control and Analysis of Periodic Systems

- VINNOVA – Process Control for Cultivation of Micro Organisms
- VINNOVA – Lund Center for Applied Software Research (LUCAS)
- VINNOVA – Green Car HCCI
- STINT – Funding for research collaboration with Caltech
- SSF – Center for Chemical Process Design and Control (CPDC)
- SSF – Computational Analysis of Dynamical Models
- SSF ARTES – Integrated Control and Scheduling
- EU ESPRIT LTR – Heterogeneous Hybrid Control (H2C)
- EU/GROWTH – Advanced Decision Systems for the Chemical/Petrochemical Manufacturing Industries (CHEM)
- EU HPRN-CT - Nonlinear and adaptive control (NACO2)
- EU IST 2001-33520 – Control and Computation (CC)
- EU IST 2001-37652 – Hard Real-time CORBA (HRTC)
- ABB Automation Technology Products/Business Unit Robotics (Research Collaboration)
- Alfa Laval Lund AB – Research and Development Agreement
- Mid Sweden University – PhD Research Project
- ABB – PhD Research Project
- Haldex Brake Products AB – PhD Research Project
- NFO Control AB – PhD Research Project
- Toyota Motor Corporation – Simulation Model

The block grant from VR and the CPDC grant from SSF are long range and some of the VINNOVA projects are also 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

The main facilities are laboratories and computer systems. During the year 2002 most of the remaining Sun workstations have been replaced, such that almost all staff use PCs running Linux. Some, especially administrative staff, have a need for Microsoft Windows. In those cases the VMware product enables them to run both Linux and Windows at the same time.

The senior academic staff have laptop computers running either Linux plus VMware/Windows or pure Windows.

There is also a reasonably powerful central computer, which is used for certain types of heavy computations.

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 more than 700 students, and on the average they spend about 20 hours each in the lab.

A certain amount of computer replacement has been done during the year, such that the teaching lab contains 40 PCs, the oldest ones delivered in 2000.

Batch Process

A batch laboratory process was developed during 2002. The process is inexpensive, modular and portable. The process can be used stand-

alone for illustrating the control problems associated with single-unit batch control. It is also possible to connect several of the processes

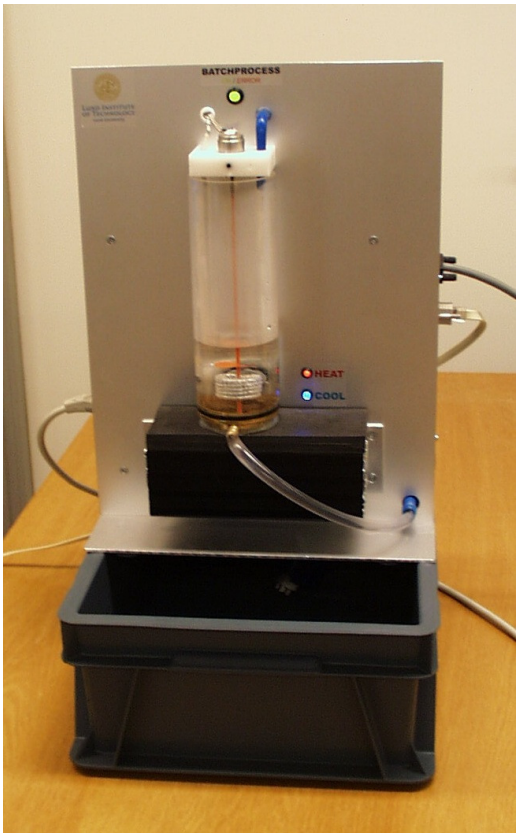


Figure 3.1 The Batch Process

together to form a multi-purpose batch cell. Used in this way the process can be used in teaching laboratories on recipe-based batch control and scheduling of batch processes.

The process consists of a water tank equipped with inlet and outlet pumps, a heating device, a cooling device, and an agitator. The sensors

consist of a level sensor and a temperature sensor. The relatively large amount of actuators means that the number of discrete operations that can be performed is quite large (start inlet pump, stop inlet pump, start heating, stop heating, etc). All actuators except the agitator can also be controlled with analog signals. This means that the tank also can be used as a continuous jacketed tank reactor. The possibility to both cool and heat can be used to emulate the temperature behavior of different types of chemical reactions. For example, the cooler can be used to simulate an endothermic reaction in the reactor. In this way the the simulation of the reaction rate can be made temperature dependent, non-linear, or constant. The process can also be used for multi-variable control experiments, e.g., simultaneous control of level and temperature. The process is made from standard components and therefore quite inexpensive. The process is also small, so small that it fits easily on the desktop on the side of the standard PC used for the control system. The connection between the process and the PC is an ordinary RS-232 serial line. This means also that it is straightforward to control the process from an ordinary laptop PC at lectures or presentations.

A Detached Process Interface

A detached process interface, having 4 analog inputs, 2 analog outputs, 6 digital inputs, and 6 digital outputs has been designed. It is connected to a computer through the serial port, and the capacity is about 100 channels/second. With this interface it will be possible to make control experiments in the field using an ordinary laptop as the process computer. It has been used successfully for control of an evaporative gas turbine at the Department of Thermal Power Engineering.

Robotics Laboratory

The Robotics Laboratory, containing three industrial robot manipulators (Irb6, Irb2000, and Irb2400) together with the Open Robot Control architecture developed at the Dept of Automatic Control (see "Looking back on Robotics Research, Annual report 2000"), serves as a common experimental platform for research activities from many different departments and research groups (including the Departments of Automatic Control, Mech. Eng., Computer Science, Mathematical Sciences).

System integration aspects of real-time research, task-level programming and high bandwidth feedback control play an important role.

Matlab/Simulink interfaces for downloading and dynamically linking new control algorithms to the robot systems and the integration of external sensors such as e.g. force/torque sensors and stereo vision cameras, offer a powerful platform for research projects. It also allows for running student projects and master thesis projects using the facilities in the RobotLab in an easy manner.

A new generation of the Open Robot Control System based on the industrial ABB-controller S4C+ is developed in close corporation with ABB Robotics.

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) and Environmental Engineering (W). Our courses are listed in Table 4.1. During 2002, 787 students passed our courses and 21 students completed their master-thesis projects. The number of registered students corresponded to 130 full-year equivalents during the year. The numbers for 2001 were 623, 28, and 96 respectively.

Topics for the master theses were in the following areas: Adaptive control (2), Control of nonlinear and uncertain systems (1), Modeling and simulation (3), Real-time systems (4), Robotics and automotive systems (8). A list of the master theses is given in Chapter 12.

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, where the students can find course plans, lecture notes, documentation, manuals, old exams, etc.

Table 4.1 Courses and the number of students who passed.

Reglerteknik AK–FEDI *FRT010*	382
(Automatic Control, basic course)	
Reglerteknik AK–M *FRT061*	179
(Automatic Control, basic course)	
Processreglering (K) *FRT080*	12
(Automatic Process Control)	
Systemteknik (W) *FRT110*	38
(Systems Engineering)	
Digital Reglering *FRT020*	30
(Computer-Controlled Systems)	
Realtidssystem *FRT031*	55
(Real-Time Systems)	
Systemidentifiering *FRT041*	12
(System Identification)	
Adaptiv reglering *FRT050*	37
(Adaptive Control)	
Olinjär reglering och Servosystem *FRT075*	17
(Nonlinear Control and Servo Systems)	
Internationell projektkurs i reglerteknik *FRT100*	10
(International Project Course in Automatic Control)	
Projekt i reglerteknik *FRT090*	2
(Project in Automatic Control)	
Examensarbete 20 poäng *FRT820*	21
(Master-thesis project, 5 months)	

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/`.

Doctorate Program

One PhD thesis was defended by Hubertus Tummescheit. This brings the total number of PhDs graduating from our department to 63. Three Lic Tech theses were completed by Stefan Solyom, Henrik Sandberg and Rasmus Olsson. Abstracts of the theses are given in Chapter 7.

We have admitted three new PhD students during the year: Ove Glenberg, Staffan Haugwitz, and Jenny Ekvall.

The following PhD courses were given:

- System Identification (R. Johansson) 2 points
- Robotics (R. Johansson) 5 points
- Time-Periodic Systems (M. Fontes and A. Rantzer) 5 points
- Linear Systems (A. Rantzer) 5 points
- Convex Optimization and Applications (Chung-Yao Kao) 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:

- Nonlinear and Uncertain Systems
- Modeling and Simulation
- Process Control
- Biotechnology Processes
- Robotics
- Real-Time Control
- Biomedical Systems
- Automotive 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.

Nonlinear and Uncertain Systems

Control of Nonlinear and Uncertain Systems

Researchers: Anders Rantzer, Andrey Gulchak, Chung-Yao Kao, Bo Lincoln and Stephen Prajna

Current developments in control theory are closely linked to the rapid improvements of computer tools for design, analysis, and simulation. The aim of this project is to pursue this combined development of theoretical and computational tools, and define new directions motivated by applications. Our main investigations deal with stability and robustness analysis as well as controller optimization.

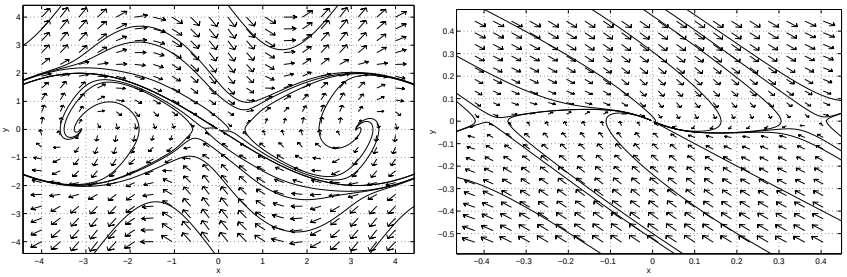


Figure 5.1 Left: Phase plot for smooth pendulum swing-up control. Right: Magnified phase plot near upright equilibrium.

Recently, we reached a considerable breakthrough in the analysis of nonlinear systems. Most classical analysis methods have been based on Lyapunov functions. This is a very strong theoretical tool, but has important shortcomings in the context of control synthesis. In particular, the set of control Lyapunov functions for a given system is generally non-convex and even disconnected. Our new result gives an alternative approach to stability of nonlinear systems, which can be viewed as a dual to Lyapunov's theory. It is different in the sense that all implications are stated in terms of "almost all trajectories" of the system. Furthermore, the new criterion enjoys a powerful convexity property in control synthesis.

As an application of the new criterion, we have derived the first known globally smooth feedback law for swing-up and stabilization of an inverted pendulum. A two-dimensional phase plot of the closed loop system is shown in Figure 5.1.

For several years, we have been developing the analysis framework based on integral quadratic constraints in cooperation with Prof. A. Megretski at MIT. This year, new constraints for time-varying time-delays have been derived by Chung-Yao Kao and Bo Lincoln. This makes it possible to study degradation of control performance due to delays in the communication network.

Andrey Gulchak has been working as a guest researcher and together

with Anders Rantzer studied optimization with frequency domain constraints. This problem area has a wide variety of applications in control. An important result is that we can use convex optimization tools to prove that certain sets of controller specifications are impossible to satisfy.

Hybrid Control

Researchers: Sven Hedlund, Bo Lincoln, Stefan Solyom, Anders Rantzer, and Karl Johan Åström

Hybrid systems is an active research area on the border between Computer Science and Automatic Control. A typical hybrid system consists of a physical process under control and supervision of a discrete computer. Not only computers, but also some physical phenomena are conveniently modeled as discrete events. Examples are mechanical systems with backlash, dead zones, and static friction, or electrical systems with switches. The department is involved in several projects devoted to hybrid control and computational approaches are developed for both analysis and synthesis.

A very promising synthesis approach is currently developed within the project based on classical dynamic programming. This method was introduced by Bellman in the 1950s and has found many important applications since then. The idea is general and very simple, but the "curse of dimensionality" is often prohibitive and restricts most applications to a discrete state space of moderate size.

We have recently initiated a very exciting development based on approximations of the cost function. It turns out that the exponential complexity of traditional dynamic programming algorithms often can be drastically reduced by relaxing the demand for optimality. An example of a problem where this method has been applied is the design of a switched power controller for DC to DC conversion. The idea is to use a set of semiconductor switches to effectively change polarity of a voltage source, and the controller has to decide which polarity to use each time slot so that the load voltage and current are kept as constant as possible; see Figure 5.2. In this case, the synthesis problem itself is very hard, and therefore we are happy if our algorithm can find

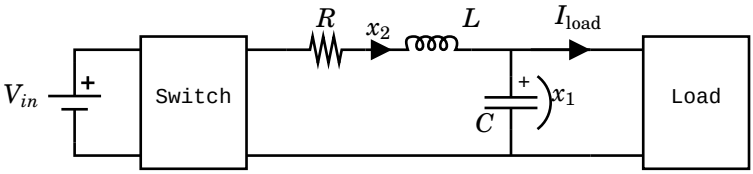


Figure 5.2 The setup for the switched DC/DC-converter.

a controller which yields less than twice the optimal cost. Using our Relaxed Dynamic Programming method with this slack gives us the explicit control law depicted in Figure 5.3. This law has been simulated for varying load current in Figure 5.4, and as can be seen, it successfully stabilizes the voltage around the nominal value of 0.5.

Modeling and Simulation

Extremal Control of Wiener Model Processes

Researchers: Björn Wittenmark in cooperation with Robin J. Evans, Dept. of Electrical and Electronic Engineering, University of Melbourne, Australia

In this project we investigate different approaches to extremal control. Especially, processes of Wiener type are considered. These models consists of a linear part followed by a nonlinearity. In the project nonlinearities having one extremum point are considered. The purpose of the control is to keep the output of the process as close as possible to the extremum point. Different control schemes are discussed and analyzed. The main problem in the control of this kind of Wiener model processes is the non-uniqueness of the inverse of the nonlinearity. This causes problems, for instance, in the estimation of the states of the process and the identification in the adaptive case. An one-step-ahead controller combined with a probabilistic-based estimator is proposed and analyzed.

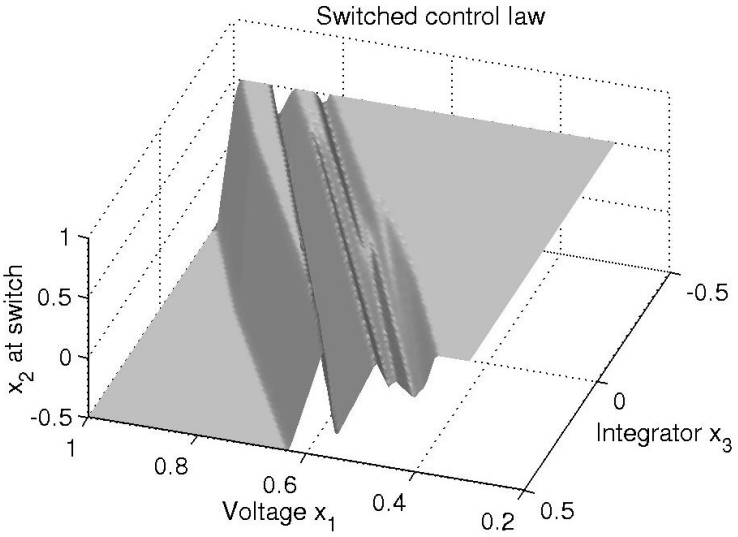


Figure 5.3 The resulting switching feedback law is monotonous in the current x_2 (by observation), and therefore it can be plotted in 3D. The plot shows at which current x_2 the switch from $s(n) = +1$ to $s(n) = -1$ takes place for varying voltages x_1 and integral states x_3. Note that the gridding is only for plotting purposes.

Modeling and Simulation of Complex Systems

Researchers: Hubertus Tummescheit, Anders Rantzer and Karl Johan Åström

The main aim of this project is to develop methods and computer tools which support development and use of mathematical models. The basic idea is to support reuse, so that a model component can be used in different applications to solve a variety of problems. Good model libraries should allow a user to make the desired model simply by combining components. Computer tools should automate the analysis and manipulation, which has to be done manually today to get the problem on a form that is efficient for numerical simulation.

The project started as a computer tool development project and later shifted towards model library development, model language

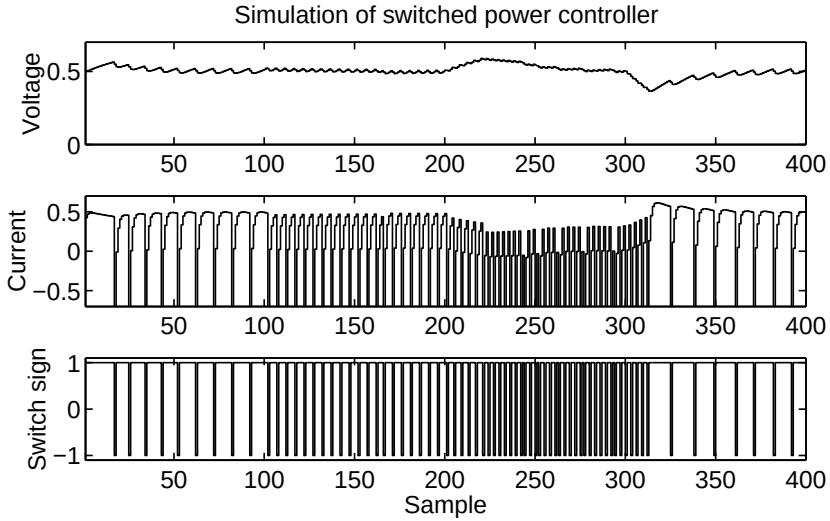


Figure 5.4 A simulation of the power system example with the obtained controller. At $n = 100$, the load current I_{load} is changed from its nominal 0.3A to 0.1A, at $n = 200$, to -0.2A and at $n = 300$ back to the nominal 0.3A.

standardization, and model reduction methods. The department is an active member in the design of the modeling language Modelica, which started at a meeting in Lund in 1996. The design of Modelica Version 1.0 was finished in September 1997. Since 2000, the non-profit Modelica Association has taken over the responsibility of the further development of the Modelica language. In February 2002, Version 2.0 was released and the commercial simulation tools Dymola and MathModelica support Modelica. Several other companies and universities have announced Modelica based tools soon to be released. The language definition and other information on the Modelica effort are available on the web site `http://www.Modelica.org`.

A very important part of the Modelica effort is development of model libraries. The department has for some years been developing models for energy processes. This has resulted in a Modelica base library for thermo-hydraulic systems, ThermoFluid. The base library contains

models for lumped or discretized control volumes, based on the physical balance equations of mass, energy and momentum. The ThermoFluid library is designed to be flexible, using Modelica class parameters to exchange medium property descriptions and machine dependent characteristics. In the library, particular attention has been given to efficient dynamic simulation involving physical property calculations, since these are usually designed for static calculations. The ThermoFluid library is now used in a variety of industrial projects for the modeling of fuel cells, micro turbine systems, steam distribution nets and refrigeration systems. For example, in the autumn of 2002, Toyota supported a research project for modeling of an oxygen sensor using the ThermoFluid library.

Reduction and Aggregation of Process Models
Researchers: Henrik Sandberg and Anders Rantzer

The goal of this project is to find methods and tools to simplify complex nonlinear or time-varying process models and to aggregate the effects of many small components.

The background for this work is that large complex mathematical models are regularly used for simulation and prediction. However, in control design it is common practice to work with as simple models as possible, often linear and time-invariant, because they are easier to analyze and evaluate. Real experiments or simulations using more accurate models are used to verify that the suggested controller really works well.

This is one reason why there is a strong need for methods and tools that can take a complex model and deduce simple models for various purposes such as control design. A more general reason is that simplified models are useful to point out the basic properties of a system and can provide good insight.

Our approach to model simplification has so far been based on linearization around trajectories. This results in time-varying linear models which can capture many effects not seen in linear time-invariant modeling, such as frequency coupling.

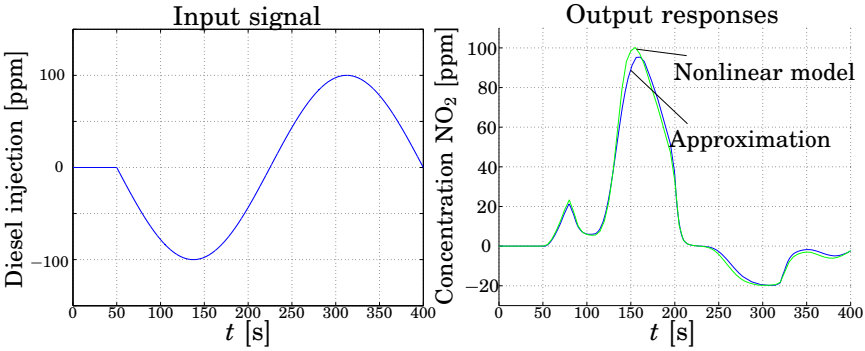


Figure 5.5 By injecting some extra diesel into the combustion catalyst the NO_x-level in the exhausts can be decreased. To the right the responses of a 24th-order nonlinear catalyst model and a first-order approximation to a sine wave diesel injection (left) can be seen. As seen, the number of equations can be significantly reduced.

During 2002 the work has been focused on balanced truncation of time-varying linear models. The method has been evaluated on a nonlinear diesel exhaust catalyst model. Figure 5.5 shows plots from a simulation of the full model with 24 states and a local approximation consisting of a single state differential equation.

System Identification Research

Researcher: Rolf Johansson

An identification algorithm that effectively fits continuous-time transfer functions and finite-bandwidth noise models to data has been published. Analysis of this class of algorithms proves convergence properties similar to that of maximum-likelihood identification of discrete-time ARMAX models. A substantial improvement of the identification accuracy of continuous-time zeros appears to be an important and attractive property of the new algorithm.

When using discrete-time data, it is necessary to make discretization somewhere in the continuous-time identification algorithms. In that context, we have studied approximation properties of a variety of the

discretization methods.

One research direction that is currently pursued is system identification methodology suitable for multi-input multi-output systems for which matrix fraction descriptions are not unique. A promising approach to system identification appears to be the continued-fraction approximation and we have published a number of new matrix fraction descriptions and theoretical results that resolve such problems of uniqueness.

However, several theoretical problems remain to be solved with regard to algorithm efficiency, statistical properties and validation aspects. An identification algorithm that effectively fits continuous-time transfer functions and finite-bandwidth noise models to data has been published. Analysis of this class of algorithms proves convergence properties similar to that of maximum-likelihood identification of discrete-time ARMAX models. A substantial improvement of the identification accuracy of continuous-time zeros appears to be an important and attractive property of the new algorithm.

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However, several theoretical problems remain to be solved with regard to algorithm efficiency, statistical properties and validation aspects.

Process Control

Center for Chemical Process Design and Control (CPDC)

Researchers: Karl-Erik Årzén, Jenny Ekvall, Per Hagander, Tore Hägglund, Staffan Haugwitz, Ari Ingimundarson, Rasmus Olsson, Henrik Sandberg, Ola Slätteke, and Björn Wittenmark

The Center for Chemical Process Design and Control (CPDC) is sponsored by the Swedish Foundation for Strategic Research (SSF) and is a cooperation between about ten departments at Chalmers University of Technology, Lund Institute of Technology, and Royal Institute of Technology. The program is administrated from Department of Automatic Control, LTH. Program director for the program is Bernt Nilsson, Chemical Engineering 1, LTH.

The purpose of the program is to look at the interplay between design and control of processes in the chemical process industry. Within CPDC chemical process industry is considered in a wide sense. The program is divided into two main lines of research, continuous processes and batch processes. In the area of continuous processes the applications are mainly within the pulp and paper industry and the batch processes are in the area of manufacturing of chemical substances for medical purposes and for uses in the pulp and paper industry. More information about the program is available at `http://www.control.lth.se/cpdc/`.

The projects at the department supported by the CPDC program are:

- Modeling and control of the drying sections of a paper machine
- Loop and quality assessment
  - Dead-time compensation in process control
  - Interaction measures in process control
- Reduction and aggregation of process models
- Control and diagnosis in batch processes
- Advanced reactor technology – Control of open plate reactor

Interaction Measures in Process Control

Researchers: Björn Wittenmark in cooperation with Mario Salgado, Universidad Técnica Federico Santa Maria, Valparaiso

In the process industry there is a great need for determining suitable structures of controllers. In many cases diagonal or block-diagonal controller structures are desired. In the literature there are many different methods for pairing of inputs and outputs. In this work a new form of interaction measure for multiple-input-multiple-output systems is introduced. The interaction measure, Hankel Interaction Index array, is an extension of the relative gain array (RGA). The advantage with the new measure is that it takes the frequency behavior of the system into account when deciding the input-output pairing of a system. The derivation is based on a gramian based interaction measure, but modifications are done which better reflect the controllability and observability of the subsystems in the process. The research has been presented at conferences and other groups have picked up the idea of using gramian based measures as interaction measures.

PID Control

Researchers: Karl Johan Åström, Tore Hägglund, Ari Ingimundarson, and Stefan Solyom

This project has been in progress since the beginning of the eighties, and resulted in industrial products as well as several PhD theses. Several monographs on PID control that are based on experiences obtained in the project have also been published.

In the PhD theses *PID Control – Design, Extension, Application* by Hélène Panagopoulos, efficient design methods for PID controllers were presented. These methods are based on constrained optimization and require that a process transfer function is available.

During the last year, these design methods have been used to develop simple tuning rules that are based on simple process models obtained from a step response experiment. By determining the static gain, the apparent time constant, and the apparent dead time of the process, simple tuning rules that provide controller parameters that differ less than 15% from the optimal ones have been derived.

Design methods of optimal PID controllers for a class of nonlinear plants have been developed. A synthesis method has been proposed that maximizes integral gain under the constraint of robust stability with respect to a static nonlinearity acting in feedback with part of the plant. The design procedure has been successfully applied in the automotive industry in the synthesis of a controller for an Anti-lock Braking System (ABS).

Control Loop Structure Assessment

Researchers: Mikael Petersson, Tore Hägglund, and Karl-Erik Årzén

The work is focused on assessing the control loop structure based on available measurements. The scenario studied consists of a SISO control loop that contains an additional exogenous signal. Methods have been developed that decides whether or not the additional signal affects the control performance, in which way it affects the control loop, if it is possible to compensate for the exogenous signal by using, for example, feedforward, or cascade control. Future activities lies in gain-scheduling and estimation of how much performance that can be gained by the compensation.

During 2002, the research has focused on cascade control, and gain scheduling.

This project is funded by VR/SSF in cooperation with ABB, and consists of an industrial PhD-student position for Mikael Petersson.

Performance Monitoring of Control Loops

Researchers: Ari Ingimundarson and Tore Hägglund

The need to monitor the performance of controllers in the process industry has been widely recognized. The research activities in this project has been focused on lambda-monitoring, or the monitoring of controllers tuned with the lambda-method. The main benefit with this new approach is that information from the tuning stage is used to commission the monitoring method. This should reduce the commissioning effort. Also it should be beneficial for the introduction of the monitoring method in a plant that it is based on a well known tuning method.

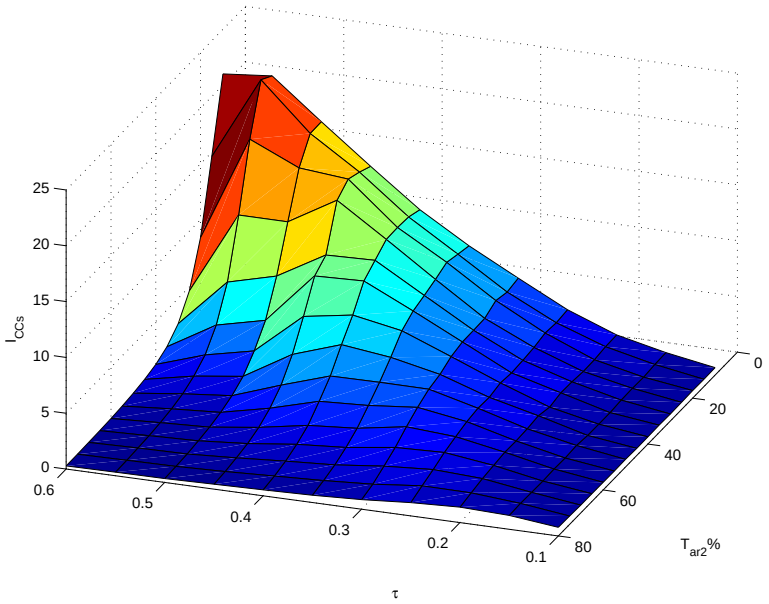

Figure 5.6 The stochastic cascade index is based on comparison of minimum achievable variance, and expresses the improvement obtained by introducing cascade control. The figure shows the index estimated for different simulated processes. The process consists of a primary and a secondary process, and the overall process has a fixed average residence time, T_{ar}. Each process section consists of a gain, a double pole, T, and a deadtime, L. The normalized deadtime, $\tau = L/(2T + L)$, which is equal for the sections, and the distribution of the average residence time, are varied to obtain the figure. The percentage of the overall residence time for the secondary process is indicated on the x-axes, while the normalized deadtime is shown on the y-axes.

Two indices have been developed. The first which is thought to be a "first indicator" of bad performance after which diagnosis algorithms could be applied to find out the reason for the performance degradation. The second one indicates whether the tuning of the loop is compatible with the disturbances affecting the loop and whether the tuning can be improved. Emphasis has been put on simplifying the algorithms to

calculate the indices so that they can be implemented in most DCSs. The methods have been tested on data from a pulp and paper mill.

The work in this project resulted in the PhD thesis "Dead-Time Compensation and Performance Monitoring in Process Control" by Ari Ingimundarson. The project is supported by the CPDC program.

Advanced Decision Support Systems for the Chemical/Petrochemical Manufacturing Industries (CHEM)
Researchers: Karl-Erik Årzén, Johan Åkesson, Rasmus Olsson

The aim of the EU/GROWTH project CHEM (http://www.chem-dss.org) is to develop an integrated set of toolboxes for various operator support functions in the process industries. CHEM started April 1, 2001 and will last for three years. The partners within CHEM are: Institut Francais de Petrol, France (Coordinator), Corus (ex. British Steel), UK, Computas, Norway, Gensym, France, KCL, Finland, LAAS, Toulouse, France, LAG, Grenoble, France, Lund University, Metso Automation, Finland, Thales (ex Thomson), France, Universitat Politecnica de Catalunya, Spain, Université des Sciences et Technologies de Lille (LAIL), France, Universitat de Girona, Spain, UPM Kymmene, Finland, VTT Automation, Finland, Warsaw University of Technology, Poland, and ZAP, Poland.

The Department of Automatic Control is responsible for the development of an operating procedure handling toolbox that will be used to support the operators in process state transitions. The toolbox is named JGrafchart and consists of of graphical procedure language editor and its associated runtime system. The JGrafchart language combines ideas from Grafcet/Sequential Function Charts, Statecharts, and object-oriented programming. Within CHEM, JGrafchart will also be used for implementing a batch recipe execution systems and as an activity flow modeling language.

JGrafchart currently supports the following features:

- Steps and transitions with parallel and alternative branches
- Macro steps with exception transitions, multiple input and output ports, and the possibility to resume execution.

- Procedures with support for parameter passing using call by value or call be reference
- Connection posts and step fusion sets.
- Hierarchically structured workspaces
- Lexically scoped name spaces
- Simple variables with four base types, and complex variables.
- Digital IO, analog IO, socket-based IO, and XML-based IO.
- XML-based storage on file.
- Support for select, connect, move, delete, undo, redo, copy, paste, cut, change size, zoom, pan, scroll, group, move to front, and print.
- Support for general graphical objects (rectangles, ellipses, texts, lines, icons, buttons, ...)

JGrafchart is implemented in Java and Swing. The following external software components are used:

- The JGo graphical object editor class package from Northwoods Corp.
- The JavaCC parser generator.
- Sun's XML parsers for Java.
- The JavaHelp system for on-line help support.
- The xmlBlaster message-oriented publish and subscribe middleware.

Within CHEM the department is also investigating the possibility to use numerical optimization techniques for grade change sequence generation. Different optimization schemes have been investigated, including MPC. The aim is to include the grade change generation with JGrafchart through automatic generation of grade change sequences.

Control and diagnosis in batch processes

Researchers: Rasmus Olsson and Karl-Erik Årzén

The aim of this project is to study integrated information and control systems for batch production. Special emphasis is put on integration of the monitoring and supervision tasks with recipe-based production. Two main issues is under investigation. The first issue studies the interaction between recipe execution and supervision. A model-based approach is taken where an internal unit model is used to check the validity of the unit operations in the recipes online. The internal unit model will also be used to structure the representation of the basic interlocking logic for safety monitoring. The second issue concentrates on the use of historical data in monitoring and supervision of batch process.

The work in the first part of the project is a continuation of the work on recipe-based batch processes by Charlotta Johnsson. The work is based on JGrafchart, a graphical sequential programming language that and its applications to batch recipe management and resource allocation. The focus of this part of the project is to extend JGrafchart by adding different features that support exception handling in batch production.

A collaboration has been started with Prof. Puigjaner's group at UPC in Barcelona. Our results will be applied to the PROCEL batch laboratory process at UPC. Our approach will be integrated with the reactive batch scheduling software developed at UPC. Part of this work is financed by the CHEM EU project.

During 2002 Rasmus Olsson presented his Licentiate thesis "Exception Handling in Recipe-Based Batch Control." During the year a new modular batch tank laboratory process was developed. The process can be used stand-alone for emulating a batch reactor or multiple processes can be connected in series to emulate a flexible batch production cell.

Control and supervision at grade changes
Researchers: Jenny Ekvall, Tore Hägglund

This is a joint project between the Network for Process Intelligence (NPI) at the Mid Sweden University and Lund University. The goal of the project is to develop strategies to improve control at planned or unplanned changes in production in process control plants.

In a first phase, the drying section in a paper mill is studied. The goal is to improve control of steam pressure and moisture content at paper web breaks so that the recovery to normal operation is obtained in a shorter time. The project is performed in collaboration with the paper mill M-real, Husum.

Control of an Open Plate Reactor
Researchers: Per Hagander and Staffan Haugwitz

The project, which started in September, is run by Alfa Laval in collaboration with several other universities and institutes. One of the departments, Le Laboratoire de Génie Chimique de Toulouse, has been visited twice this year. The project is funded by Alfa Laval and CPDC.

A plate reactor is a modified plate heat exchanger, where one side is a reactor, with reacting chemicals and the other side is a water flow. Depending on the reaction, there is a need for the water flow to cool or heat the reactor, i.e. if the reaction is exothermic or endothermic. By combining a reactor and a plate heat exchanger, the resulting plate reactor has a substantially higher heat transfer capability compared to a normal tank reactor process, just to mention one of the advantages.

When the reactions are exothermic and fast, the reactants are often dissolved into low concentration solutions to ensure that the temperature in the tank reactor does not rise above a dangerous level. By using a plate reactor, solutions of higher concentrations can be used, thus increasing the productivity and safety.

The plate reactor can be approximated as a one dimensional tube reactor. A typical reaction can be stated as:

$$A + B \rightarrow C$$

Reactant A enters the tube reactor. Reactant B is injected in the beginning of the tube reactor, multiple injection locations along the tube reactor are possible if desired. When A and B mix, the substance C is produced. If the reaction is exothermic, heat is generated and the temperature of the fluid increases. For each injection point, there will be a local temperature maximum, called a hot spot. To cool the reactor cold water flows around the tube.

A main control objective is to keep the process at the pre-calculated optimal operating point, regardless of perturbations. One crucial part of the control system will be the start-up and shut-down procedure. The control system will also be involved in the safety management part, e.g. to prevent the reactor temperature to rise above a certain critical limit or to take appropriate actions during different types of reactor failures. The objectives of the control system can be summarized as:

- Utilize reactor maximally in a safe way
- Reaction is to be completed within the reactor
- Reactants are to be in the right proportions
- Should be able to work with highly concentrated solutions
- Avoid side reactions
- Achieve and maintain desired operating conditions
- Fast and safe start-up/shut-down
- Emergency shut-down procedure
- Robustness towards disturbances in the process

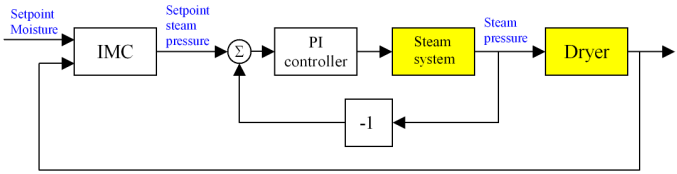

Figure 5.7 The paper machine moisture control loop. IMC is a shortening for Internal Model Control.

Modeling and Control of the Drying Sections of a Paper Machine

Researchers: Ola Slätteke, ABB and LTH, Björn Wittenmark, and Tore Hägglund, in cooperation with Krister Forsman, ABB Process Industries

The paper making process is essentially a very large drainage process. Consistency of the stock flow entering the paper machine head box is typically around 0.2% – 1.0% (2–10 g fiber per kg water). Although the drying section is only responsible for removing less than 1% of this water content, this is the part of the paper machine that, by far, consumes most energy. It is also in the drying section where most paper web strength forms and web shrinkage occurs and the part where the actual moisture control is performed. These are some of the reasons why this part of the paper machine is critical for the final paper qualities.

A dryer section in a paper machine can consist of up to one hundred steam heated cylinders and the length of the drying section can be above 100 meters. The cylinders are divided in 5 – 10 steam groups. The control of the steam pressure in these cylinder groups is in cascade control with the moisture control loop. This project is focused on the modeling and control tuning of this process. From mathematical model building and experiments on industrial paper machines it is found that the dynamics from the steam valves to the steam pressure in the cylinders can be described by a simple process model, the so called IPZ model. See Figure 5.7. This model has an integrator, one pole, and one zero. The dynamics from the steam pressure to the moisture in the paper can be described by a first order model plus dead time, where

the dead time is the dominating part.

During the last year, a simple tuning method for the pressure controller (a PI-controller) has been developed that is based on the four process parameters of the IPZ model. The process parameters can easily be obtained by a simple open loop step response.

Biotechnology Processes

Control of Biotechnology Processes

Researchers: Lena de Maré, Stéphane Velut, and Per Hagander in cooperation with Jan Peter Axelsson, Pharmacia AB, 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 Pharmacia & Upjohn, Process R&D. 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 analyzed for stability.

The feeding strategy relies on good control of the dissolved oxygen concentration. Variations in the oxygen dynamics during a fed-batch cultivation often cause tuning problems when using a controller with fixed parameters. A control approach based on gain scheduling from the stirrer speed is suggested.

The strategy is now implemented at the Departments of Biotechnology and Chemical Engineering, Lund University, at Active Biotech, in Lund and at SBL Vaccin, Stockholm, at Pharmacia AB, Stockholm and Strängnäs, and tested with different E. coli strains and operating conditions. Good cultivation conditions and high production levels could be obtained from the first experiment. The strategy is also tested with good results in production scale and for other organisms like bakers yeast and cholera bacteria.

The work is funded by Vinnova, “Bioprocesser i industrin”, together with Pharmacia AB and SBL Vaccin.

Robotics

Robotics Research and Nonlinear Systems Research

Researchers: Rolf Johansson, Klas Nilsson, Anders Robertsson, and Torgny Brogårdh, ABB Robotics

The laboratory for robotics and real-time systems is centered around an ABB Irb-6 robot and an ABB Irb-2000 robot. Hardware interfaces have been developed to create an open system suitable for control experiments. The computer hardware is VME-based with both micro processors and signal processors integrated into an embedded system for hard real-time control. The system is connected to a network with workstations, which are used for program development and control design.

A purpose of the current project is to show how to organize open robot control systems and to verify these ideas by means of experiments. One goal is to permit efficient specification and generation of fast robot motions along a geometric path which requires coordinated adjustment of the individual joint motions. Another aspect of robot motion control is how to to integrate simultaneous control of force and position according to ideas of impedance control in which stability is an important theoretical issue. A major topic in this project is to integrate aspects of control, sensor fusion and application demands using robot vision and force sensing.

Another project is on the structure and programming of control systems for industrial robots. The problem addressed is how the software architecture and the real-time structure of a robot control system should be designed to allow easy and flexible incorporation of additional sensors and new control algorithms. A software layer between a supervisory sequence control layer and the basic control level has been proposed. Case studies and prototype experiments show promising results and further implementation is going on.

The project 'Autofett' aims towards use of force control in manufacturing operations such as robotized fettling. New sensor interfaces with modification of hardware and real-time software architectures have been developed to accommodate the use of force control algorithms based on work-space sensing.

Real-Time Control

Center for Applied Software Research (LUCAS)

Researchers: Karl-Erik Årzén, Rolf Johansson, Anders Robertsson, Anton Cervin, Dan Henriksson, Bo Lincoln, Magnus Gäfvert, Anders Blomdell, Leif Andersson, in collaboration with Department of Computer Science and Department of Communications Systems

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. During 2002 Ericsson Mobile Platforms, Sony Ericsson Mobile, and ABB Automation Technology Products were gold members. Silver members were Q-Labs, Telelogic, and Ericsson Microwave.

Integrated Control and Scheduling

Researchers: Anton Cervin, Dan Henriksson, Anders Blomdell, Bo Lincoln and Karl-Erik Årzén, with Teleca as the industrial node

The ARTES project "Integrated Control and Scheduling" is aimed at practical management of hard real-time demands in embedded software. The project consists of two sub-projects: "Feedback Scheduling" undertaken by the Department of Automatic Control, Lund University, and "Flexible Automatic Memory Management" performed by the Department of Computer Science, Lund University. The real-time software consulting company Teleca is the industrial ARTES node associated with the project. The project finances two ARTES PhD students, Anton Cervin at Automatic Control, and Sven Gestegård Robertz at Computer Science. The PhD student Dan Henriksson is also contributing to the project.

During 2002, the development of the MATLAB/Simulink-based real-time control systems simulator `TrueTime` was continued. `TrueTime` allows co-simulation of continuous process dynamics and multi-tasking real-time kernels and communication networks. The new version of the simulator is event-based, written in C, and allows the user tasks to be defined as M functions, C functions, or Simulink diagrams.

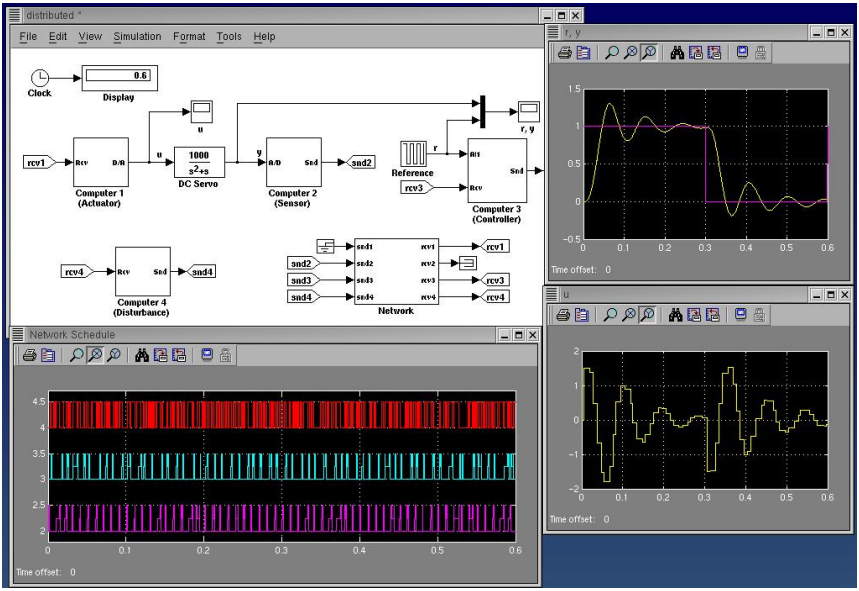

Figure 5.8 Screenshot of the `TrueTime` simulator.

The MATLAB-based analysis tool `Jitterbug` was also further developed during the year. `Jitterbug` allows evaluation of a quadratic performance criterion for a control loop under various timing conditions. The tool is quite general and can be used to investigate the effect of jitter, delay, aborted computations, etc., on control performance.

The Control Server, a new computational model for controller tasks has been defined and implemented. The model combines time-triggered I/O with dynamic, reservation-based task scheduling. The model provides short input-output latencies and minimal jitter for the controllers. It also allows control tasks to be treated as scalable real-time components with predictable performance.

The work on feedback scheduling has also continued. We have started to work on feedback scheduling of Model Predictive Controllers (MPC). These controllers are difficult to schedule using traditional real-time

methods, since they can exhibit very large variation in execution time. The MPC controllers can be viewed as anytime algorithms, i.e., anytime controllers, that gradually improve the control performance the longer the optimization may proceed. We have also started to study anytime sensors in the form is cameras and how they should be scheduled.

Hard Real-Time CORBA for Control

Researchers: Karl-Erik Årzén, Johan Eker, Anders Blomdell in cooperation with Klas Nilsson and Christian Andersson, Dept. of Computer Science, Lund Institute of Technology

The Hard Real-Time CORBA for Control (HRTC) project is a one-year EU IST FP5 project with the aim to extend the application areas of the distributed object and component technology CORBA to also include hard real-time applications, e.g., networked control loops. The other partners in the project are Universitat Politecnica de Madrid, TU Vienna, and SCILabs.

The approach taken is to provide a deterministic pluggable transport layer that provides bounded network latencies. Two paths are followed. In one approach the time-triggered protocol TTP/C is used. In Lund we instead base the transport on scheduled switched Ethernet.

The results of the project will be demonstrated in two test-beds: a industrial robotics test-bed implemented in Lund and a process control testbed implemented in Madrid.

Admission Control in Communication Networks

Researchers: Anders Robertsson and Björn Wittenmark in cooperation with Maria Kihl, Dept. of Telecommunications, Lund Institute of Technology

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 plays 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 effect of different arrival and service process distributions are evaluated. Stability analysis and controller design for both continuous and discrete-time models are considered.

Minimum Data Rates for Stabilizing Linear Systems with Unknown Parameters

Researchers: Björn Wittenmark in cooperation with Girish N. Nair, Robin J. Evans, University of Melbourne, Australia

One of the most fundamental questions in the field of joint communication and control is the following: if a plant and controller communicate at a limited data rate and no restrictions but causality are placed on the coding and control policy, what is the smallest rate at which stabilization is possible? In this work, the problem of stabilizing a deterministic, partially observed, discrete-time, linear time-invariant system using a finite data rate is investigated, with the additional complication that the system parameters are unknown constants.

The formulation in terms of moments allows the control problem to be converted into a recursive quantization problem with a mean-mth-power-error cost. By using a new quantizer error lower bound it is shown that the data rate R in bits per interval must satisfy

$$R > \sum_{|\lambda_i|>\rho} \log_2 \left| \frac{\lambda_d}{\rho} \right|$$

where $\lambda_1, \ldots \lambda_d$ are the eigenvalues of the open-loop plant.

Computer Control

Researchers: Karl-Erik Årzén, Karl Johan Åström, and Björn Wittenmark

Computer control is entering all facets of life from home electronics to production of different products and material. Many of the computers are embedded and thus “hidden” for the user. In many situations it is not necessary to know anything about computer control or real-time systems to implement a simple controller. There are, however, many

situations where the result will be much better when the sampled-data aspects of the system are taken into consideration when the controller is designed. Also, it is very important that the real-time aspects are regarded. The real-time system influences the timing in the computer and can thus minimize latency and delays in the feedback controller. In the work we consider some of the pitfalls of computer control.

This project summarizes some of the research on implementation of computer-controlled systems, both from the controller point of view as well as the real-time aspects of the implementation. The result is a *Professional Brief* published on the web by IFAC, see `http://guada.disca.upv.es/ifac/PBRIEFS/pbriefs.htm`.

Distributed Control of Safety Critical Mechanical Systems
Researchers: Magnus Gäfvert and Björn Wittenmark, in cooperation with Department of Computer Engineering, Chalmers, Department of Mechanical Elements, KTH, and Volvo Technological Development

It is believed that the design and understanding of distributed safety-critical control systems can be greatly enhanced by applying and combining methods within the areas of automatic control, computer engineering, and mechatronics. A case study, initiated with Volvo TD, on a braking system of a tractor-semitrailer has served as a catalyst in this project.

The results include a study of present braking systems in literature and practice, proposals on novel system architectures based on, e.g., dependability analysis, dynamic models of the tractor-semitrailer, and studies on strategies for active stability-control by unilateral braking. Figure 5.9 shows a simulation of a lane-change maneuver with a 9-DOF model. The influence on closed-loop control performance of transient hardware faults in CPUs executing control algorithms was studied in cooperation with Department of Computer Engineering, Chalmers. A novel method to handle such faults has been presented, that is based on artificial signal-limits in combination with anti-windup schemes. In the past year the influence on closed-loop control performance of transient hardware faults in CPUs executing control algorithms was studied in cooperation with Department of Computer Engineering, Chalmers. A

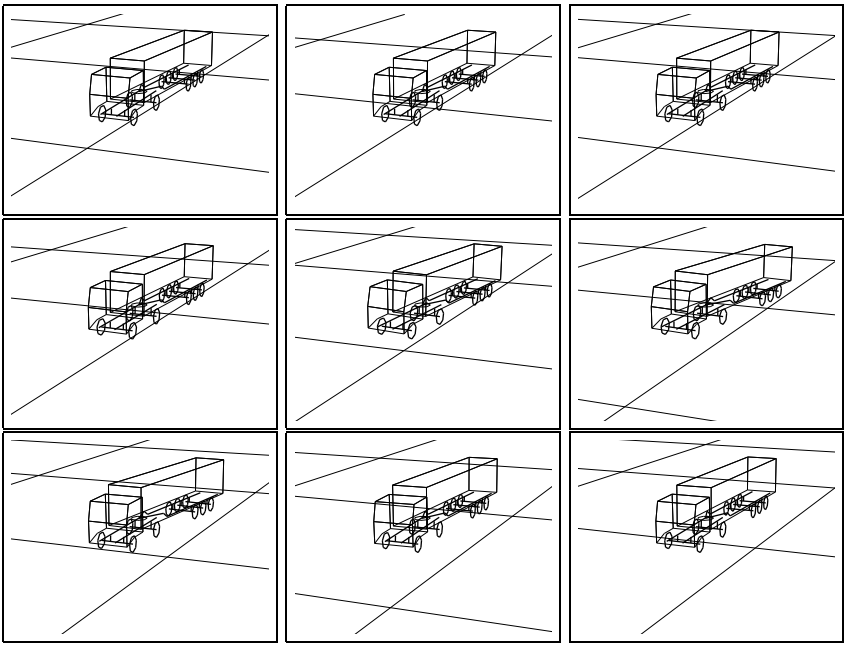

Figure 5.9 The 9-DOF tractor-semitrailer model is implemented in Matlab/Simulink. A tool for 3D-animations of simulation results is part of the implementation. The sequence above shows a lane-change maneuver at 80 km/h with 2.5 deg maximum wheel-angle. The wheel-angle input is obtained from recordings of a real driving experiment

novel method to handle such faults was presented, which is based on artificial signal limits in combination with anti-windup schemes. Furthermore, a novel tire-model for describing the produced forces under combined braking and cornering has been developed. The model is based on combining available empirical data for pure braking and pure cornering with a theoretical model of tire mechanics. The model is expected to be of practical use in simulations of any vehicles with pneumatic tires running on paved roads, and has the advantage of introducing few additional parameters.

Biomedical Systems

Biomedical Modeling and Control

Researchers: Rolf Johansson in cooperation with Dr Måns Magnusson, Department of Oto-Rhino-Laryngology, 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 multi-sensory 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 afference. To this purpose, stability properties are studied by means of induced perturbations specific to each sensory feedback loop by using system identification methodology. The work is supported by the Swedish Medical Research Council and the Faculty of Medicine, Lund University.

Cardiologic Analysis and Modeling

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

This project is directed towards chronic atrial fibrillation (CAF), one of the most common cardiac arrhythmias 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 intra-atrial electrical re-entry. 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 re-entry mechanisms. In addition, areas with organized activation were identified. The nature of the organized activation suggested re-entry in an anatomical structure, like the right annular bundle surrounding

the tricuspid valve. In patients without signs of organized activation, multiple activation waves continuously re-enter 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.

Automotive Systems

Control of Antilock Braking Systems

Researchers: Stefan Solyom and Anders Rantzer

The Antilock Braking System is an important component of the complex steering system of a modern car. The first ABS systems were implemented in the late 70's, the main objective of the control system being prevention of wheel-lock. Most of ABS controllers available on the market are table and relay-feedback based, making use of hydraulic actuators to deliver the braking force. In the latest generation of "brake by wire" systems, electro-mechanic actuators are capable of delivering continuously varying and different brake forces independently to the four wheels. The control objective shifts to maintain a specified tire slip rather then just preventing wheel-lock. The set-point slip is supposed to be provided by a higher level in the hierarchy (e.g. an ESP system), and can be used for stabilizing the steering dynamics of the car while braking. This might imply different slip reference values for each wheel.

It turns out that the slip control task is not trivial, one of the main reasons being the high amount of uncertainty involved. Most uncertainty arises from the friction between the tires and the road surface. In addition, the tire-road characteristics is highly nonlinear. A special problem arises due to potential fast change in surface conditions while braking (e.g. a wet spot on a dry surface).

Within this project, we have developed a gain scheduled PI controller, based on tire-slip value, velocity over ground and the maximum friction coefficient (i.e. friction coefficient at the top of the friction curve). This enables the controller to adapt to various fast changing road conditions.

Figure 5.10 Test vehicle for the H2C project

The controller robustly stabilizes the system for different slopes of the friction curve. Furthermore, it tolerates the time variations due to the decreasing velocity over ground of the car.

Tests have been carried out in a Mercedes E220 vehicle (Figure 5.10), provided by DaimlerChrysler, equipped with electro-mechanical brakes and brake-by-wire system.

The controller described above achieved the shortest braking distance of all controllers tested in the vehicle and outperformed the ABS used in series production.

Adaptive Cruise Control and Driver Models

Researchers: Rolf Johansson, Johan Bengtsson in cooperation with A. Sjögren, Volvo Technical Development, Inc., Gothenburg

This project is directed towards adaptive cruise control for automotive application in dense traffic and in conditions of automated highways. Radar sensing with Doppler-shift measurement permits feedback to

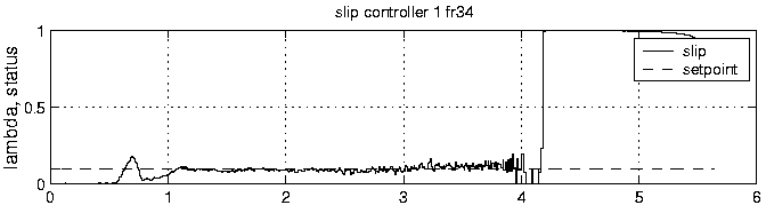

Figure 5.11 Test result for an emergency braking on dry asphalt. The longitudinal tire slip is depicted while braking from an initial velocity of $30 m/s$ until standstill is achieved.

maintain relative distance and relative velocity to vehicles ahead. A stop-and-go controller for adaptive cruise control has been developed, tested and reported. Current work is directed towards driver-model support.

Closed-loop Control of an Homogeneous Charge Compression Ignition (HCCI) Combustion Engine

Researchers: Johan Bengtsson and Rolf Johansson in cooperation with B. Johansson, J.O. Olsson, P. Strandh, and P. Tunestål, Div. Combustion Engines, Department of Heat and Power Engineering, Lund University

Homogeneous Charge Compression Ignition 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 auto-ignition, 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.

Tire Models for Control and Friction Estimation

Researchers: Jacob Svendenius, Haldex Brake Products AB and LTH, Björn Wittenmark and Magnus Gäfvert LTH in cooperation with Haldex Brake Products AB

The future trend for brake systems seems to be a change to the use of electrical power in control and actuation instead of pneumatics. Using electrical brakes will not only result in a faster and more controllable system. It will also introduce new needs of adjustment and safety thinking. The brake system is one of the most critical systems in the vehicle and new and different disturbances that can risk the safety will occur. The possibility of faster and more accurate control of the brake actuator has also led a need of better knowledge of the vehicle system. The entire system does not only incorporate the electro-mechanical components and the dynamics of the vehicle. Even changeable factors as the driving conditions and the adhesion between the tire and the road has to be included. To be able to adjust for different conditions there is a need of adaptive control laws and identification of uncertain parameters. This has lead the project into modeling of the tire and its interaction with the road. The main aspect is how to estimate the adhesion limit for the tire and road surfaces and how it changes for different circumstances, for example, when the driver both turns and brakes at the same time.

Accurate tire models are necessary components of models aimed at analyzing or simulating vehicle motion in real driving conditions. With new active chassis-control systems that are based on unilateral braking it is increasingly important to describe the effects of combined braking and cornering correctly. A new easy-to-use tire-force model aimed at simulation of vehicle dynamics is developed for this purpose. The model is based on combining empirical models for pure braking and cornering with brush-model tire mechanics.

Natural Field Oriented Control (NFO) for Control of Induction Motor Drives

Researchers: Rolf Johansson in cooperation with Ragnar Jönsson and Ove Glenberg, NFO Control AB, Lund

The AC induction motor has been the workhorse in industry for more than 100 years, and it is still the dominating motor type in all areas of applications. However, it is non-trivial to control this motor and conventional frequency inverter are not sufficient for precision control. Moreover, classical frequency inverters are based on U/f-inverters with poor performance, especially at low motor speeds. Demonstration of high-performance AC induction motor as servomotor was made first made by Blaschke in Prof. Leonhard's team in Braunschweig using vectorial control.

Natural Field Orientation (NFO) is a 'sensorless vector control system' for the AC induction motor, a feedback control that does not rely on sensors of mechanical quantities such as velocity or position. Historically, it has been difficult to combine vector control with sensorless operation. NFO stands for vector control with "Natural Field Orientation". The two words "field orientation" tell that the control signals are oriented in relation to the magnetic field inside the motor. The word "natural" tells that the control principle is simple and natural. The patented NFO scheme generates control signals and trusts that the motor generates a correct field. The current project aims towards higher control performance in of DSP-implemented NFO control in induction motor drive applications, the project being supported by Vinnova.

6. External Contacts

The roles of the universities in technology transfer has recently been emphasized in Swedish research policy as “the third mission” (tredje uppgiften). This means that we now also have responsibility for transfer of research to industry.

At present we have a healthy mixture of fundamental and applied work. The purpose of the theory activity is to develop new ideas, concepts and theories that capture the essence of real control problems. We are of course delighted to find applications of the theory but the focus is always on methodology. 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. The applications projects also provide very good background for our educational activities.

Technology transfer takes many forms. One is to take results from our research and present them so that they are easy to use. Probably the best way to do this is through personal exchange between industry and university. Students are a very effective vehicle for the transfer.

Realizing that the majority of the research is done outside Sweden another important role for universities in a small country is to take existing knowledge and organize it 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. We have been active in technology transfer for a long time, good examples of this type of exchange where we have transferred ideas are self-tuning control, automatic tuning, and computer-aided control engineering. More details have been presented in previous activity reports.

Industrial Contacts

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

ABB,
Alfa Laval Lund AB,
BlueCell,
Computas,
ConnectBlue,
Corus,
C-Technology,
DaimlerChrysler,
Dynasim AB,
Ericsson Microwave,
Ericsson Mobile Platforms,
Gensym Corp.,
Haldex Brake Products AB,
IFP,
KPS Rinas,
Kranendonk Production Systems BV,
NFO Control AB,
Pharmacia AB,
Q-labs,
SBL Vaccine AB,
Scania Trucks,
SCILabs,
Sony Ericsson Mobile,
Sydkraft,
TAC,
Thales,
Teleca,
Telelogic,

Tetra Pak Research & Development,
Toyota Motor Company,
UPM-Kymmene,
Volvo Car Corporation,
Volvo Powertrain, and
Volvo Technical Development,

We have had smaller projects with

Alstom AG,
Axis Communications AB,
ConnectBlue,
Ericsson Mobile Communication,
MA System,
M-real Husum AB,
Stora Enso Hylte AB,
TAC, and
TeleLogic
and meetings and discussions with many other companies.

European Collaboration

The department coordinated one Expession of Interest for the 6th frame program of the European Union and participated in 12 others.

7. Dissertations

One PhD thesis was defended by Hubertus Tummescheit; and three Lic Tech were completed by Stefan Solyom, Henrik Sandberg, and Rasmus Olsson.

The abstracts are presented here in chronological order.

Synthesis of a Model-Based Tire Slip Controller

Stefan Solyom
Lic Tech dissertation, June 14, 2002

Opponent: Tekn Dr Mats Andersson, Volvo Teknisk Utveckling, Gothenburg, Sweden.

The Anti-lock Braking System (ABS) is an important component of a complex steering system for the modern car. In the latest generation of brake-by-wire systems, the performance requirements on the ABS have changed. The controllers have to be able to maintain a specified tire slip for each wheel during braking. This thesis proposes a design model and based on that a hybrid controller that regulates the tire-slip. Simulation and test results are presented.

A design method for robust PID controllers is presented. Robustness is ensured with respect to a cone bounded static nonlinearity acting on the plant. Additional constraints on maximum sensitivity are also considered. The design procedure has been successfully applied in the synthesis of the proposed hybrid ABS controller.

Trajectory convergence for a class of nonlinear systems is analyzed. The servo problem for piecewise linear systems is treated. Convex optimization is used to describe the behavior of system trajectories of a piecewise linear system with respect to some input signals.

Design and Implementation of Object-Oriented Model Libraries using Modelica

Hubertus Tummescheit
PhD dissertation, August 2002

Opponent: Prof. Richard Murray, Dept. of Control & Dyn. Syst., Caltech, California, USA. Committee: Prof. Bengt Sundén, Lund Institute of Technology, Dept. of Heat and Power Engineering, Lund, Sweden; Prof. Jonas Sjöberg, Chalmers, Gothenburg, Sweden; Prof. Per Grove Thomsen, DTU, Numerical Analysis, Lyngby, Denmark; Ass. prof. Sven Spanne, Lund Institute of Technology, Mathematics, Lund, Sweden.

This thesis describes basic models for thermo-fluid systems and the implementation of the model using a flexible object-oriented structure in the ThermoFluid library. Model libraries provide an excellent way to package engineering knowledge of systems to be reused by non-experts. Many commercial simulation packages provide good model libraries, but they are usually domain specific and closed. Modelica(TM) is an open standard of an object-oriented modeling language for heterogeneous, multi-domain dynamic systems. Modelica combines the expressive power of equation based modeling with advanced object-oriented structuring features. A unique feature of Modelica are class parameters which allow a high-level parameterization of physical phenomena.

The models are based on first principles. Control volumes contain the thermodynamic balance equations in lumped or one-dimensional discretized form. The library is built to be flexible: fluid property models in the control volume can be exchanged, single- or multi-component fluids are supported and the momentum balance submodel can be static or dynamic. Chemical reactions can be added to the model separately from other phenomena. Thermodynamic Jacobians are used to transform the dynamic equations into an efficient form. Low order moving boundary models for two phase flows are another result of the thesis. They make use of a novel approach for approximating the mean void fraction in the two phase region.

The experiences from designing an object-oriented, reusable model library are summarized using design patterns. Design patterns are an attempt to describe "good practice" in modeling in a semi-formal way.

The library has been used successfully for a broad range of industrial applications, among other modeling of micro gas turbine systems, carbon-dioxide based refrigeration systems, fuel cells, power plants and steam networks. The applications are briefly described in the thesis.

Linear Time-Varying Systems: Modeling and Reduction

Henrik Sandberg
Lic Tech dissertation, November 19, 2002

Opponent: Prof. Alexandre Megretski, Dept. of Electrical Engineering, MIT, Cambridge, USA.

Linear time-invariant models are widely used in the control community. They often serve as approximations of nonlinear systems. For control purposes linear approximations are often good enough since feedback control systems are inherently robust to model errors. In this thesis some of the possibilities for linear time-varying modeling are studied.

In the thesis it is shown that the balanced truncation procedure can be applied to reduce the order of linear time-varying systems. Many of the attractive properties of balanced truncation for time-invariant systems can be generalized into the time-varying framework. For example, it is shown that a truncated input-output stable system will be input-output stable, and computable simple worst-case error bounds are derived. The method is illustrated with model reduction of a nonlinear diesel exhaust catalyst model.

It is also shown that linear time-periodic models can be used for analysis of systems with power converters. Power converters produce harmonics in the power grids and give frequency coupling that cannot be modeled with standard time-invariant linear models. With time-periodic models we can visualize the coupling and also use all the available tools for linear time-varying systems, such as balanced truncation. The method is illustrated on inverter locomotives.

Exception Handling in Recipe-Based Batch Control

Rasmus Olsson
Lic Tech dissertation, December 6, 2002

Opponent: PhD Charlotta Johnsson, Siemens Orsi Automation, Genua, Italy.

The focus of this thesis is exception handling in recipe-based batch control. Exception handling is a critical element for achieving long-term success in batch production. It is reported to constitute 40-60 percent of the batch control design and implementation effort. Correct handling of exceptions is a key element in process safety, consistent product quality, and production cost minimization.

The previous work on Grafchart for sequential programming, batch process recipe handling and resource allocation is extended to also include exception handling. The work is based on two new language features: MIMO macro steps and step fusion sets. A MIMO macro step is a macro step with multiple input ports and multiple output ports. It can be conveniently used to represent hierarchical states in state-machine based control systems. The functionality is similar to the super-states in Statecharts. Step fusion sets provide a way to have multiple graphical representations, or views, of the same step. Using step fusion sets it is possible to separate the exception-handling logic from the normal operation sequences in a way that improves usability.

An internal model approach is proposed where each equipment object in the control system is extended with a state-machine based model that is used on-line to structure and implement the safety interlock logic. The thesis treats exception handling both at the unit supervision level and at the recipe level. The goal is to provide a structure, which makes the implementation of exception handling in batch processes easier. The proposed approach uses the MIMO macro step functionality to implement the state machines and step fusion sets to provide separation between the exception handling logic and the logic for normal, fault-free operation. The approach has been implemented and tested on a batch pilot plant at UPC in Barcelona, Spain. The work follows the batch control standard S88.

An inexpensive, portable, and flexible laboratory batch process has been developed. The process is used within the chemical engineering education at Lund Institute of Technology. The process can be used for teaching sequential, PID, multi-variable, and recipe-based control.

8. Honors and Awards

Leif Andersson, **Britt-Marie Mårtensson**, and **Eva Schildt** received awards for *"nit och redlighet i rikets tjänst" (zealous and devoted service)*.

The Great Gold Model (Stora Guldmedaljen) of the Royal Swedish Academy of Engineering Sciences was given **Karl Johan Åström** for *"his unique work within a broad control field as researcher, teacher, and inspirer"*. You find the link to IVA's homepage at http://www.iva.se/.

Tore Hägglund received the distinction *Excellent Teaching Practice (ETP)*.

Anders Robertsson was awarded best Lecturer 2001/2002 on the Electrical Engineering Programme, Lund Institute of Technology, Lund, Sweden.

9. Personnel and Visitors

Personnel

During 2002 the following persons have been employed at the department. The list shows the *status of December 2002* if nothing else is mentioned.

Professors

Karl-Erik Årzén
Karl Johan Åström (emeritus)
Bo Bernhardsson *(on leave from May 2001)*
Per Hagander
Tore Hägglund
Rolf Johansson
Anders Rantzer
Björn Wittenmark

Associate Professor

Anders Robertsson

Research Engineers

Leif Andersson
Anders Blomdell
Rolf Braun

Researcher

Johan Eker *(January–April, October–December)*

Guest Professors

Andrey Gulchak *(until June)*

PhD Students

Johan Åkesson
Johan Bengtsson
Anton Cervin
Lena de Maré
Jenny Ekvall
Magnus Gäfvert
Ove Glenberg *(from March)*
Sven Hedlund
Staffan Haugwitz *(from March)*
Dan Henriksson
Ari Ingimundarson
Bo Lincoln
Rasmus Olsson
Tomas Olsson
Mikael Petersson
Henrik Sandberg
Ola Slätteke
Stefan Solyom
Jacob Svendenius
Hubertus Tummescheit
Stéphane Velut

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.

Claudio Aurora *April 1–August 30, 2002*
University Pavia, Italy

Stephen Prajna *April 21–July 6, 2002*
Caltech, USA

Chung-Yao Kao *September 1–December 31, 2002*
MIT, USA

J.J. Wang *October 7–October 27, 2002*
ABB Robotics, USA

Angel Valera Fernandez *September 2–October 2, 2002*
Universidad Politecnica de Valencia, Spain

Marina Valles *September 6–November 6, 2002*
Universidad Politecnica de Valenca, Spain

David Angeli *June 9–June 16, 2002*
University of Firenze, Italy

Dawn Tilbury *August 12–August 16, 2002*
University of Michigan

Anton Shiriaev *August 1–August 31, 2002*
Odense University, denmark

Visiting Students

The following foreign students have stayed with the department and followed the courses. Many of them have made their master's theses. Students marked with "(E)" are from the ERASMUS program.

Alex Alcocer [E] *until October 2002*
U.P.C. Barcelona, Spain

Javier Antonio Martinez Serradell [E] *until June 2002*
Politecnica Cartagena, Spain

Jee Hui Wong [E] *until October 2002*
Imperial College, London, GB

Teck Her Woon [E] *until October 2002*
Imperial College, London, GB

Francesco Calugi [E] *until April 2002*
University of Florence, Italy

Erik Casagrande [E] *from June 2002*
University Padova, Italy

Xavier Callier [B] *from August 2002*
ISMRA, France

Nicolaus Correll [E] *until June 2002*
ETH Zürich, Switzerland

Samuel Kasper [E] *from October 2002*
Eidgenössische Technische Hochschule, Switzerland

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

MSc, graduate student since January 2001. Johan's main research interest is in the field of decision support structures for chemical process industry. He is currently working in the EC project CHEM. Johan's research interests also includes stabilization of unstable systems subject to input saturation. During 2002, Johan was a teaching assistant in the courses Systems Engineering and Real Time Systems.

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.

In April 27 Leif became a proud grandfather to a little boy named Simon.

Årzén, Karl-Erik

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

Project leader for the SSF/ARTES project on integrated control and scheduling and for the VR industrial PhD project on industrial aspects of monitoring and diagnosis. Member of the steering committee of LUCAS (Center for Applied Software Research). During the year he has personally primarily been involved in the EU CHEM project on decision support systems for the process industries and in the SSF/ARTES project. He has been responsible for and taught the undergraduate course on Real-Time Systems and the International Project Course in Automatic Control. He is partly or fully involved in the supervision of six PhD students.

Åström, Karl Johan

Professor since 1965, Emeritus from 2000. He founded the department and has broad interests in control including physical modeling, PID control, switched and adaptive systems. He has an emerging interest in control of biological systems. This year he has worked to improve the curriculum with development of new lecture notes. He has also participated in the Panel Future Directions in Control. Dynamics and Systems supported by the Airforce Office of Scientific Research (AFOSR). The panel report will be published by SIAM and a brief summary will appear in the IEEE Control Systems Magazine in 2003.

Bengtsson, Johan

Lic Tech in November 2001, graduate student since April 1999. He is interested in system identification, modeling and visual servoing. He is working in cooperation with Volvo cars, Volvo Technical Development and SAAB Scania on modeling and control of a 6-cylinder HCCI engine. During the year he has been teaching assistant in the System Identification course.

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, communication protocols, and computer languages for control engineering.

During the previous years, much effort has been spent at enhancing and porting the STORK Real Time Kernel to the various computer platforms used at the department (m680x0, PowerPC, Solaris and WindowsNT). A closely related project is the Modula-2 to C translator used in the real-time research and education at the department.

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

Lic Tech in May 2000, graduate student since May 1998. Anton's research topic is real-time systems, and he is involved in the SSF/ARTES project "Integrated Control and Scheduling". During the year he has been a teaching assistant in the courses Computer-Controlled Systems and Automatic Control, Basic Course. Research activities during the year have included the development of two Matlab toolboxes for analysis and simulation of real-time control systems: Jitterbug and TrueTime.

de Maré, Lena

MSc, graduate student since August 1999. She is interested in control of biotechnical processes and is working together with Stephane Velut and Per Hagander in the project 'Process control for cultivation of genetically modified micro-organisms' funded by Vinnova. A collaboration together with Olle Holst and Santosh Ramshuran at the biotechnology department (LTH) on temperature-limited fed-batch cultivations with *E.coli* has also taken place. During 2002 she has been a teaching assistant in Automatic control, basic course.

Ekvall, Jenny

Graduate student since January 2002. Jenny's main research interest is in the field of monitoring and supervision. Her present project is control and supervision at grade changes, in collaboration with M-real, Husum.

The process she studies is the drying section of a paper machine. 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.

Gäfvert, Magnus

MSc, graduate student since July 1996. Magnus is interested in topics on distributed control and real-time systems in automotive applications. During the year he has worked with off-sprung topics from a case study on a truck braking system, provided by Volvo Technological Development within the NUTEK project DICOSMOS. One topic is the study of the effects on closed-loop performance of transient hardware-faults in processors executing control-algorithms in safety-critical control systems. Another is the study of tire-modeling with the construction of a new model for combined braking and cornering, in cooperation with Jacob Svendenius.

Previous work include the modelling of a tractor-semitrailer vehicle, and the study of anti-skidding control by unilateral braking. It also include a controller design for GDI engines, a benchmark problem provided by Siemens Automotive, within the EU Esprit project FAMIMO. Previous work also regard modeling, analysis and control of systems with friction. Magnus is involved in the development and support of the computer based interactive tools for control education, ICTools. During the year he was a teaching assistant in the International Project Course given in cooperation with Ecole des Mines in Nantes.

Glenberg, Ove

MSc, graduate student since September 1994. Ove's research interest is sensorless control of the Induction Motor especially at low speed including 0 Hz. He is involved in the Vinnova project "Gröna Bilen" since January 2002 and most of the work is done at the company NFO Control in Lund. Parallel with the work he is studying courses at the department of Automatic Control in Lund.

Gulchak, Andrey

PhD, Guest Lecturer and Researcher since September 1998. His research interest includes analysis and design of robust control systems, constrained H^∞ and multi-objective optimization, systems with delays as well as the general operator theory and functional analysis. He develops methods and MATLAB software for robust controller design by convex optimization.

Andrey left the department in June to work with Malmö University.

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 2002 he taught Process Control (K), Systems Engineering (W), and Automatic Control, Basic Course (AK M). He is leading a project with Pharmacia AB, on multivariable control of genetically engineered E. Coli. The work is also a collaboration with the Department of Biotechnology, Lund University and SBL Vaccine. A new project on the control of a special type of continuous chemical reactors was started together with Alfa Laval AB within the Center for Process Design and Control (CPDC).

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, supervision, and detection.

Main research activities during the year have been design of PID controllers, and development and implementation of performance monitoring tools for process control.

Haugwitz, Staffan

MSc, graduate student since August 2002. Staffan is working with Per Hagander on the project "Control of a Open Plate Reactor". The project

is run by Alfa Laval in collaboration with several other universities and institutes. One of the departments, Le Laboratoire de Génie Chimique de Toulouse, has been visited twice this year.

During the fall Staffan has been teaching assistant in the Automatic Control basic course.

Hedlund, Sven

Lic Tech since September 1999, graduate student since September 1997 His main research interest is analysis and synthesis of hybrid systems.

During 2002, Sven has been a teaching assistant in the undergraduate basic course in Automatic Control.

Henriksson, Dan

MSc, graduate student since December 2000. Dan's research interests concern design and analysis of real-time control systems, and he is involved in the SSF/ARTES++ project "Flexible Embedded Control Systems" (FLEXCON). During 2002 Dan has been teaching assistant in Computer-Controlled Systems and Real-Time Systems.

Ingimundarson, Ari

MSc, graduate student since November 1998. His research interests include aspects of process control such as PID control and performance monitoring. The main research topic this year has been performance monitoring of lambda-tuned controllers. Ari is working within the CPDC project. He was a teaching assistant in the course, Automatic Control, basic course, during Fall 2002.

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 coordinating director of Robotics Laboratory with cooperation partners from Dept Computer Science, Dept Mechanical Engineering and industrial partners. He has industrial cooperation with ABB Robotics, NFO Control AB, Volvo Technical Development, 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.

Lincoln, Bo

MSc, graduate student since February 1999. He is working on control problems in the networked control domain and optimal control using dynamic programming. For networked control he is studying the impact of time-varying delays on stability and performance. The optimal control research is focused on relaxed dynamic programming, aimed at solving control problems almost optimally. A typical problem is switched linear control. His advisor is Professor Anders Rantzer.

Bo has been a teaching assistant in the basic control course four times, and in the course in nonlinear systems twice. He has also been in the working group for the new digital control course.

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.

Olsson, Rasmus

Lic Tech in December 2002, graduate student since August 1999. Rasmus area of research is batch control, and he is part of the CPDC graduate school. His focus has been on exception handling in recipe-based batch control. During 2002 he has been teaching assistant in the undergraduate courses Automatic Process Control and Real-Time Systems.

Olsson, Tomas

MSc, graduate student since December 2001. His main research interests are robotic force control, visual servoing, and observer-based

visual position tracking. He is currently working with applications of force control in the EU project Autofett. During the year Tomas has been a teaching assistant in the basic course in Automatic Control, and in Real-Time Systems. Thomas has also co-supervised several Master's Thesis projects in the Robotics lab.

Petersson, Mikael

Graduate student since 1997. Petersson holds a position at the Automation Technologies division of ABB as an industrial PhD-student. His research interests is in control loop performance monitoring of industrial processes, and applying and evaluating advanced theory in this area.

The research has been focused on assessing the control structure based on measurements and particular work has been carried out on feedforward control structure, with a patent pending, cascade control, and gain scheduling.

Rantzer, Anders

Professor of Automatic Control since 1999. Joined the department in 1993 after a PhD at KTH 1991 and a post-doc position at IMA, University of Minnesota. He has broad interests in modeling, analysis and synthesis of control systems, with particular attention to computational methods for uncertainty, nonlinearities and hybrid phenomena.

During 2002, Anders Rantzer was the main supervisor for the PhD students Hedlund, Lincoln, Sandberg, Solyom and Tummescheit and served on several committees within the university. He gave plenary lectures at Reglermöte 2002 in Linköping and SICE Annual Conference in Osaka. He served on the editorial board of two journals, several international committees and one evaluation board at the Swedish Research Council.

Robertsson, Anders

Assistant Professor (May 2001), 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 in network nodes in cooperation with the Department of Telecommunications, LTH. He has lectured the basic course of Automatic Control for electrical engineers, the Nonlinear Control and Servo Systems, the Control Project course and the Geometric Algebra Course. He has also lectured in the graduate course on Robotics and acted as advisor for several Master's Thesis projects.

Sandberg, Henrik

Lic Tech in November 2002, graduate student since January 2000. Henrik is interested in analysis, reduction, and control of periodic and time-varying systems. He is involved in the CPDC-project "Reduction and aggregation of process models" and the VR-project "Theory for modelling, control and analysis of periodic systems". During the year Henrik has been teaching assistant in the courses Nonlinear Control and Servo Systems, Automatic Control Basic Course, and Real-Time Systems.

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.

Slätteke, Ola

MSc, graduate student since January 2001. Employed by ABB Industries as an industrial PhD-student. His work is focused on modeling and control of the drying section of a paper machine within the CPDC-project. Ola also has a few years of experience of the pulp and paper industry, working at Stora Enso Nymölla AB as a control engineer. Ola ha also been a teaching assistant in Automatic Control, basic course, during the fall.

Solyom, Stefan

MSc, graduate student since August 1999. His research interest is in nonlinear and hybrid control strategies. In particular, he is interested in piecewise linear systems. During the year he has worked on an Anti-lock Braking System within the ESPRIT project H2C. Here, tests have been carried out in cooperation with DaimlerChrysler. Recently he started working in a European project on Computation and Control (CC). He has also been teaching assistant in the courses Adaptive Control, Automatic Control (basic course).

Svendenius, Jacob

M Sc in mechanical engineering and started to work in the laboratory at Haldex Brake Product AB 1998. He has mainly worked with performance testing of brakes for heavy vehicle. 2001 he started to work at the department in a project together with Haldex. In the spring 2002 Jacob was teaching assistent on the Automatic control basic course.

Tummescheit, Hubertus

Graduate student since 1996, graduate student in Lund since 1998. Interested in physical system modeling, modeling language design and numerical analysis. Since 1997 he is a member of the Modelica Association which continuously works on the advancement of the Modelica physical systems modeling language.

Tuszyński, Agneta

Secretary at the department since 1981. She is responsible for registration of the student's course entries and exam results, and supervises the invoice payments from the department. She works with word processing in LaTeX. Agneta is also responsible for Activity Report 2002 together with Tore Hägglund.

The highlight of the year was when she got her first grandchild, Hugo, on October 5.

Velut, Stéphane

Graduate student since July 1999. Interested in control of biotechnological processes and extremum control. He is working together with Lena

de Maré and Per Hagander in the Vinnova project "Process control for cultures of genetically modified microorganisms". He is also involved in the NACO2 project on nonlinear and adaptive control.

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. Björn was also chairman of the department during July–December.

External Assignments

Opponent and Member of Examination Committee

Karl-Erik Årzén: Member of the examination board of the PhD thesis by Flavius Gruian Dept of Computer Science, Lund Institute of Technology, Dec 17.

Per Hagander: Member of the Examination Committee for Christian Cimander, Linköping, Sweden, December 12 and for Pernille Ingildsen, IEA, Lund Institute of Technology, Lund, Sweden, May 23. Also Member of the Examination Committee for Sofia Andersson, Department of Mathematical Statistics, Lund Institute of Technolgy, Lund, Sweden, June 7.

Tore Hägglund: Member of the Examination Committee for the PhD thesis by Thomas Svantesson, Lund University, Lund, Sweden.

Rolf Johansson: Member of Examination Committee for A. Johansson, Luleå University of Technology, Luleå, Sweden, January 18. Member of Examination Committee for O. Kolesnichenko, Syddansk Universitetet, Odense, Denmark, November 28.

Anders Robertsson: Faculty opponent to Måns Östring's licentiate thesis, Linköping Institute of Technology, Linköping, Sweden, June 7. Deputy member of board for Håkan Petersson's PhD thesis, Lund Institute of Technology, Lund, Swedden, September 13.

Björn Wittenmark: Faculty opponent for Wolfgang Birk, Luleå Technical University, Luleå, Sweden, September 27.

Board Member

Karl-Erik Årzén: Member of the Board of SSF ARTES program, the Swedish real-time research network. Member of the Board of SNART (Swedish National Association for Real-Time Systems).

Tore Hägglund: Member of the Education Board of Computer Science and Technology, and of the Promotions Committee for FIME - physics, informatics mathematics and electrical engineering, both at Lund Institute of Technology, Lund, Sweden.

Anders Rantzer: Member of the evaluation board 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 scientific steering committee for the spring semester 2003 at the Institut Mittag-Leffler of the Royal Swedish Academy of Sciences. Member of the organizing committee for the international symposium New Directions in Mathematical Systems Theory and Optimization, Stockholm, November 2002.

Björn Wittenmark: Board member of the Research Board FIME–Physics, Informatics Mathematics and Electrial Engineering, Lund Institute of Technology, Lund, Sweden. Board member of LUCAS–Center for Applied Software Research. Board member of IEEE Control Systems Society. President and board member of the Royal Physiographic Society, Lund, Sweden. Swedish representative of European Union Control Association (EUCA) Council. Member of the Disciplinary Committee at Lund University, Lund, Sweden. Expert member in legal proceedings for patent at Svea Court of Appeal, 2001–2003.

Book and Journal Editor

Tore Hägglund: Associate editor for Control Engineering Practice.

Rolf Johansson: Associate editor of Int. J. Adaptive Control and Signal Processing. Editor of “Nonlinear and Hybrid Systems in Automotive Control” published by Springer Verlag, London.

Anders Rantzer: Associate editor of Systems and Control Letters. Member of the editorial board for International Journal of Robust and Nonlinear Control. Editor of the book "Directions in Mathematical Systems Theory and Optimization" published by Springer-Verlag, Berlin Heidelberg, on the occasion of Anders Lindquist's 60th birthday. Editor of the book "Nonlinear and Hybrid Systems in Automotive Control" published by Springer-Verlag, London.

Björn Wittenmark: Member of Editorial Board: Optimal Control Applicatins & Methods, Journal of Forecasting, International Journal of Adaptive Control and Signal Processing, and Springer series on Advances in Industrial Control. Reviewer for research evaluations for the Swedish Research Council, Australian Research Council, and Norwegian Research Council.

Advisory Committees and Working Groups

Karl-Erik Årzén: Chairman of the IEEE Control Systems Society Technical Committe on Real-Time Control, Computing and Signal Processing. Vice Chairman of the IFAC Technical Committe on Computers and Control.

Tore Hägglund: IFAC Technical Committee on Adaptive and Learning Systems.

Anders Rantzer: Member of IEEE CSS Tech. Com. on Nonlinear Systems and Control.

Björn Wittenmark: Chairman of the committee for IFAC Control Engineering Practice Price. Chairman IEEE Control System Society Distinguished Lecturer in the *Distinguished Lectures Program of the IEEE Control Society* 1993–.

Member of International Program Committee (IPC)

Karl-Erik Årzén: Member of the IPC for ADHS'03 (IFAC Conference of Analysis and Design of Hybrid Systems). Member of the IPC for the 15th Euromicro Conference on Real-Time Systems. Member of the IPC for the RTAS 2002, The 8th IEEE Real-Time and Embedded Technology and Applications Symposium, San Jose, September, 2002.

Anton Cervin: Member of IPC for the 5th Portugese Control Conference (Controlo 2002).

Per Hagander: Member of TCs IFAC TC-BIOMED - Control of Biotchnological Processes.

Tore Hägglund: Member of the International Program Committees for the conference Control Systems 2002 in Stockholm, and for the conference Controlo 2002 - 5th Portuguese Control Conference.

Rolf Johansson: Member of 9th IEEE Conference on Mechatronics and Machine Vision in Practice (M2VIP), Chiang Mai, Thailand, September 10-12.

Anders Rantzer: Member of IPC for European Control Conference 2003. Member of IPC for 4th IFAC Symposium on Robust Control Design (ROCOND-2003). Member of IPC for 6th Int. Workshop: Hybrid Systems: Computation and Control, 2003.

Björn Wittenmark: Member of the International Program Committee for International Symposium on Advanced Control of Industrial Processes, Kumamoto, Japan, June 10–11. Member of the Technical Committee for IFAC Adaptive Control and Learning. Member of the IEEE Control System Society Long-Range Planning Committee.

Other Assignments Björn Wittenmark: During March 18 to April 5 Björn Wittenmark was visiting professor at Imperial College, London, Great Britain and during April 22 to May 7 he was visiting professor at University of Illinois, Urbana-Champaigne, USA.

11. Publications and Conference Contributions

This year 1 book, 8 book contribution, 21 journal papers and 44 conference contributions have been published.

Book

Johansson, Rolf, and Anders Rantzer (Eds.): *Nonlinear and Hybrid Systems in Automotive Control*. Number ISBN 1-85233-652-8. Springer-Verlag, London, 2003.

Book Contributions

Åström, Karl Johan: "Model uncertainty and feedback." In Albertos and Sala, Eds., *Iterative Identification and Control*. Springer Verlag, 2002.

Åström, Karl Johan: "Modeling of complex systems." In Cai, Ed., *Modeling, Control and Optimization of Complex Systems - In Honor of Professor Yu-Chi Ho*. Kluwer, 2002.

Bengtsson, Johan, Rolf Johansson, and Agneta Sjögren: "Modeling of driver's longitudinal behavior." In Johansson and Rantzer, Eds., *Nonlinear and Hybrid Systems in Automotive Control*, pp. 41–58. London, 2002.

Gäfvert, Magnus, and Karl-Erik Årzén: "Control of Gasoline Direct Injection Engines using Torque." In *NACO2 Workshop on Automative Control*. Lund, Sweden, May 2002.

Golubev, A. E., Rolf Johansson, Anders Robertsson, and S. B. Tkachev: "Stabilizatsiya Vykhoda Neminimal'no-fazovykh Sistem c Po-

moshch'yu Obratnogo khoda po Nablyudatelyu (output stabilization of nonminimum phse systems using observer backstepping." In Emel'yanov and Korovin, Eds., *Nelineinaya Dinamika i Upravlenie (Nonlinear Dynamics and Control)*, pp. 115–124. Fizmatlit, Moscow, 2002.

Johansson, Rolf: "Continuous-time Identification." In *Encyclopedia of Life Support Systems (EOLSS)*, number 6.43.9.6. EOLSS Publishers, Oxtord, Britain, 2002.

Johansson, Rolf: "z-Transform and Digital Systems." In Bishop, Ed., *The Mechatronics Handbook*, pp. 23–40. CRC Press, Boca Raton, FL, 2002.

Solyom, Stefan, and Anders Rantzer: "ABS control – a design model and control structure." In *Nonlinear and Hybrid Control in Automotive Applications*, pp. 85–96. Springer Verlag, 2002.

Journal Papers

Åström, Karl Johan, Karl Henrik Johansson, and Q.G. Wang: "Design of decoupled PI controller for two-by-two systems." *IEE Proceedings on Control Theory and Applications*, **149**, January, pp. 74–81, January 2002.

Cervin, Anton, Johan Eker, Bo Bernhardsson, and Karl-Erik Årzén: "Feedback-feedforward scheduling of control tasks." *Real-Time Systems*, **23:1**, July 2002.

Fransson, Per-Anders, Fredrik Tjernström, Anna Hafström, Måns Magnusson, and Rolf Johansson: "Analysis of short-and long-term effects of adaptation in human postural control." *Biological Cybernetics*, **86**, pp. 355–365, 2002.

Ghulchak, Andrey, and Anders Rantzer: "Duality in H^∞ cone optimization." *SIAM Journal on Control and Optimization*, 2002. Accepted, to appear.

Ghulchak, Andrey, and Anders Rantzer: "Robust control under parametric uncertainty via primal-dual convex analysis." *IEEE Transactions on Automatic Control*, **47:4**, pp. 632–636, 2002.

Ghulchak, Andrey, and Henrik Sandberg: "Book review: Computer control systems. Analysis and design with process-oriented models, by E. Rosenwasser and B. Lampe." *Automatica*, **38**, October, pp. 2031–2035, October 2002.

Hägglund, Tore: "A friction compensator for pneumatic control valves." *Journal of Process Control*, **12**, pp. 897–904, 2002.

Hägglund, Tore, and Karl Johan Åström: "Revisiting the Ziegler-Nichols tuning rules for PI control." *Asian Journal of Control*, **4:4**, pp. 364–380, December 2002.

Hang, C.C., and Karl Johan Åström: "Relay feedback auto-tuning of process controllers – a tutorial review." *Journal of Process Control*, **12**, pp. 143–162, 2002.

Hedlund, Sven, and Anders Rantzer: "Convex dynamic programming for hybrid systems." *IEEE Transactions on Automatic Control*, **47:9**, pp. 1536–1540, September 2002.

Ingimundarson, Ari, and Tore Hägglund: "Performance comparison between PID and dead-time compensating controllers." *Journal of Process Control*, **12**, pp. 887–895, 2002.

Isaksson, Alf, and Tore Hägglund: "Editorial – PID control." *IEE Proc. Control Theory Appl.*, **149:1**, pp. 1 – 2, January 2002.

Johansson, Karl Henrik, A. E. Barabanov, and Karl Johan Åström: "Limit cycles with chattering in relay feedback systems." *IEEE Transactions on Automatic Control*, **47:9**, pp. 1414–1423, 2002.

Johansson, Rolf, and Anders Robertsson: "Observer-based strict positive real (SPR) feedback control system design." *Automatica*, **38:9**, pp. 1557–1564, 2002.

Lincoln, Bo, and Bo Bernhardsson: "LQR optimization of linear system switching." *IEEE Transactions on Automatic Control*, **47**, October, pp. 1701–1705, October 2002.

Ng, Kuan Luen, and Rolf Johansson: "Evolving programs and solutions using genetic programming with application to learning and adaptive control." *Journal of Intelligent and Robotic Systems*, **35:3**, pp. 289–307, 2002.

Panagopoulos, Hélène, Karl Johan Åström, and Tore Hägglund: "Design of PID controllers based on constrained optimisation." *IEE Proc. Control Theory Appl.*, **149:1**, pp. 32–40, January 2002.

Ramchuran, Santosh, Eva Nordberg Karlsson, Stephané Velut, Lena de Maré, Per Hagander, and Olle Holst: "Production of heterologous thermostable glycoside hydrolases and the presence of host-cell proteases in substrate limited fed-batch cultures of escherichia coli bl21(de3)." *Applied Microbiology and Biotechnology*, **60:4**, pp. 408–416, December 2002.

Solyom, Stefan, and Ari Ingimundarson: "A synthesis method for robust PID controllers for a class of uncertain systems." *Asian Journal of Control*, **4:4**, December 2002.

Wallén, Anders, Karl Johan Åström, and Tore Hägglund: "Loop-shaping design of PID controllers with constant Ti/Td ratio." *Asian Journal of Control*, **4:4**, pp. 403–409, 2002.

Yuzhu, Zhang, Q. G Wang, and Karl Johan Åström: "Dominant pole placement for multi-loop control systems." *Automatica*, **No 38**, pp. 1213–1220, 2002.

Conference Papers

Åkesson, Johan, and Karl-Erik Årzén: "A frame work for process state transitions: Grade changes." In *Preprints Reglermöte 2002*, pp. 370–375, Linköping, Sweden, May 2002.

Årzén, Karl-Erik: "Jgrafchart: Sequence control and procedure handling in java." In *Proceedings of Reglermötet 2002*, May 2002.

Årzén, Karl-Erik, Rasmus Olsson, and Johan Åkesson: "Grafchart for procedural operator support tasks." In *Proceedings of the 15th IFAC World Congress, Barcelona, Spain*, July 2002.

Askerdal, Örjan, Magnus Gäfvert, Martin Hiller, and Neeraj Suri: "A control theory approach for analyzing the effects of data errors in safety-critical control systems." In *Proceedings of the Pacific Rim International Symposium on Dependable Computing*, 2002.

Åström, Karl Johan, and Bo Bernhardsson: "Comparison of Riemann and Lebesque sampling for first order stochastic systems." In *Proceedings of the 41st IEEE Conference on Decision and Control*, vol. 2, pp. 2011–2016, 2002.

Bengtsson, Johan, Mathias Haage, and Rolf Johansson: "Variable time delays in visual servoing and task execution control." In *2nd IFAC Conference on Mechatronic Systems*, Berkeley, December 2002.

Calugi, Francesco, Anders Robertsson, and Rolf Johansson: "Output feedback adaptive control of robot manipulators using observer backstepping." In *Proc. 2002 IEEE/RSJ Intl. Conference on Intelligent Robots and Systems (IROS 2002)*, pp. 2091–2096, EPFL, Lausanne, Switzerland, October 2002.

Cervin, Anton, Dan Henriksson, Bo Lincoln, and Karl-Erik Årzén: "Jitterbug and TrueTime: Analysis tools for real-time control systems." In *Proceedings of the 2nd Workshop on Real-Time Tools*, Copenhagen, Denmark, August 2002.

de Maré, Lena, Lena Andersson, and Per Hagander: "Cultivations of vibrio cholerae using probing control of glucose feeding." In *International conference on Trends in Monitoring and Control of Life Science Applications*, p. 62. Section on Biochemical Engineering Science European Federation of Biotechnology, October 2002. Poster presentation.

Eborn, Jonas: "Chemical reaction modeling with thermofluid/mf and multiflash." In Otter, Ed., *Proceedings of the 2nd International Modelica Conference 2002*, pp. 31–41, Oberpfaffenhofen, Germany, March 2002.

Ericsson, Stefan, Tore Hägglund, and Per Rudfjäll: "Implementation of an on-line detection procedure for oscillating control loops." In *Control Systems 2002*, Stockholm, Sweden, 2002.

Hägglund, Tore: "Industrial applications of automatic performance monitoring tools." In *IFAC World Congress*, Barcelona, Spain, 2002.

Henriksson, Dan, Anton Cervin, Johan Åkesson, and Karl-Erik Årzén: "Feedback scheduling of model predictive controllers." In *Proceedings of the 8th IEEE Real-Time and Embedded Technology and Applications Symposium*, San Jose, CA, September 2002.

Henriksson, Dan, Anton Cervin, Johan Åkesson, and Karl-Erik Årzén: "On dynamic real-time scheduling of model predictive controllers." In *Proceedings of the 41st IEEE Conference on Decision and Control*, Las Vegas, NV, December 2002.

Henriksson, Dan, Anton Cervin, and Karl-Erik Årzén: "TrueTime: Simulation of control loops under shared computer resources." In *Proceedings of the 15th IFAC World Congress on Automatic Control*, Barcelona, Spain, July 2002.

Ingimundarson, Ari: "Performance monitoring of pi controllers using a synthetic gradient of a quadratic cost function." In *Proceedings of the 15th IFAC World Congress*, Barcelona, Spain, 2002.

Johansson, Rolf: "Continuous-time identification using LQG-balanced model reduction." In *IFAC 15th World Congress*, Barcelona, Spain, July 2002.

Johansson, Rolf: "System identification using LQG-balanced model reduction,." In *IEEE Conf. Decision and Control (CDC 2002)*, pp. 258–263, Las Vegas, Nevada, December 2002.

Lincoln, Bo: "Jitter compensation in digital control systems." In *Proceedings of the 2002 American Control Conference*, May 2002.

Lincoln, Bo: "A simple stability criterion for control systems with varying delays." In *Proceedings of the 15th IFAC World Congress*, July 2002.

Lincoln, Bo, and Anton Cervin: "Jitterbug: A tool for analysis of real-time control performance." In *Proceedings of the 41st IEEE Conference on Decision and Control*, Las Vegas, NV, December 2002.

Lincoln, Bo, and Anders Rantzer: "Suboptimal dynamic programming with error bounds." In *Proceedings of the 41st Conference on Decision and Control*, December 2002.

Magni, L., R. Scattolini, and Karl Johan Åström: "Global stabilization of the inverted pendulum using model predictive control." In *Proceedings 19th IFAC World Congress*, Barcelona, Spain, 2002.

Nair, G., Robin Evans, and Björn Wittenmark: "Minimum data rates for stabilising linear systems with unknown parameters." In *Preprints MTNS*, South Bend, Indiana, 2002.

Olsson, Rasmus, and Karl-Erik Årzén: "Exception handling in s88 using grafchart." In *Proc. of World Batch Forum North American Conference, Woodcliff Lake, NJ, USA*, April 2002.

Olsson, Rasmus, Henrik Sandberg, and Karl-Erik Årzén: "Developement of a batch reactor laboratory process." In *Proc. of Reglermöte 2002, Linköping*, pp. 31–35, May 2002.

Olsson, Tomas, Johan Bengtsson, Rolf Johansson, and Henrik Malm: "Force control and visual servoing using planar surface identification." In *IEEE Int. Conference on Robotics and Automation*, pp. 4211–4216, Washington D.C., USA, May 2002.

Petersson, Mikael: "Measurement based control structure assessment of ordinary control loops." In *Preprints Reglermöte 2002*, Linköping, Sweden, May 2002.

Petersson, Mikael, Karl-Erik Årzén, Henrik Sandberg, and Lena de Maré: "Implementation of a tool for control structure assessment." In *Proceedings of the 15th IFAC World Congress*, Barcelona, Spain, July 2002.

Petersson, Mikael, Lars Pernebo, Bengt Hansson, Karl-Erik Årzén, and Tore Hägglund: "Control structure assessment in an industrial control system." In *Control Systems 2002*, Stockholm, Sweden, June 2002.

Rantzer, Anders: "A converse theorem for density functions." In *Proceedings of IEEE Conference of Decision and Control*, pp. 1890–1891, Las Vegas, December 2002.

Robertsson, Anders, Domenico Scalamogna, Mattias Grundelius, and Rolf Johansson: "Cascaded iterative learning control for improved task execution of optimal control." In *Proceedings of IEEE Int Conf on Robotics and Automation (ICRA'02)*, vol. 2, pp. 1290–1295, Washington D.C., USA, May 2002.

Robertsson, Anders, Domenico Scalamogna, Mattias Grundelius, and Rolf Johansson: "Using cascaded iterative learning control for improved task execution." In *Preprints, Reglermöte'02*, Linköping, Sweden, May 2002.

Sandberg, Henrik, and Anders Rantzer: "Balanced model reduction of linear time-varying systems." In *Proceedings of the 15th IFAC World Congress*, Barcelona, Spain, July 2002.

Sandberg, Henrik, and Anders Rantzer: "Error bounds for balanced truncation of linear time-varying systems." In *Proceedings of the 41st IEEE Conference on Decision and Control*, Las Vegas, Nevada, December 2002.

Schinkel, Michael, Wen-Hua Chen, and Anders Rantzer: "Optimal control for systems with varying sampling rate." In *Proceedings of American Control Conference*, Anchorage, May 2002.

Slätteke, Ola, Krister Forsman, Tore Hägglund, and Björn Wittenmark: "On identification and control tuning of cylinder dryers." In *Proceedings Control Systems 2002*, pp. 298–302, Stockholm, June 2002.

Slätteke, Ola, and Magnus Karlsson: "Modeling and control tuning of multi-cylinder dryers." In *Reglermöte 2002*, pp. 46–48, May 2002.

Solyom, Stefan, and Ari Ingimundarson: "On a synthesis method for robust PID controllers for a class of uncertainties." In *Proceedings of Reglermöte 2002, Linköping*, pp. 154–159, May 2002.

Solyom, Stefan, and Anders Rantzer: "The servo problem for piecewise linear systems." In *Proceedings of the Fifteenth International Symposium on Mathematical Theory of Networks and Systems*, Notre Dame, August 2002.

Stenström, Stig, Magnus Karlsson, Ola Slätteke, Björn Wittenmark, and Krister Forsman: "Productivity increase from a better understanding of dynamic processes and control of the paper dryer." In *Preprints 7th New Available Technologies*, pp. 70–73, Stockholm, 2002.

Wallén, Anders, and Karl Johan Åström: "Pulse-step control." In *Proceedings 15th IFAC World Congress*, Barcelona, Spain, 2002.

Wittenmark, Björn, and Robin Evans: "Extremal control of Wiener processes." In *IEEE Conference on Decision and Control*, Las Vegas, December 2002.

Wittenmark, Björn, and Mario E. Salgado: "Hankel-norm based interaction measure for input-output pairing." In *Proceedings 15th IFAC World Congress*, 2002.

12. Reports

During this year 1 PhD theses and 3 Lic Tech thesis have been published. The abstracts are presented in Chapter 7. Also 18 master theses and 7 internal reports have been completed.

Dissertations

Olsson, Rasmus: "Exception handling in recipe-based batch control." Technical Report Licentiate thesis ISRN LUTFD2/TFRT--3230--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, December 2002.

Sandberg, Henrik: "Linear time-varying systems: Modeling and reduction." Technical Report Licentiate thesis ISRN LUTFD2/TFRT--3229--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, November 2002.

Solyom, Stefan: "Synthesis of a model-based tire slip controller." Technical Report Licentiate thesis LUTFD2/ TFRT--3228--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, June 2002.

Tummescheit, Hubertus: *Design and Implementation of Object-Oriented Model Libraries using Modelica*. PhD thesis ISRN LUTFD2/TFRT--1063--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, August 2002.

Master Theses

Alcocer Peñas, Alex: "Force estimation and control in vehicles and robots." Technical Report Masters thesis ISRN LUTFD2/TFRT--5693--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, October 2002.

Alriksson, Peter: “Automatic gain control in high speed wcdma terminals.” Technical Report Masters thesis ISRN LUTFD2/TFRT--5691--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, September 2002.

Andersson, Stefan, and Tedde Julén: “A graphical programmable control language for hubit.” Technical Report Masters thesis ISRN LUTFD2/TFRT--5682--SE, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, 2002.

Attnäs, Mats, and Ulrik Laurén: “Porting the ericsson bluetooth stack - a real-time analysis.” Technical Report Masters thesis ISRN LUTFD2/TFRT--5684--SE, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, April 2002.

Bruce, Maria: “Distributed brake-by-wire based on ttp/c.” Technical Report Masters thesis ISRN LUTFD2/TFRT--5688--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, June 2002.

Calugi, Francesco: “Observer-based adaptive control.” Technical Report Masters thesis ISRN LUTFD2/TFRT--5685--SE, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, April 2002.

Correll, Nikolaus: “6-dof visual servoing using the lie group of affine transformation.” Technical Report Masters thesis ISRN LUTFD2/TFRT--5690--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, June 2002.

Fredriksson, Henrik: “Implementering och design av en intelligent och dynamisk fjärrkontroll i palm os (implementation and design of an intelligent and dynamic remote).” Technical Report Masters thesis ISRN LUTFD2/TFRT--5700--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, December 2002.

Ge, Tao, and Karl Johan Nilsson: “Styrning av undervattensfarkost.” Technical Report Masters thesis ISRN LUTFD2/TFRT--5696--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, November 2002.

Haugwitz, Staffan: "Modelling of microturbine systems." Technical Report Masters thesis ISRN LUTFD2/TFRT--5687--SE, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, May 2002.

Lasic, Nenad: "Optimal vehicle dynamics - yaw rate and side slip angle control using 4-wheel steering." Technical Report Masters thesis ISRN LUTFD2/TFRT--5697--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, October 2002.

Luis de Mena, José: "Virtual environment for development of visual servoing control algorithms." Technical Report Masters thesis ISRN LUTFD2/TFRT--5686--SE, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, May 2002.

Martinez Serradell, Javier A.: "Estimation of inertial parameters." Technical Report Masters thesis ISRN LUTFD2/TFRT--5689--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, June 2002.

Martinsson, Anders: "Scheduling of real-time traffic in a switched ethernet network." Technical Report Masters thesis ISRN LUTFD2/TFRT--5683--SE, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, March 2002.

Nilsson, Håkan: "Rapid prototyping with matlab/simulink– a case study." Technical Report Masters thesis ISRN LUTFD2/TFRT--5692--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, August 2002.

Wong, Jee Hui: "Simulation of visual servoing in grasping objects moving by newtonian dynamics." Technical Report Masters thesis ISRN LUTFD2/TFRT--5694--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, October 2002.

Woon, Teck Her: "Modelbased visual servoing grasping of objects moving by newtonian dynamics." Technical Report Masters thesis ISRN LUTFD2/TFRT--5695--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, October 2002.

Zhimin, Zhang: "Controller synthesis by linear programming." Technical Report Masters thesis ISRN LUTFD2/TFRT--5698--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, November 2002.

Other Reports

Andersson, S., Tobias Rydén, and Rolf Johansson: "Linear filtering and state-space representations of hidden Markov models." Technical Report LUTFMS-5019-2002, Center for Mathematical Sciences, Mathematical Statistics, Lund University, 2002.

de Maré, Lena, and Per Hagander: "Simuleringar och analys av v. cholerae odling där feeden styrs genom återkoppling från ättiksyramätningar," (Simulations and analysis of a v. cholerae cultivation where feedback from acetic acid measurements is used to control the feed.). Technical Report ISRN LUTFD2/TFRT--7600--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, March 2002.

Johansson, Rolf, and Agneta Tuszynski: "Automatic control 2001. activity report." Technical Report ISRN LUTFD2/TFRT--4029--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, May 2002.

Tummescheit, Hubertus: "Research abstracts 2002." Technical Report ISRN LUTFD2/TFRT--7603--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, November 2002.

Velut, Stephané, Lena de Maré, Jan Peter Axelsson, and Per Hagander: "Evaluation of a probing feeding strategy in large scale cultivations." Technical Report ISRN LUTFD2/TFRT--7601--SE, Department of Automatic Control, Lund Institute of Technology, Sweden, April 2002.

Velut, Stéphane, and Per Hagander: "Analysis of a probing control strategy." Technical Report ISRN LUTFD2/TFRT--7602--SE, Department of Automatic Control, Lund Institute of Technology, Swe-

den, November 2002. Accepted for American Control Conference 2003.

Wittenmark, Björn, Karl Johan Åström, and Karl-Erik Årzén: "Computer control: An overview." Technical Report, 2002. IFAC professional brief.

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.

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13. Lectures by the Staff Outside the Department

Seminars and lectures given by the staff outside the department. The persons are listed alphabetically.

Årzén, Karl-Erik

JGrafchart: Sequence Control and Procedure Handling in Java, Reglermöte, Linköping, Sweden, May 29.

JGrafchart: a Java-based Graphical Language Environment for Sequences, Procedures, and State-Machines, Dept of Electrical Engineering & Computer Science, Univ of California Berkeley, USA.

Åström, Karl Johan

Control - The Hidden Technology, The Mohammed Daleh Symposium, University of California, Santa Barbara, USA, February 8.

Control - The Hidden Technology, Caltech Pasadena, USA, February 27.

Control - The Hidden Technology, University of Glasgow, Scotland, April 24.

Challenges for a Hidden Technology AFOSR Meeting on Future Directions in Control, Arlington, VA, April 26.

Control - The Hidden Technology, The Second Antonio Ruberti Lecture, Rome, Italy, May 27.

Emergence and Development of the Field of Control, Hungarian Academy of Sciences, Budapest, Hungary, June 17.

Pulse-Step Control, IFAC World Congress, Barcelona, Spain, July.

Control - The Hidden Technology, UCLA, USA, October 11.

Comparison of Riemann and Lebesgue Sampling for First Order Stochastic Systems, IEEE CDC Las Vegas, USA, December 11.

Cervin, Anton

Analysis, Simulation, and Design of Real-Time Programs for Control, LUCAS Cluster Day on Industrial Automation, Lund Institute of Technology, February 26.

Jitterbug and TrueTime: Analysis Tools for Real-Time Control Systems, 2nd Workshop on Real-Time Tools, Copenhagen, Denmark, August 1.

Integrated Control and Scheduling, Annual LUCAS Days, Lund Institute of Technology, October 22.

Hagander, Per

Peer Review in Engineering Education, our Experiences, Invited talk together with Christoffer Norberg at the LTH/DTU-seminar.

A challenge - The development of training of engineers - A meeting over Öresund, November 28. *Probing Control of Glucose Feeding of Aerobic Cultivations,* talk and three posters at Vinnova Conference on Bioprocesses in Industry, April 24–25.

Hägglund, Tore

Process Control in Practice, Industrial course. Stockholm, Sweden, Jan 30–31.

Process Control in Practice, Industrial course. Stockholm, Sweden, March 5–6.

Project Planning – The ECA400 Controller, Invited lecture. Royal Institute of Technology, Stockholm, Sweden, April 18.

Process Control in Practice, Industrial course. Stockholm, Sweden, April 23–24.

Industrial Applications of Automatic Performance Monitoring Tools, IFAC World Congress, Barcelona, Spain, July 22.

Process Control in Practice, Industrial course. Stockholm, Sweden, November 26–27.

Henriksson, Dan

Feedback Scheduling of Model Predictive Controllers, ARTES Graduate Student Conference, Uppsala, Sweden, April 19.

TrueTime: Simulation of Control Loops Under Shared Computer Resources, IFAC World Congress, Barcelona, Spain, July 25.

Feedback Scheduling of Model Predictive Controllers, Real-Time and Embedded Technology and Applications Symposium, San José, California, USA, September 26.

Simulation and Feedback Scheduling of Real-Time Control Systems, Department of Signals, Sensors and Systems, Royal Institute of Technology, Stockholm, Sweden, October 17.

On Dynamic Real-Time Scheduling of Model Predictive Controllers, Conference on Decision and Control, Las Vegas, Nevada, USA, December 11.

Johansson, Rolf

Geometric and Dynamic Identification in MR Images, Lund University Hospital, Lund, February 13.

Subspace-based Model Identification, Dept Electrical Engineering and Computer Science, University of Colorado at Boulder, Boulder, Colorado, USA, June 27.

Continuous-Time Identification using LQG-Balanced Model Reduction, IFAC 15th World Congress, Barcelona, Spain, July 23.

Optimization in Systems Theory, Öresund Symposium on Optimization Methods, Lund University, Centre for Mathematical Sciences November 12.

Observer-based Strict Positive Real (SPR) Feedback, Control System Design, Odense University, Odense, Denmark, November 20.

System Identification using LQG-Balanced Model, Reduction, IEEE Conf. Decision and Control (CDC 2002), Las Vegas, Nevada, USA, December 10.

Lincoln, Bo

Control over Networks, Department of Signals and Systems, Royal Institute of Technology, Stockholm, January 9.

Control of a DVD player, Department of Signals and Systems, Royal Institute of Technology, Stockholm, January 10.

Realaxing Dynamic Programming, Universitá di Siena, Siena, Italy, April 16.

Jitter Compensation in Digital Control Systems, American Control Conference, Anchorage, USA, May 9.

Suboptimal Dynamic Programming with Error Bounds, Conference on Decision and Control, Las Vegas, USA, Dec 11.

Jitterbug: A Tool for Analysis of Real-Time Control Performance, Conference on Decision and Control, Las Vegas, USA, Dec 11.

Olsson, Tomas

Force Control and Visual Servoing Using Planar Surface Identification, IEEE Int. Conference on Robotics and Automation, Washington D.C., USA, May 15.

Rantzer, Anders

Analysis of interconnected systems using density functions, Invited lecture at Mathematisches Forschungsinstitut Oberwolfach, Germany, February 28.

Density and flow: A different view on nonlinear control, Seminar at Cambridge University, United Kingdom, May 9.

Density and flow: A different view on nonlinear control, Seminar at Imperial College, United Kingdom , May 13.

Breaking complexity by relaxing optimality in dynamic programming, Plenary lecture at Reglermöte 2002, Linköping, Sweden, May 30.

Breaking complexity by relaxing optimality in dynamic programming, Plenary lecture at SICE annual conference 2002, Osaka, Japan, August 7.

Delta-sigma modulator synthesis, 15th Int. Symposium on Mathematical Theory of Networks and Systems, August 12, South Bend, Indiana, USA.

Following time-varying reference values in systems with saturations, Invited lecture at IEEE Workshop on Anti-windup, bumpless transfer and related problems, Leicester, United Kingdom, September 9.

On existence and computation of density functions, Seminar at Politecnico di Torino, Italy, October 23.

Density and flow: A different view on nonlinear control, Seminar at ETH, Zürich, Switzerland, October 28.

On existence and computation of homogeneous density functions, Int. Symposium on New Directions in Mathematical Systems Theory and Optimization, Stockholm, Sweden, November 15.

An converse theorem for density functions, 40th IEEE Conference on Decision and Control, Las Vegas, USA, December 11.

Robertsson, Anders

Output Feedback Adaptive Control of Robot Manipulators Using Observer Backstepping, Presentation at International Conference on Robotics and Automation, Washington DC, USA, May.

Cascaded Iterative Learning Control for Improved Task Execution of Optimal Control, Presentation at IROS-02, Lausanne, Switzerland, September.

Cascaded Iterative Learning Control for Improved Task Execution of Optimal Control, Invied seminar at United Technologies Research Center, Hartford, CT, USA, May 17.

Sandberg, Henrik

Balanced Model Reduction of Linear Time-Varying Systems, IFAC World Congress, Barcelona, Spain, July 23.

Balanced Truncation of a Diesel Exhaust Catalyst Model, CPDC-Workshop: Model Reduction for Process Control, Lund, Sweden, November 18.

Error Bounds for Balanced Truncation of Linear-Time Varying Systems, IEEE Conference on Decision and Control, Las Vegas, Nevada, USA, December 12.

Slätteke, Ola

Control of the Drying Section of a Paper Machine, Industrial course, Halmstad, Sweden, March 6.

On Identification and Control Tuning of Cylinder Dryers, Presentation at Control Systems 2002, Stockholm, Sweden, June 5.

Solyom, Stefan

On a Synthesis Method for Robust PID Controllers for a Class of Uncertainties, Reglermöte 2002, Linköping, May 29.

The Servo Problem for Piecewise Linear Systems, The Fifteenth International Symposium on Mathematical Theory of Networks and Systems, Notre Dame, IN, USA, August 14.

Synthesis of a Model-based Tire Slip Controller, Decision and Control Laboratory, University of Illinois at Urbana-Champaign, USA, August 19.

On Tracking Performance of Piecewise Linear Systems, Computation and Control (CC) project meeting, Ascona, Switzerland, October 30.

Wittenmark, Björn

Hankel-norm Based Interaction Measure for Input-output Pairing, DTU, Lyngby, January 8, 2002.

Extremal Control of Hammerstein and Wiener Model Processes, Imperial College, Great Britain, March 20.

Sample-induced Delays in Synchronous Multirate Systems, University of Illinois, USA, April 26.

Extremal Control of Hammerstein and Wiener Model Processes, University of Illinois, USA, May 1.

Hankel-norm Based Interaction Measure for Input-output Pairing, 15th IFAC World Congress, Barcelona, Spain, July 24.

The Art of Control, Annual Meeting of the Royal Physiographic Society, Lund, Sweden, December 2.

Extremal Control of Wiener Model processes, 1st Conference on Decision and Control, Las Vegas, USA, December 13.

14. Seminars at the Department

Seminars presented in order of date. The seminars were given at the department during 2002, both by the staff and by invited lecturers. Dissertations and master theses presentations are also included.

AC = Department of Automatic Control, Lund Institute of Technology
LTH = Lund Institute of Technology

Jan 17: **Phillipe Chevrel** (EMN), *Methodology for H2 and Hinf Control.*

Jan 21: **Stefan Andersson, Tedde Julén**(LTH), *A Graphical Programmable Control Language for Hubit.* MSc-thesis presentation.

Feb 13: **R. Johansson, G. Sparr, F. Ståhlberg** (LTH), *Geometric and Dynamic Identification in MR-Pictures.*

March 4: **Anders Martinsson**(LTH), *Scheduling of Real-Time Traffic in a Switched Ethernet Network.*, MSc-thesis presentation.

March 7: **Niklas Karlsson**(UCSB), *Constructive Methods for Nonlinear Control of Finite and Infinite Dimensional Systems.*

March 15: **Anton Shiriaev**(Odense University), *Criterion of Partial Stabilization Based on Pozharitsky Theorem.*

April 2: **Timothy Salsbury**(Johnson Controls, Inc.), *A System identification Method for Commissioning HVAC Systems.*

April 2: **José Luis de Mena**(Universidad de Valladolid, Spain), *Virtual Environment for Development of Visual Servoing Control Strategies.* MSc-thesis presentation.

April 18: **Mats Attnäs, Ulrik Laurén**(LTH), *Porting of the Ericsson Bluetooth Stack.* MSc-thesis presentation.

April 19: **Karl Johan Åström**(AC), *Control - The Hidden Technology.*

April 25: **Francesco Calugi**(Universitá degli studi di Firenze, Italy), *Observer Based Adaptive Control.* MSc-thesis presentation.

May 6: **Stephen Pranja**(Caltech, USA), *Algorithmic Synthesis of Lyapunov Functions: A Sum of Squares Decomposition Approach.*

May 7: **Claudio Aurora**(Pavia Univ. Italy), *Industrial MPC of a Thermal Power Plant - A Preliminary Study.*

May 15: **Ulf Jönsson**(KTH), *On Reachability Analysis of Uncertain Systems.*

May 16: **Staffan Haugwitz**(LTH), *Modelling of Microturbine Systems.* MSc-thesis presentation.

June 3: **Claudio Aurora**(Pavia Univ. Italy), *Speed Control of an Induction Motor: A Sliding Mode Approach.*

June 7: **Maria Bruce**(LTH), *Distributed brake-by-wire based TTP/C.* MSc-thesis presentation.

June 11: **David Angeli**(University of Firenze, Florens, Italy), *The Input-to-State Stability Approach to Robustness Analysis: Known Results and Open Questions.*

June 14: **Stefan Solyom**(AC), *Synthesis of a Model-Based Tire Slip Controller.* Lic Tech dissertation seminar.

June 27: **Nikolaus Correll**(ETH Zürich), *Visual Servoing using the Lie Group of Affine Transformations.*

July 19: **Javier Martinez Serradell**(Universidad Politecnica de Cartegna, Spain), *Estimation of Inertial Parameters.* MSc-thesis presentation.

July 19: **Rolf Johansson**(AC), *Continuous-Time Identification Using LQG-Balanced Model Reduction.*

Aug 13: **Dawn Tilbury**(University of Michigan, USA), *Reconfigurable Logic Control for High Volume Manufacturing Systems.*

Aug 14: **Dawn Tilbury**(University of Michigan, USA), Design and Analysis of Networked Controllers for Mechanical Systems

Aug 15: **Per-Olof Gutman**(Technion, Israel), *Control of the Aero-Electric Powerstation.*

Aug 15: **Dawn Tilbury**(University of Michigan, USA), *Demonstration and Discussion of Control Tutorials for MATLAB and Simulink: A Web-Based Approach.*

Aug 30: **Hubertus Tummescheit**(AC), *Object-oriented Modeling: Design and Implementation of Libraries using Modelica.* Doctoral dissertation defence.

Sep 2: **Richard M. Murray**(California Institute of Technology, USA), *Information Flow and Cooperative Control of Vehicle Formations.*

Sep 5: **Peter Alriksson**(LTH), *Automatic Gain Control for High Speed Terminals.* MSc-thesis presentation.

Sep 25: **Chung-Yao Kao**(MIT, USA) *Efficient Computational Algorithms for IQC Analysis.*

Oct 3: **Mikael Johansson**(KTH), *Simultaneous Routing and Resource Allocation in Wireless Data Networks.*

Oct 4: **Alex Alcocer**(Universidad Politecnica de Catalunya, Spain), *Force Estimation and Control in Vehicles and Robots.* MSc-thesis presentation.

Oct 7: **Jee Hui Woon, Teck Her Woon**(Imperial College, GB), *Model-based Visual Servoing Grasping of Objects Moving by Newtonian Dynamics.* MSc-thesis presentation.

Oct 21: **Nenad Lazic**(LTH), *Optimal Vehicle Dynamics — Yaw Rate and Side Slip Angle Control Using 4-Wheel Steering.* MSc-thesis presentation.

Nov 5: **Tao Ge, Karl Johan Nilsson**(LTH), *Control of a Submarine Vehicle.* MSc-thesis presentation.

Nov 7: **Martin Nilsson**(SICS), *Robot Kinematics and Design: A Trade-off between Mathematics and Reality.*

Nov 19: **Henrik Sandberg**(AC) *Linear Time-Varying Systems: Modeling and Reduction.* Lic Tech dissertation seminar.

Nov 19: **Alexander Megretski**(MIT), *Model Reduction for Parameter-Dependent Linear Models.*

Nov 27: **Zhang Zhimin**(LTH), *Controller Synthesis by Linear Programming.* MSc-thesis presentation.

Dec 4: **Karl Henrik Johansson**(KTH), *Dither in Nonsmooth Feedback Systems.*

Dec 12: **Rasmus Olsson**(AC), *Exception Handling in Recipe-Based Batch Control.* Lic Tech dissertation seminar.

Dec 18: **Henrik Fredriksson**(LTH), *Implementation and Design of an Intelligent and Dynamic Remote Control in Palm OS.* MSc-thesis presentation.

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