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Activity Report

Automatic Control

1993–1994

Department of Automatic Control
Lund Institute of Technology

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Activity Report

Automatic Control

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Contents

1. Introduction

This report covers the activities at the Department of Automatic Control at Lund Institute of Technology (LTH) during the period 1 July 1993 – 30 June 1994, which is the academic year 1993/94. The budget for the year was 17.5 MSEK. This figure does not include rent for offices and laboratories.

During this period Bernt Nilsson completed his PhD thesis. This brings the total number of PhDs graduating from our department to 41. Thirty-eight students completed their MSc degree at the department. 24 journal papers or book chapters and 29 conference papers were published by staff members.

About 650 students graduated from seven courses in the civ.ing. program. There was a very high activity in the control laboratory with 260 groups of experiments. Four PhD courses were given during the academic year.

Research has continued in established areas such as adaptive control, expert control, computer aided control engineering, robotics, and information technology.

The report is organized as follows. Economy and facilities are presented in Chapter 2. The educational activity is described in Chapter 3. Some project areas are highlighted in Chapter 4, and the dissertations completed during the year are presented in Chapter 5. A look back at our research on simulation methodology is given in Chapter 6. Detailed informations about awards, theses, publications, seminars and lectures are given in the Appendices.

Acknowledgement

We want to thank our sponsors, the Swedish National Board for Industrial and Technical Development (NUTEK), the Swedish Research

Council for Engineering Sciences (TFR), the Swedish Council for Planning and Coordination of Research (FRN), the Swedish Medical Research Council (MFR), ABB, the Bo Rydin Foundation, and Sydkraft for their support to our projects.

2. Economy and Facilities

Economy

The income for the academic year 1993/94 was 17.5 MSEK. This does not include rent for offices and laboratories, which is paid from other accounts. The income is distributed as follows: 50% from the university, 37% from government agencies, 8% directly from industry, and 5% from software contracts and small projects.

The operating costs were: salaries 10.9 MSEK, university overhead 1.0 MSEK, and operating costs 1.7 MSEK. The operating costs cover the costs for running computers and laboratories, publishing, travel etc.

Facilities

The following computers are now available for research and education:

1 Sun4/690, 2 processors, 4 GB disk
2 SparcStation 20 with color
10 SparcStation 2, 5 or LX with color
25 SparcStation 1, SLC or ELC monochrome
7 PC 486
13 IBM PC/AT
8 Macintosh computers
1 Plug-in board with TI TMS320C30 signal processor
2 VME based control computers MC68030/68040
1 VME board with 6 AT&T DSP32C signal processors

The robotics lab contains the following robots:

1 ABB Irb-6
1 ABB Irb-2000

with specially designed interfaces.

3. 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 is equivalent 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 Enginering (M), and Chemical Engineering (K).

During the year the following courses were given at the department:

Course	**Number of graduated students**
Reglerteknik AK–FED *FRT010* (Automatic control, basic course)	282
Reglerteknik AK–M *FRT060* (Automatic control, basic course)	90
Processreglering (K) *FRT080* (Automatic process control)	85
Digital Reglering (FED) *FRT020* (Computer-controlled systems)	77
Realtidsystem (FED) *FRT031* (Real-time Systems)	41
Processidentifiering (FED) *FRT040* (Process identification)	19
Adaptiv reglering (FED) *FRT050* (Adaptive control)	28
Olinjär reglering och servosystem (FED) *FRT075* (Nonlinear Control and Servo Systems)	24

The first five courses are comparable to undergraduate courses and

the last two are equivalent to graduate courses in the US system. In summary 646 students have passed courses at the department during the academic year 1993/94.

The control laboratory has been used extensively during the year. Simple fixed experiments are done in the basic courses. In the courses on adaptive control and system identification there are also open ended experiments. In the basic courses we can have for one group up to eight parallel experiments, and in the elective courses we have four in parallel. There were 260 groups of students that made four-hour laboratories at the department. To handle this many groups there are many experiments in the evenings.

Master Theses

Thirtyeight students completed their master theses during the year. A list is given in Appendix E.

The theses concerned the following application areas: Adaptive control (6), Computer-aided control engineering (3), Digital control (1), Discrete-events systems and Petri nets (3), Fuzzy control (1), Neural networks (2) Power systems (1), Process control (2), Robotics (4), Servo systems (3), Stochastic control (1), Vehicle dynamics (5).

Doctorate Program

One PhD thesis was completed during the period by Bernt Nilsson (1993). The abstract is given in Chapter 5. This brings the total number of PhDs graduating from our department to 41. Three new PhD students (Lennart Andersson, Charlotta Johnsson, Anders Robertsson) were admitted to the department.

The following PhD courses have been given:

- Nonlinear Control Theory (B. Bernhardsson/A. Rantzer) 8 p
- Petri Nets and Grafcet (K-E. Årzén) 4 p

- Current Papers Seminar (B. Wittenmark) 3 p
- Linear systems (P. Hagander) 10 p

The department has recently taken the initiative to create a graduate program in Systems and Applied Mathematics at Lunds Institute of Technology. The program is a cooperation between the departments of Mathematics, Mathematical statistics, Automatic control, Telecommunication theory, Communications systems, Information theory, and Computer sciences. The goal with this program is to coordinate and develop the graduate courses within the area of systems and applied mathematics. A new course "Simulation of deterministic and stochastic systems," was organized by several of the departments within the program and was given for the first time during the fall of 1992.

4. Research

Research at the department concerns theory and applications. The major research areas are:

- Adaptive control
- Control theory
- Computer aided control engineering
- Applications

Adaptive Control

Frequency Domain Adaptive Control

Researchers: Björn Wittenmark and Per-Olof Källén

In this project we analyze an adaptive control scheme that is based on a frequency domain system description. Due to the frequency domain viewpoint the scheme differs from most other adaptive schemes. It has been shown that the proposed scheme has several good properties.

To obtain a well behaved adaptive system, both the estimation, and the controller design have to work properly. A large part of the work has therefore been to analyze the different components of the adaptive controller. There is currently a large interest in the interplay between estimation and design in adaptive control. This often amounts to chosing an optimal data filtering in the estimator to enhance the proper frequency interval. Because the considered frequency response estimates are decoupled in the frequency domain this type of interplay is of less concern in the considered scheme.

In the frequency domain adaptive controller the process is modeled by a number of points on the Nyquist curve. These points are estimated using low order parametric models based on band pass filtered data. The

properties of the frequency response estimators have been analyzed. For a model with at least two parameters it has been shown that the estimates converge as the filter width decreases irrespective of the true process order. This makes it possible to use low order parametric models to estimate points on the Nyquist curve of high order processes. To choose band pass filters a trade-off has to be made between estimation accuracy and adaptation speed. This has been analyzed and resulted in some guidelines for the choice of band pass filters. These results were presented at the SYSID symposium in Copenhagen, 1994.

The design method can be considered as an approximation method and is primarily used for designing low order controllers. The basic design method has been modified to improve the robustness of the closed loop system. Connections to the polynomial pole placement design have also been established.

It has turned out the the desired closed loop bandwidth is a crucial parameter in the design method. Guidelines have been determined for how to choose the structure of the desired closed loop response. For instance, it is hazardous to choose a desired response of too low order. To improve the applicability of the design method it is possible to incorporate a procedure that automaticly chooses the appropriate closed loop bandwidth. With bandwidth adaptation it is not necessary to choose a desired bandwidth a priori, and further, it also gives closed loop specifications that adapt to changing process dynamics. A startup procedure has been developed, which makes it easier to use the adaptive controller. This startup procedure can to a large degree be automated.

Robust and Nonlinear Adaptive Control

Researchers: Bo Bernhardsson, Johan Nilsson, Henrik Olsson, Björn Wittenmark, and Karl Johan Åström

To construct robust adaptive controllers it is crucial to develop methods to use information about unmodeled dynamics and parameter uncertainties. It is also important to understand the interplay between control and identification.

Substantial work has been put into generalizing the μ-design methodology by Doyle and others to use knowledge about the time-variations of uncertain parameters. This research is described further under the title "control of uncertain systems".

Another interesting research problem is iterative design procedures that involve batch identification. The possible equilibria for such an iteration have been determined for an illustrative example. A design procedure where the choice of estimation filter is chosen based on the obtained controller and desired closed loop system has been analyzed. The filter is chosen as

$$\frac{R(s)}{A_m(s)A_o(s)}$$

where the controller is given by $-S(s)/R(s)$, the closed-loop poles are given by A_m, and A_o is the observer polynomial. This choice of prefilter seems very reasonable. For reasonable designs it will be a band-pass filter that focuses the identification on frequencies where good models are needed for the design.

The new friction model developed in collaboration with Laboratoire d'Automatique de Grenoble, which was presented at ACC93, has been further investigated resulting in a full journal paper scheduled for publication in IEEE Transactions on Automatic Control in March 1995. The model is simple yet it captures many of the friction properties observed in real systems. The model can be seen as a generalization of existing models. Work has also been initiated to use the new model in the study of the effects of friction on control loops in order to further understand how control of systems with friction best should be done.

Research has also been initiated on adaptive control of systems with simple nonlinearities such as dead-zones and backlash.

The department is participating in two networks in the Human Capital and Mobility Program in this area. The network *Nonlinear and Adaptive Control* is a cooperation between seven different universities and the network *European Robust and Adaptive Control Network—EURACO Network* consists of 12 universities. There has been a large

exchange of visitors within the networks, Lund has been one of the most popular cites to visit.

Autonomous Control

Researchers: Karl Johan Åström, Tore Hägglund, Per Persson, Anders Wallén, and Karl-Erik Årzén

The goal of this project is to develop the principles for design of autonomous controllers. Such controllers represent a significant increase of the automation level. In addition to normal control functions like automatic tuning, gain scheduling and adaptation they can provide diagnosis, process supervision, loop assessment, and performance assessment. Improved methods for tuning PID controllers have also been developed. A closer investigation of the dominant pole design method recently published (Persson and Åström 1992) has shown that for the standard processes typically encountered in process control it is possible to characterize process dynamics by three parameters only. New tuning methods based on this observation have been developed. These methods will be published in a monograph on PID control for the Instrument Society of America. We are also collaborating with local industry to evaluate the new methods in industry.

Autonomous controllers are typical examples of hybrid systems because they combine continuous algorithms with logic. We have experimented with different architectures. The possibilities of using extended Grafcet is being explored. Several diagnostic schemes have also been investigated.

A good collaboration with the pulp and paper industry has been established to get access to a number of realistic examples. A specific result of this work has been a new simple method for detection of friction generated oscillations. One version has been implemented in the controllers manufactured by Alfa-Laval Automation.

Control Theory

Control of Uncertain Systems

Researchers: Anders Rantzer, Bo Bernhardsson, Ulf Jönsson, and Per Hagander

The research has focused on two problem areas: Robustness analysis of systems with time-varying perturbations and system theory connected with the so called "real perturbation values."

The successful development of computational methods for structured singular values has recently improved the possibilities to do robustness analysis for parametric uncertainty. However to improve the reliability of the results, it would often be desirable to take possible time-variations into account in the analysis. Bounds on the rate of variation are then necessary in order to avoid overly pessimistic results. Our ongoing work suggests two ways to do this.

One approach generalizes results from the 60s, with bounds on the derivatives of the uncertain parameters. The other one is instead based on bounds on the frequency content of the time-variations. Known results for constant, periodic and arbitrarily time-varying parameters respectively, all appear as extreme cases.

Both our techniques for uncertain time-variations are so called multiplier methods. Such methods have been used for nonlinear systems for a long time, but for two reasons their applicability has been restricted. One is lack of efficient computational methods for finding good multipliers. Another is theoretical obstacles in the treatment of so called anticausal multipliers. However, recent progress on both these aspects, indicate a very promising future for such methods.

Another research topic in this area, motivated by a variety of engineering applications, is to find the smallest perturbation of a matrix that changes its rank. For complex matrices, this reduces to textbook material and the result is given by the classical singular values. Our recent work has had a breakthrough on the more complicated problem with real perturbations to complex matrices. This appears in robustness

analysis with respect to parametric uncertainty. The following problem is solved: Given $M \in C^{p\times m}$, compute

$$\tau_k(M) := [\min\{\|\Delta\| : \Delta \in R^{m\times p} \text{ and } \operatorname{rank}(I_m - \Delta M) = m - k\}]^{-1}.$$

Note that Δ is here assumed *real*, while M is a complex matrix. The size of Δ is measured by its largest singular value. This solution has the form of a simple formula, relating the real perturbation values to ordinary singular values.

$$\tau_k(M) = \inf_{\gamma\in(0,1]} \sigma_{2k}\left(\begin{bmatrix} \operatorname{Re} M & -\gamma \operatorname{Im} M \\ \gamma^{-1}\operatorname{Im} M & \operatorname{Re} M \end{bmatrix}\right),$$

where $\sigma_1 \geq \sigma_2 \geq \ldots$ denote the standard singular values of a matrix.

Control of Critical Processes

Researchers: Anders Hansson, Per Hagander, and Lennart Andersson

Many processes in industry are critical. They are often critical in the sense that they have a limiting level. This can be either physical or artificial. Examples of the former are such levels that cannot be exceeded without catastrophic consequences, e.g. explosion. One example on the latter is alarm levels, which if they are exceeded will initiate emergency shutdown or a change in operational conditions. Another is quality levels, which if they are exceeded will cause unsatisfied customers. Common to the critical processes are that they enter their critical region abruptly as a signal exceeds a limiting level.

The research within this area covers both finding optimal feedback controllers for avoiding exceedances of critical levels, as well as design of schemes for automatic modifications of reference values based on discrete events such as alarm signals. The former approach is interesting when designing controllers for new plants or when redesigning controllers for existing plants. The latter approach is interesting when trying to improve a working installation without breaking up the existing feedback loops.

Initial results within the area of nonlinear feedback control were obtained in a master thesis project, and the work is continuing. Some results on optimal modification of reference signals has also been presented. However, most results are within the area of linear feedback control. The so called Minimum Upcrossing (MU) controller, which minimizes the mean number of exceedances of the critical level, has been proposed as a solution to the problem. This has been compared with the well-known minimum variance controller with respect to different criterions capturing the control objectives described above. It has been shown that it is possible to compute the MU controller by making a one-dimensional optimization over LQG-problem solutions. The existence of the the MU controller has been investigated. To this end some research in the area of singular LQG problems has been done.

System Identification Theory

Researcher: Rolf Johansson

Research on several issues in system identification, especially modeling and identification of continuous-time systems, has been reported in the recently published monograph *System Modeling and Identification*.

An identification algorithm that effectively fits continuous-time transfer functions and finite-bandwidth noise models to data has been presented. 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.

One research direction that is currently pursued is system identification methodology suitable for multi-input multi-output systems. Several theoretical problems remain to be solved both with regard to system representation, algorithms and validation aspects.

Computer Aided Control Engineering

Modeling and Simulation Environments

Researchers: Sven Erik Mattsson, Mats Andersson, Bernt Nilsson, and Tomas Schönthal

The CACE project has for a number of years focused on modeling and simulation. A new object-oriented and equation based modeling language called Omola has been developed to support modeling and reuse of models for various purposes in different applications. Models can be decomposed hierarchically with well-defined interfaces for describing interactions. All components are represented as classes. Inheritance and specialization support easy modification. Descriptions of behavior can be given in terms of differential-algebraic equations, difference equations and elements of discrete events. The primitives for describing discrete events support events that depends on the values of the continuous time variables and allows implementation of high level descriptions as Petri nets and Grafcet.

OmSim is an environment of tools supporting modeling and simulation of Omola models. It includes an editor for defining models graphically as a diagram of connected objects. The simulator tools include facilities for extensive analysis and manipulation to check for structural defects and for transforming the model to a representation well-suited for numerical simulation. For example, time independent variables are sorted out and constant parts of remaining equations are evaluated. Algebraic variables are eliminated symbolically when feasible and the differential-algebraic index is reduced to one. OmSim includes well-proven numerical software, for example the numerical differential-algebraic equation solvers DASSL and DASRT with facilities to detect discrete events. OmSim also supports use of matrices of real numbers. OmSim has been used in a couple of application projects in the areas of power systems and chemical processes (see below). It is a prototype environment and not a full-fledged professional and commercial product. The aim has been to develop and implement an environment which can be used in academia and industry for feasibility studies and as a basis

for further research and commercial products. OmSim currently runs on Sun-4 workstations under the X Window System. It is implemented in C++ and uses only public domain software. OmSim is available via anonymous FTP from `ftp.control.lth.se` in directory `/pub/cace`.

The current developments include better support of combined continuous and discrete event models with support to find consistent initial values. We are also improving the manipulation routines and numerical routines for simulation. Another direction is development of model libraries for various applications.

Combined Continuous and Discrete Event Models

Researchers: Mats Andersson and Sven Erik Mattsson

Modeling and simulation of Continuous Variable Dynamical Systems (CVDS) and Discrete Event Dynamical Systems (DEDS) have developed as two separate cultures. CVDS are typically natural, physical systems that obey the fundamental laws of matter and energy conservation. Their behaviors are described by differential and algebraic equations. DEDS are usually man-made systems like control, manufacturing and information systems. There is no uniform formalism for representing DEDS systems, comparable to differential equations for continuous systems.

Hybrid Systems are 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. Physical systems may show behavior that is convenient to model as discrete events. Examples are mechanical systems with backlash, dead zones, and static friction, or electrical systems with switches. A valve in a process model may become stuck because of high friction. Switching between the two states stuck and moving are discrete events. Whether a physical phenomenon is modeled as a continuous evolution or a discrete event, depends on the desired level of detail in the model, and its relative time scale, compared to other interesting phenomena in the system.

A hybrid model formalism used as a basis for representation and simulation of combined CVDS and DEDS in the Omola/OmSim environment has been developed. The formalism includes differential and algebraic equations to define continuous time behavior, boolean invariant expressions to define event occurrences, and state transformation equations to define discrete behavior. The hybrid formalism supports formal analysis to detect structural insufficiency, automatic translation into other formalisms and symbolic manipulations and transformation to representations that are more efficient for simulation. A simulator for hybrid systems is more complicated than a simulator for purely continuous systems. A formal basis for the model representation helps to verify the correct behavior of the simulator. A mathematical and logical formalism helps to focus on fundamental mathematical problems in simulation of hybrid systems.

Object-Oriented Modeling of Chemical Processes

Researcher: Bernt Nilsson

This work developed an object-oriented methodology for modeling of complex chemical processes. The results were presented in a PhD thesis in 1993. Although we primarily deal with chemical processes much of the methodology can also be applied to other complex technical systems. The object-oriented modeling language, Omola, is used as a tool for illustration of the ideas.

The main results of the thesis are guidelines for structure and class hierarchy decomposition. A chemical plant model is decomposed into smaller and smaller pieces following the guidelines for model structure decomposition. The libraries of predefined models are organized following the guidelines for class decomposition. These guidelines cooperate to create well defined model modules that are easy to reuse in new applications.

Other important results are particular modeling methods. Medium and machine decomposition is a method to separate the description of the process media and the processing unit machine. Methods for control system abstraction are also presented together with parameterization

methods for reusable models with complex interiors. The guidelines and these methods are used in a chemical plant application and they are shown to be successful in an Omola implementation. Some modeling methods need extensions of the current Omola. Examples are concepts for regular structures as well as abstract and parameterized classes. A method for batch process modeling is also suggested that uses automatic switching between different internal descriptions.

Modeling and Simulation of Power Plants

Researchers: Bernt Nilsson and Jonas Eborn

This work is a cooperation with Sydkraft Konsult AB and the purpose is to develop libraries of basic unit models for thermal power generation plants.

The models are developed in Omola and are separated into three levels: systems, units and subunits. Systems are application oriented models described as a structure of units. Examples of systems are the pan section, the condenser section etc. Unit models are commonly used system components like pumps, valves, heat exchangers etc. Subunit models describe particular phenomena like a volume of medium with dynamic mass and energy or flow resistors with variable friction loss.

One application study focuses particularly on a combined cycle power plant. The plant is composed of a gas turbine and a heat recovery steam generation cycle. Combustion of fuel gas is done in a conventional gas turbine for production of electric power. The exhaust gas enters heat exchangers and boilers for steam generation. The produced steam is expanded in a steam turbine to produce electric power and condensed hot water is used for distant heat generation.

Applications

Integrated Control and Diagnosis

Researchers: Karl-Erik Årzén and Jan Eric Larsson

The goal of this project is development of methods for integrated design of control and supervisory functions, development of model-based diagnosis techniques, and implementational issues of on-line diagnosis systems.

The focus over the last year has been control and diagnosis of sequential processes. The work on object-oriented extensions of the Grafcet sequential function chart formalism has continued. This has been combined with model-based diagnosis methods. It is currently also being applied to control and diagnosis of recipe-based batch productions systems.

Fuzzy Control

Researchers: Anders Hansson, Karl-Erik Årzén, and Mikael Johansson

The impact of fuzzy logic on design of controllers has increased dramatically since the first industrial application, the control of a cement kiln, by Holmblad and Ostergard in the beginning of the eighties. Fuzzy logic was introduced already in 1965 by Zadeh, but the applications to control were popularized by the so called inference-rules of fuzzy logic in 1973. These rules make it possible to describe the control action in terms of `if ... then ... else`-constructions that mimics the human way of doing manual control.

The research at the department covers both the theory and practice of fuzzy control. One of the more important areas is analysis of fuzzy controllers which is motivated by the need to understand how fuzzy controllers work. The current work is focused on viewing fuzzy control as a nonlinear interpolation method.

Within the area of applications the design of anti-windup schemes for PID controllers has been investigated. A similar scheme has in corpo-

ration with Landis & Gyr AG been designed for their heating controller Sigmagyr RVP110.

The department is an associated member of the Esprit-III Basic Research Working Group FALCON (Fuzzy Algorithms for Control). The aim of the working group is to "meet the Japanese and American challenge in the area of Fuzzy Control by pooling efficiently existing European potentials in the areas of Artificial Intelligence, Control Engineering and Operations Research." The coordinator for the project is ELITE – European Laboratory for Intelligent Techniques Engineering in Aachen and the partners consist of eight universities and one industry which all are internationally well known in the fuzzy control field. This year project meetings have been held in Aachen and in Bruges.

Robotics

Researchers: Rolf Johansson, Klas Nilsson, and Anders Robertsson

The laboratory for robotics has been centered around an ABB Irb-6 robot and now it also includes 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 Sun workstations, which are used for program development and control analysis.

A main research project has been path following. The goal is to have efficient specification and generation of fast robot motions along a geometric path when the motion is limited by torque constraints. Typical applications are gluing, arc welding, and laser cutting. A feedback scheme for path following by trajectory time-scaling has been developed and tested experimentally. A key idea is that a scalar quantity, the path acceleration, is modified by a secondary control loop, resulting in coordinated adjustment of the individual joint motions.

Another main 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 and further research is going on.

A NUTEK-sponsored research program *Lund Research Programme in Autonomous Robotics* with cooperation partners from Dept Production and Materials Engineering and Dept Industrial Electrical Engineering and Automation and industrial partners was established during the year. A major effort in this project is to integrate aspects of control, sensor fusion and application demands. Some preliminary results on simultaneous force and position control were published during the year.

Real-Time Control

Researchers: Klas Nilsson, Karl-Erik Årzén, Leif Andersson, and Anders Blomdell

Real-time systems and real-time programming are treated in an ongoing research project named "Application specific real-time systems." The project has so far focused on "Real-time primitives and kernels supporting traditional real-time programming" and "Application aspects and real-time demands for open and layered control systems," while activities within "Formal methods for real-time programming to ensure correctness" are planned.

We use industrial robot control systems as a typical hard real-time application. We have a well proven experimental platform including two ABB robots controlled from our VME-based computers with Sun workstations being used as host computers. Our own real-time kernel allows us easy introduction of new real-time solutions. The kernel currently supports M68k processors, PCs and Sun Solaris. Programming languages currently used are C++, Modula-2, and C.

Concerning the application aspects, our approach is to have tools supporting and restricting the programmer in a proper way depending on the specific system and application. Another key issue in our approach is layered and open control systems. The aim here is to improve com-

bined safety, flexibility and efficiency in real-time programming of such embedded systems.

An activity that has close relations to real-time control is the work we are doing on graphical Petri net and Grafcet based languages for sequential supervisory control applications. The platform for this work is G2, a commercial object-oriented environment for real-time applications. We have developed Grafchart, a toolbox that combines real-time expert system techniques with Grafcet. This is a commercial product that currently is being applied for supervisory control in a US oil refinery and for the automation of flexible macining cells in Spain. Grafchart is currently being extended in different object-oriented directions.

Collaboration with the Pulp and Paper Industry

Researcher: Tore Hägglund

The aim of this project, which is supported by the Bo Rydin foundation, is to establish a closer collaboration with the pulp and paper industry. The idea is to investigate what kind of control problems that is of most interest for the pulp and paper industry, and to make field tests of our new research results.

We have discussed control problems with several pulp and paper companies, and received valuable inputs to our research. The Predictive PI controller (a dead-time compensating controller) as well as the Control Loop Performance Monitor (a procedure to detect oscillations in the control loop) were both field tested in the pulp and paper industry before they were implemented in the industrial controller SattControl ECA400.

Modeling and Control in Medical Systems

Researchers: Rolf Johansson in cooperation with Dr Måns Magnusson (Department of Oto-Rhino-Laryngology, Lund University Hospital)

This project treats the estimation of parameters and modeling of human postural dynamics. The goal is to find diagnostic parameters that describe the human ability to maintain posture and the methods developed are intended for use in diagnosis and rehabilitation of human

balance disorders. 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. Stability properties are studied by means of induced perturbations specific to each sensory feedback loop using system identification methodology.

The work is sponsored by the Swedish Medical Research Council (MFR) and the Söderberg Foundation. In December 1993 the Swedish Medical Society awarded the C. A. Hamberger prize to the Vestibular Laboratory for outstanding vestibular research and advisorship of graduate students.

Control of Biotechnology Processes

Researchers: Per Hagander in cooperation with Bo Mathiasson and Olle Holst (Department of Biotechnology)

In our collaboration with the Department of Biotechnology preliminary experiments have now started with genetically modified *E. coli*. Two fed-batch stages are normally used, one growth phase producing cell mass and one production phase. It is important to design good strategies for the substrate-dosage control in order to achieve reproducible cultivations with high cell densities and high productivity. The growth rate is then substrate-limited to avoid by-product formation and oxygen limitation. As a test system we work with the production of an antibody-binding protein, Protein L. Preliminary contacts are also established with Pharmacia BioScience Center.

Advanced Engine Control for Ultra-Low Emissions

Researchers: Rolf Johansson in cooperation with Gunnar Lundholm and Per Tunestål (Div. Combustion Engines)

In the Co-Nordic Gas Bus Project two city bus engines were adapted for low-emission duty with natural gas. One of them, a Scania DS11 was adapted by Ricardo in England and this engine is now at the Combustion Engines Division at Lund Institute of Technology. A research

project concerning modeling and control of air/fuel ratio with the purpose of ultra-low emissions has been started in cooperation with the Department of Automatic Control.

Rolling Mill Control

Researchers: Lars Malcolm Pedersen and Björn Wittenmark

The subject of this project is the improvement of the thickness tolerances of the plates rolled by the plate mill at The Danish Steel Works Ltd. (DDS) in Frederiksværk, Denmark. The improvement of the thickness accuracy will be obtained by designing a better controller for the process. The project includes literature study, development of dynamical models, and design of a suitable controller for the process. The final report in connection with the project will be the basis for obtaining the Lic. Tech. degree. Lars Malcolm Pedersen is an employee of DDS, he works at both the Steelwork and at the Department of Automatic Control. The project is supported financially by DDS and The Nordic Fund for Technology and Industrial Development.

By now the literature study is finished and a literature review has been made. Furthermore physical models have been derived for the hydraulic positioning system and the mill stand. Data have been collected and the parameters of the models have been found using system identification. For the time being the models are analyzed in order to choose a suitable control strategy for the problem.

5. Dissertations

One PhD dissertations was defended during the year. The abstract is presented below.

Object-Oriented Modeling of Chemical Processes

Bernt Nilsson
PhD dissertation, 15 October 1993

Models are important for almost all engineering activities. This thesis presents an object-oriented methodology for development of models for complex chemical processes. Although we primarily deal with chemical processes much of the methodology can also be applied to other complex technical systems. An object-oriented modeling language, Omola, is used as a tool throughout the thesis.

The main results of the thesis are guidelines for structure and class hierarchy decomposition. A chemical plant model is decomposed into smaller and smaller pieces following the guidelines for model structure decomposition. The libraries of predefined models are organized following the guidelines for class decomposition. These guidelines cooperate to create well defined model modules that are easy to reuse in new applications.

Other important results are particular modeling methods. Medium and machine decomposition is a method to separate the description of the process media and the processing unit machine. Methods for control system abstraction are also presented together with parameterization methods for reusable models with complex interiors. The guidelines and these methods are used in a chemical plant application and they are shown to be successful in an Omola implementation.

Some modeling methods need extensions in current Omola. Examples are concepts for regular structures as well as abstract and parameterized classes. A method for batch process modeling is also suggested that uses automatic switching between different internal descriptions.

6. Looking Back on Simnon

This time we will look at a research project that was started 1972 as a master's thesis, Elmqvist (1972). The project has had a major impact on the development of computational tools for control engineering. Its results are still used daily in our department and has led to a commercial product that is used in more than 40 countries.

Background

In the early 1970s we had started research on development of computational tools for control engineering under contract from STU (The Swedish Board of Technical Development). At that time the activity was called interactive computing. Johan Wieslander, who had this as his PhD project, was a main contributor. The software was developed on a minicomputer, PDP 15. This machine had a core memory of 16 Kwords (18 bit) and a disk of 500 Kwords. Interactive computing was the first major project that was inspired by our applications projects, which indicated a clear need for computer tools that would make it possible to solve control problems more cost effectively. Several interactive tools, IDPAC for system identification and SYNPAC and POLPAC for control system design, had already been developed. These tools were based on linear control theory.

There was a clear need for a nonlinear simulation tool to verify the properties of the designed control systems. We had a good insight into such problems because K. J. Åström had been working in a group at IBM Research where computer based simulators were developed. A standard for digital simulators CSSL had also been published in 1967. Although this standard was supposed to mimic the highly interactive analog simulation, the ideas behind the standard were mainly influenced by batch computing. We felt strongly that much could be gained by interactive computing and defined a master's project was defined to explore this. We were lucky to recruit a very talented student, Hilding

Elmqvist, who had strong computer science interest. He did in fact define a new simulation language Simnon with a highly interactive environment. Elmqvist also did a strawman implementation. The potential of the project was obvious. Based on the master thesis we received a one year grant form ITM (The Institute of Applied Mathematics) to continue the development. This project also went very well and we had a basic working system after one year. The system was written in Fortran and was easy to port to other platforms. The project also aroused a significant industrial interest. We got additional funding from STU, the system was extended and ported to several platforms. A useful version of the program that could be distributed appeared in 1973, see Elmqvist (1973).

Simnon

Simnon is extremely easy to use because of the parsimony of the language. Here are some important features:

- A clear distinction between the language for system descriptions and the language for execution of simulation experiments.
- The modeling language is simple and it has a number of safety features.
- The language admits an efficient implementation.
- The users do not have to know anything about computer programming.

There are three data types in the language: continuous time systems, discrete time systems and connecting systems. It is particularly well suited to simulate computer controlled systems. A handful of commands are sufficient to execute the simulations. Simnon quickly gained popularity as a research tool and later as a teaching tool. There was much cross-fertilization between the development of Simnon and the development of other CACE tools, because they all used the same program module Intrac as their user interface. This contributed significantly to the ease-of-use of the software.

The industrial interest in Simnon also grew. A major limitation of Simnon was that the system descriptions could only use real variables. It

was possible to include system descriptions in Fortran, at the cost of less convenience and less security. There were demands for extensions, for example, vectors, matrices, and hierarchical system descriptions. After careful consideration we decided that it was not a very challenging research topic to make these additions, particularly since our experience had shown that Fortran was too limited for our purposes. Instead we decided that it would be much more intellectually rewarding for Elmqvist to start from scratch in his PhD-thesis and investigate what properties a simulation language should have in general. His work on Simnon had given him an excellent base for this. This research resulted in an interesting dissertation (Elmqvist (1978)) that far exceeded our expectations. Also, a new language, Dymola, was developed, which gave a particularly nice solution to the problem of hierarchical system descriptions. Dymola was written in Simula which was not a very widely spread language. There is a very interesting continuation of this story that we will tell at some other time.

Commercial Exploitation

In the 1970s the Swedish Board of Technical Development (STU) had a policy that research results should be exploited commercially. Therefore we were not allowed to distribute Simnon freely. Instead we were requested to attempt commercialization. We contacted various software houses and tried to get them to take over Simnon, but without success. Since this did not work, we saw no other possibility than to sell licenses from the department. To make things simple we signed over all rights to the university and we started to distribute the software ourselves. We also set up a simple software service. After a while we got a reasonably simple and smooth distribution system and we were able to repay STU for a large part of the research grants.

We distributed a large number of licenses. Several Swedish companies obtained licenses. Simnon was used by Alfa-Laval, ASEA, Billerud, Bofors, FFA, FOA, Gambro, Kockumation, Philips, Saab Scania, SSPA, STFI Studsvik Energiteknik, Sydkraft, Vattenfall, Volvo Flygmotor and many universities. The feedback obtained from these companies was very useful. We had a particularly useful collaboration with SSPA. They

had earlier used analog simulation of ships and platforms, but they switched over to Simnon with a considerable increase of engineering efficiency. They are using Simnon as a vehicle to deliver tailor made simulators with elaborate man-machine interfaces. The switch to Simnon from general computer languages gave a significantly increased efficiency. These were the first real-time applications of Simnon.

It was a major breakthrough when General Electric in USA acquired our software for internal use. We had a very simple agreement: We supplied the source code and their control research department handled the rest. The best part of this was their excellent feedback, which was one major reason for our continued progress.

During the seventies Simnon was ported to a number of different platforms, mostly main frames and mini computers. In the eighties we had replaced our PDP 15 with a VAX. This machine, which initially had a main memory of 512 kB and a disk of 56 MB, became the primary vehicle for the development. We had early recognized the importance of portability, and we worked hard to improve it. This effort was probably as large as that of providing new functionality. The major difficulties were due to file handling and graphics. Although Simnon's graphics demands by todays standards are modest, we had to write support code for many combinations of plotters and terminals.

The project on interactive computing was finished in 1981, see Åström and Wieslander (1981). The major reasons were that we saw severe limitations with the programming language we used, Fortran, and that by now we had most of the problem oriented tools we needed. There were other interesting developments, e.g. Matlab, which appeared in 1980, and workstations, which were on the horizon. Two PhD dissertations had been finished, Elmqvist (1978) and Wieslander (1979), and many masters theses, but we saw limited possibilities of making new innovative dissertations with the approaches we were using.

Porting Simnon to the IBM-PC

Personal computers emerged in the 1970s. A major event was the announcement of the IBM PC in 1981, which indicated that the personal

computer was to be taken seriously. In 1984 we were fortunate to receive a donation of two PCs from IBM, and we immediately started to explore their potential for various educational purposes. These studies indicated that Simnon could be run on a PC. We saw many educational advantages by this, and in 1985 we initiated a project to make a PC version of Simnon. This work was carried out by Tomas Schönthal. He quickly had a crude version running, which proved that the project indeed was feasible. The simulations, however, were quite slow because the intermediate code (p-code) was interpreted. The system was based on the VAX version and had most of its functionality except for a stiff solver and the ability to describe models in Fortran. Between March and June 1985 the programming was interrupted for a visit to John Little at The Mathworks, Inc., USA. Little had just released PC-Matlab and very generously shared his experiences of software implementation on a PC with us.

The first version of Simnon for the PC was shipped to paying customers in September 1986 (Elmqvist *et al.* (1986)). From then on we operated like a small software company. This involved everything from copying diskettes to answering customer questions.

Version 1.0 turned out to be quite stable and remained intact for about 18 months. It supported most of the popular graphics boards at the time, and was about ten times faster than the first crude version. It could simulate models that were substantially larger than any model ever simulated by any version of Simnon, yet demanded as little as 256 kB of main memory. On an 8088/8087-based PC it would simulate at about 1/3 the speed of a VAX/VMS 11/780 system. Version 2.0 was further sped up twice. It also contained many features requested by the users i.e. pure time delays, ability to read input variables from files, publication quality PostScript, etc. Finally, version 3, offered a real-time capability and a much improved manual. Version 3, July 1990, represented a milestone in that it was the last version of Simnon that the department produced (Elmqvist *et al.* (1990)).

Transfer to Industry

The university is not the ideal place for software development. The reason we got involved was the pressure from STU to get results out to industry. We learned a lot about software engineering. It is also fair to say that our simulation methodology would not have been spread at all as widely if we had not entered the software development. It also gave the department a reasonable net revenue. We were also able to repay a substantial amount of the research funding to STU.

In 1989 we had about 100 licenses of Simnon for main frames and about 500 licenses for PC Simnon. The task of maintaining these and supporting the customers was becoming to much to do as a side activity for a university department. We had been looking for a suitable company that could take over the the activity. In the end of 1989 we signed a contract with SSPA in Gothenburg, who took over the responsibilities for Simnon. SSPA had a lot of Simnon expertise. They had a reasonably sized staff who were using Simnon extensively in house for simulation of ship steering and offshore platforms.

How Simnon Is Used at Our Department

Although Simnon was developed a long time ago, it is still used extensively at our department. It is our standard simulation tool, which is used daily by many of us. In textbooks and other teaching material we document all simulations as Simnon macro files, see Åström and Wittenmark (1984) and Åström and Wittenmark (1989). By giving students access to those files it is possible for them to study, recreate and modify all simulation experiments. In this way it has been possible to use much more realistic problems in our education. Simnon is also used extensively in many masters theses. The real-time version of Simnon is the work horse for many of our laboratory experiments used in the courses. Use of real-time Simnon has drastically reduced the effort to develop new laboratory experiments. We also have a code generator for conversion of Simnon to Modula II, see Dahl (1989).

Research Impact

We were among the very first groups to do research on interactive computing for automatic control. When this emerged as a research field in the 1980s, with major conferences organized by IFAC and IEEE, we were major contributors, see Åström (1983). Many of the ideas we presented have been taken up by other research groups. From a research perspective Simnon has given us very valuable insight into the problems of modeling and simulation. This knowledge was used as a background for a new project on Computer Aided Control Engineering (CACE) that was initiated in 1985, but that is also another story.

What We Learned

In retrospect the Simnon adventure was an interesting experience. It gave us good insight and knowledge of handling a commercial software development. This is directly reflected in software we are now generating in research projects. The pressure from STU had good and bad effects. It limited our possibilities to distribute software freely and pushed us into commercial ventures. This attitude was not unique to STU but was quite fashionable among research agencies in Europe at the time. There was an even stricter regime in the UK. The main advantage was that this forced us to try to collaborate with industry. It made us very aware of the importance of packaging research results well in order to spread them widely to industry. The feedback we got from users was very beneficial both for the Simnon project and for other projects. The efforts were severely restricted by a lack of interest from the university and a lack of local infrastructure of entrepreneurship and start-up companies. To some extent this was compensated for by our international network of contacts but it would unquestionably have been desirable to transfer Simnon earlier than 1989.

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Åström, Karl Johan, and Björn Wittenmark: *Computer Controlled Systems—Theory and Design.* Prentice-Hall, Englewood Cliffs, New Jersey, 1984.

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Elmqvist, Hilding: *A Structured Model Language for Large Continuous Systems.* PhD thesis TFRT-1015, May 1978.

Elmqvist, Hilding, Karl Johan Åström, and Tomas Schönthal: *SIMNON User's Guide for MS-DOS Computers.* Studentlitteratur, Lund, Sweden, 1986.

Elmqvist, Hilding, Karl Johan Åström, Tomas Schönthal, and Björn Wittenmark: *Simnon User's Guide.* SSPA, Göteborg, Sweden, 1990.

Wieslander, Johan: *Interaction in Computer Aided Analysis and Design of Control Systems.* PhD thesis TFRT-1019, May 1979.

A. Personnel and Visitors

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`

During the year the following persons have been employed at the department. The list shows the *status of June 1994* if nothing else is mentioned.

Personnel

Professors

Karl Johan Åström
Björn Wittenmark

Associate Professors

Per Hagander
Tore Hägglund
Rolf Johansson

Research Associates

Karl-Erik Årzén
Bo Bernhardsson
Kjell Gustafsson (until Dec 31, 1993)
Sven Erik Mattsson

Bernt Nilsson
Anders Rantzer

Research Engineers

Leif Andersson
Anders Blomdell
Rolf Braun
Tomas Schönthal

PhD Students

Lennart Andersson
Mats Andersson
Anders Hansson
Karl Henrik Johansson
Charlotta Johnsson
Ulf Jönsson
Per-Olof Källén
Jan Eric Larsson (until Aug 31, 1993)
Jörgen Malmborg
Johan Nilsson
Klas Nilsson
Henrik Olsson
Anders Robertsson
Anders Wallén (previous Nilsson)

Secretaries

Eva Dagnegård (part time)
Britt-Marie Mårtensson
Eva Schildt
Agneta Tuszynski (part time)

Temporary Appointments

Tord Björsne
Anders Carlsson

Jonas Eborn
Johan Eker
Mikael Johansson

Visiting Scientists

The following researchers have stayed with the department for about a week by the least.

Mr Lars Malcolm Pedersen
The Danish Steelworks Ltd, Frederiksværk, Denmark
(From 1 July 1992)

Dr Tim Berg
University of Oxford, UK
(25 Jan 1993 – 31 Jan 1994)

Mr Michel Colombo
ENSIEG, Grenoble, France
(19 April – 10 September 1993)

Dr Doug Looze
University of Massachusetts, USA
17 Aug 1993 – 5 Jan 1994)

Dr Josef Böhm
Prague, Czech Republic
(15 Sep – 6 Oct 1993)

Dr Albert-Jan Baerveldt
ETH, Zurich, Switzerland
(29 Nov 1993 – 20 May 1994)

Dr Carlos Canudas de Wit
ENSIEG, Grenoble, France
(21–26 Jan 1994)

Mr Juan Jose Ramos Gonzales
Universitat Autonoma de Barcelona, Spain
(1 Feb – 25 June 1994)

Mr Raul Savimaa
Tallinn Technical University, Estonia
(1 Feb – 30 July 1994)

Dr Alexander Kutznetsov
University of Oxford, UK
(7–12 March 1994)

Mr Michele Gianino
Politecnico di Torino, Italy
(17 March – 3 Oct 1994)

Mr Peter Müller
Technische Universität München, Germany
(10 May – 24 Nov 1994)

Mr Billy Chow
University of Oxford, UK
(24–30 May 1994)

Mr Jesus Pico
Valencia, Spain
(20 June – 15 Aug 1994)

Prof Rogelio Lozano
University of Compiegne, France
(27 June – 1 July 1994)

B. Awards

Karl Johan Åström and **Björn Wittenmark** received the IFAC Congress Control Engineering Textbook Prize in July 1993 for the outstanding textbook *Computer Controlled Systems—Theory and Design*, published by Prentice Hall, with the quotation "this book has had a major impact on the teaching and practice of control".

Karl Johan Åström received *Stora Energipriset 1993* (The Great Energy Prize 1993), shared with Lars Jensen (Dept of Building Science), for "Pioneering work on use of computer control of systems for heating, ventilation and airconditioning, from ideas and concepts to systems in operational use."

Bo Bernhardsson and **Karl Henrik Johansson** received an honourable mention as one of five finalists for the *Young Author Prize* at the 12th International Federation of Automatic Control World Congress 1993 in Sydney, Australia.

Tore Hägglund received the award *Innovation Cup*, which is sponsored by Skandia and Dagens Industri. His contribution was "A Control Loop Performance Monitor".

Karl Henrik Johansson received the *Peccei Award* during the Young Scientists' Summer Program 1993 at the International Institute of Applied System Analysis in Laxenburg, Austria.

Charlotta Johnsson received the *Trollhättans kommun Scholarship* in September 1993.

Bernt Nilsson received the *Sydkraft Research Scholarship* for his work in Computer-Aided Modeling in May 1994.

Klas Nilsson received the *Saab-Scania Scholarship* in April 1994.

Henrik Olsson received the *Saab-Scania Scholarship* in April 1994.

C. External Assignments

Member of Advisory Committees and Working Groups

Karl-Erik Årzén. Member of IFAC Technical Committee on Computers. Member of IFAC Technical Committee on Applications, Working Group on Chemical Process Control.

Karl Johan Åström. Member of TFR (Swedish Research Council for Engineering Science). Member of Research Advisory Council for the Institute for Systems Research, University of Maryland. Member of the IFAC Theory Committee. Member of the IEEE Control Systems Award Committee. Chairman of the Committee for the IFAC Quazza Medal. Member of the Mathematical Sciences Review Panel University of Toronto. Member of the International Advisory Panel Singapore National University. Member of the Jury for the Francquir Prize, Brussels, Belgium.

Per Hagander. Member of IFAC Technical Committee on Biomedical Engineering Control (TC-BIOMED).

Tore Hägglund. Member of IFAC Technical Committee on Applications.

Sven Erik Mattsson. Chairman of the Joint IFAC/IEEE Working Group on Guidelines and Standards for Computer Aided Control System Design, since March 1994. Member since its forming in August 1986.

Björn Wittenmark. Member of IFAC Technical Committee on Applications. Member of Advisory Committee for Food Engineering within NUTEK's DUP program. Lecturer within the Distinguished Lectures Program of the IEE Control System Society.

Board Member

Karl Johan Åström. Vice President Royal Swedish Academy of Engineering Sciences (IVA).

Anders Rantzer. Member of IEEE Editorial Board for CDC and ACC conferences.

Björn Wittenmark. Member of Board of Governors of IEEE Control System Society. Member of the Board of Lund Institute of Technology, Sweden. Chairperson of the Committee for Equal Opportunities at University of Lund, Sweden.

Book and Journal Editor

Karl-Erik Årzén. Associate editor of Automatica.

Karl Johan Åström. Member of Editorial advisory board for Systems and Control Encyclopedia. Editor of Automatica and International Journal of Adaptive Control and Signal Processing. Member of editorial board of International Journal on Control. Member of Advisory Board for the IEEE Transactions on Control Systems Technology. Associate editor of Progress in Systems and Control Theory.

Björn Wittenmark. Associate editor of Journal of Forecasting, member of editorial board of International Journal of Adaptive Control and Signal Processing, Optimal Control Applications and Methods, and the book series Advances in Industrial Control.

Member of International Program Committee (IPC)

Karl-Erik Årzén. Chairman of the IPC and of the NOC for the 2nd IFAC Workshop on "Computer Software Structures Integrating AI/KBS in Process Control," Lund, August 1994. Member of IPC for Second International Conference on "Intelligent Systems Engineering", Hamburg-Harburg, September 1994.

Karl Johan Åström. Member of IPC for the 12th IFAC World Congress, Sydney, Australia, July 1993. Member of IPC for the 2nd IFAC

Workshop on Computer Software Structures Integrating AI/KBS Systems in Process Control, Lund, Sweden, August 1994.

Sven Erik Mattsson. Program Co-Chairman of the IEEE/IFAC Joint Symposium on Computer-Aided Control System Design, March 1994, Tucson, Arizona. Chairman of the Object-Oriented Modeling and Simulation Conference at the European Simulation Multiconference (ESM '94), June 1994, Barcelona, Spain.

Björn Wittenmark. Member of IPC for the 3rd IEEE Conference on Control Applications, Glasgow, August 1994.

Opponent and Member of Examination Committee

Karl-Erik Årzén. External examiner of the licentiate thesis by P. Loborg, University of Linköping, June 1994.

Karl Johan Åström. Member of the Jury for the dissertation of A. J. Krijgsman, Technical University, Delft, November 23, 1993.

Bo Bernhardsson. External examiner for a licentiate thesis by Torbjörn Andersson, University of Linköping, June 1994.

Per Hagander. Member of examination committee of the thesis by Tobias Rydén, Lund Institute of Technology, November 1993.

Sven Erik Mattsson. External examiner of the MPhil-thesis "Object oriented modelling languages in computer aided control system design" by Hywel James Williams, Computer Science Department, University College of Swansea, Wales, June 1994. External examiner of the PhD thesis "Development of Object-Oriented Software for Analysis and Design of Linear Control Systems" by Roumen B. Antonov, Department of Electrical and Electronic Engineering, University College of Swansea, Wales, June 1994.

Björn Wittenmark. Censor of the PhD thesis by Olafur Petur Palsson, DTH, Denmark, January 1994.

D. External Publications

Papers

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Årzén, Karl-Erik, Anders Wallén, and T. F. Petti: "Model-based diagnosis—state transition events and constraint equations." In Tzafestas and Verbruggen, Eds., *Artificial Intelligence in Industrial Decision Making, Control and Automation.* Kluwer Academic Publishers, 1994.

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Wittenmark, Björn: "Adaptive control of a stochastic non-linear system: An example." *Int. J. Adaptive Control and Signal Processing*, **7**, pp. 327–337, 1993.

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Andersson, Mats: "Modelling of combined discrete event and continuous time dynamical systems." In *Preprints IFAC 12th World Congress*, volume 9, pp. 69–72, Sydney, Australia, July 1993.

Andersson, Mats, Sven Erik Mattsson, Dag Brück, and Tomas Schönthal: "OmSim—An integrated environment for object-oriented modelling and simulation." In Mattsson *et al.*, Eds., *Proceedings of the IEEE/IFAC Joint Symposium on Computer-Aided Control System Design, CACSD'94*, pp. 285–290, Tucson, Arizona, March 1994.

Årzén, Karl-Erik: "Grafcet for intelligent real-time systems." In *Preprints IFAC 12th World Congress*, Sydney, Australia, 1993.

Årzén, Karl-Erik: "Using real-time expert systems for control system prototyping." In *IEEE Systems, Man and Cybernetics Conference*, Le Touquet, France, 1993. Invited session paper.

Årzén, Karl-Erik, and Karl Johan Åström: "Expert systems in control engineering: State of the art." In *First European Congress on Fuzzy and Intelligent Technologies*, Aachen, Germany, 1993. Invited paper.

Bernhardsson, Bo: "Robust stochastic performance optimization." In *Preprints IFAC 12th World Congress*, Sydney, Australia, 1993.

Bernhardsson, Bo: "Sampling of state space systems with several time delays." In *Preprints IFAC 12th World Congress*, Sydney, Australia, 1993.

Bernhardsson, Bo, and Karl Henrik Johansson: "On simultaneous H_2-optimization of several performance bounds." In *Preprints IFAC 12th World Congress*, volume 2, pp. 471–474, Sydney, Australia, 1993.

Canudas de Wit, C., Henrik Olsson, Karl Johan Åström, and P. Lischinsky: "A new friction model for control design." In *Int. Conference on Control Theory and Its Applications*, Kibbutz Maale HaChamisha, Israel, 1993.

Dahl, Ola: "Path constrained robot control with limited torques – experimental evaluation." In *Preprints IFAC 12th World Congress*, Sydney, Australia, July 1993.

Hägglund, Tore: "Automatic monitoring of control loop performance." In *Control Systems 94—Conference on Control Systems in the Pulp and Paper Industry*, Stockholm, Sweden, 1994.

Hägglund, Tore: "Automatic supervision of control valves." In *IFAC Symposium on Fault Detection, Supervision and Safety for Technical Processes*, Helsinki, Finland, 1994.

Hansson, Anders: "Minimum upcrossing control of ARMAX-processes." In *Preprints IFAC 12th World Congress*, Sydney, Australia, 1993.

Hansson, Anders: "Optimal modifications of reference signals for critical processes using alarm signals." In *Preprints IFAC 12th World Congress*, Sydney, Australia, 1993.

Hansson, Anders, P. Gruber, and J. Tödtli: "Fuzzy anti-reset windup for PID controllers." In *Preprints IFAC 12th World Congress*, Sydney, Australia, 1993.

Holm, M., P. Blomström, J. Brandt, R. Johansson, and C. Lührs: "Localization of preferential atrial excitation routes during fibrillation by temporal averaging of multiple discret excitation vectors." In *11th Int. Congress The New Frontiers of Arrythmias*, pp. 141–146, Marilleva, Italy, January 1994.

Johansson, Rolf, and M. W. Spong: "Quadratic optimization of impedance control." In *Proc. IEEE Int. Conf. Robotics and Automation*, pp. 616–621, San Diego, California, May 1994.

Källén, Per-Olof, and Björn Wittenmark: "A frequency domain adaptive

controller." In *Preprints IFAC 12th World Congress*, Sydney, Australia, July 1993.

Mattsson, Sven Erik: "Simulation of object-oriented continuous time models." In Troch and Breitenecker, Eds., *Proceedings of the IMACS Symposium on Matematical Modelling*, pp. 85–88, Vienna, Austria, February 1994. Invited session paper.

Mattsson, Sven Erik, Mats Andersson, and Karl Johan Åström: "Modeling and simulation of behavioral systems." In *Proceedings of the 32nd IEEE Conference on Decision and Control*, volume 4, pp. 3636–3641, San Antonio, Texas, December 1993.

Mattsson, Sven Erik, Magnus Ericson, and Patrik Östberg: "An object-oriented model of a heat-exchanger unit." In *Proceedings of the European Simulation Multiconference, ESM'94*, pp. 297–303, Barcelona, Spain, June 1994. SCS, The Society for Computer Simulation.

Megretski, A., and Anders Rantzer: "Robust control synthesis by convex optimization: Projective parametrization and duality." In *Preprints IFAC 12th World Congress*, Sydney, Australia, 1993.

Nilsson, Bernt: "Modeling Process Control System in Omola." In *Preprints IFAC 12th World Congress*, volume VI, pp. 197–200, Sydney, Australia, July 1993.

Nilsson, Bernt: "Dynamic Modeling of Chemical Processes using Omola." In *4th European Symp. on Computer Aided Process Engineering—ESCAPE 4*, pp. 103–110, 1994.

Nilsson, Bernt: "Guidelines for process model libraries using an object-oriented approach." In *Proceedings of the European Simulation Multiconference, ESM'94*, pp. 349–353, Barcelona, Spain, June 1994. SCS, The Society for Computer Simulation.

Nilsson, Klas: "Object oriented DSP programming." In *Proceedings of The Fourth International Conference on Signal Processing Applications & Technology*, volume 1, pp. 561–570. DSP Associates, Santa Clara, California, Sept/Oct 1993.

Persson, Per, and Karl Johan Åström: "PID control revisited." In *Preprints IFAC 12th World Congress*, Sydney, Australia, July 1993.

Qiu, L., B. Bernhardsson, A. Rantzer, E. J. Davison, P. M. Young, and J. C. Doyle: "On the real structured stability radius." In *Preprints IFAC 12th World Congress*, Sydney, Australia, 1993.

Rantzer, Anders: "Linear matrix inequalities for rank one robust synthesis." In *Proceedings of Conference on Decision and Control*, pp. 2207–2209, 1993.

Technical Reports

Johansson, Karl Henrik: "On market dependencies of agents' learning for a hyperinflation model." Technical Report WP–93–47, International Institute of Applied Systems Analysis, Laxenburg, Austria, 1993.

E. Reports

Dissertations

Nilsson, Bernt: *Object-Oriented Modeling of Chemical Processes.* PhD thesis ISRN LUTFD2/TFRT--1041--SE, August 1993.

Master Theses

Andersson, Lennart: "Olinjär stokastisk reglering av extremvärden," (Non-linear stochastic control of extreme values). Master thesis ISRN LUTFD2/TFRT--5480--SE, September 1993.

Andreff, Nicolas: "Robustness to jitter in real time systems." Master thesis ISRN LUTFD2/TFRT--5507--SE, June 1994.

Bannura, Patrik: "Programpaket för uppsättning och intrimning av PID-regulatorer," (Program package for initiating and tuning of PID controllers). Master thesis ISRN LUTFD2/TFRT--5508--SE, June 1994.

Björsne, Tord: "Passiv optisk avståndsmätning för robotstyrning," (Passive optical distance estimation for robotic control). Master thesis ISRN LUTFD2/TFRT--5495--SE, December 1993.

Carlsson, Mats: "Användarvänliga system – snabb framtagning av prototyper till grafiska användningsgränssnitt," (User friendly systems—rapid prototyping of graphical user interfacts). Master thesis ISRN LUTFD2/TFRT--5489--SE, December 1993.

Colombo, Michel: "Implementation of a toolbox for hybrid Petri nets in G2." Master thesis ISRN LUTFD2/TFRT--5482--SE, September 1993.

Eborn, Jonas: "Modelling and simulation of an industrial control loop with friction." Master thesis ISRN LUTFD2/TFRT--5501--SE, March 1994.

Eker, Johan, and Stefan Vlachos: "Classification of system dynamics

using neural networks." Master thesis ISRN LUTFD2/TFRT--5476--SE, August 1993.

Ericsson, Magnus, and Patrik Östberg: "Dynamisk provning av värmeväxlarsystem," (Dynamical testing of heat exchanger systems). Master thesis ISRN LUTFD2/TFRT--5490--SE, December 1993.

Fälth, Björn: "State of charge observer for hybrid vehicles." Master thesis ISRN LUTFD2/TFRT--5499--SE, March 1994.

Göransson, Tor: "Introduction of adaptive active filters in HVDC systems." Master thesis ISRN LUTFD2/TFRT--5492--SE, December 1993.

Hägerdahl, Martin: "Bridging over FPGA computer tools with VHDL." Master thesis ISRN LUTFD2/TFRT--5502--SE, March 1994.

Hermanson, Lars: "Investigation of Lewis' servomechanism." Master thesis ISRN LUTFD2/TFRT--5506--SE, May 1994.

Hesslevik, Rikard, and Pehr Hjalmarsson: "Temperaturreglering av förpackningsmaskin," (Temperature control of a packaging machine). Master thesis ISRN LUTFD2/TFRT--5497--SE, February 1994.

Holmström, Torgny: "Feasibility study of a hold of device." Master thesis ISRN LUTFD2/TFRT--5505--SE, May 1994.

Johansson, Mikael: "Nonlinearities and interpolation in fuzzy control." Master thesis ISRN LUTFD2/TFRT--5491--SE, December 1993.

Johansson, Ola, and Magnus A. R. Andersson: "Produktionsplanering med hjälp av genetiska algoritmer och neurala nätverk," (Production planning using genetic algorithms and neural networks). Master thesis ISRN LUTFD2/TFRT--5485--SE, October 1993.

Johnsson, Charlotta: "Réseaux de Petri continus asymptotiques." Master thesis ISRN LUTFD2/TFRT--5478--SE, July 1993.

Karlsson, Mats: "Implementering av experimentella robotsystem," (Implementation of experimental robot control systems). Master thesis ISRN LUTFD2/TFRT--5475--SE, November 1993.

Lantorp, Per: "Test unit for a final folder." Master thesis ISRN LUTFD2/TFRT--5479--SE, August 1993.

Larsson, Mats: "Adaptiv effektreglering av kokarvattenreaktor," (Adaptive control of boiling water reactor). Master thesis ISRN LUTFD2/TFRT--5486--SE, October 1993.

Larsson, Stefan: "Simulering av skjutande luftvärnspjäs," (Simulation of a firing anti-aircraft gun). Master thesis ISRN LUTFD2/TFRT--5496--SE, January 1994.

Lekman, Michael: "A quantitative feedback theory toolbox for Matlab 4.1." Master thesis ISRN LUTFD2/TFRT--5477--SE, August 1993.

Moritz-Olsen, Harald: "Identification of ocean vehicles and their thrusters." Master thesis ISRN LUTFD2/TFRT--5503--SE, March 1994.

Neving, Per: "Design av ubåtsstyrautomat som minimerar inverkan av vågstörningar," (Design of controllers for submarines that reduct the effect of waves). Master thesis ISRN LUTFD2/TFRT--5484--SE, September 1993.

Nilsson, Henrik, and Tony Sandberg: "Självinställande extremalsökare," (Selftuning extremum control). Master thesis ISRN LUTFD2/TFRT--5481--SE, September 1993.

Olofsson, Patrik: "Optimering av tillgängliga produktionsresurser i en elkraftsbalans," (Optimization of available production resources in an electric power balance). Master thesis ISRN LUTFD2/TFRT--5488--SE, November 1993.

Olsson, Niclas, and Pär Larsson: "Implementering av en direkt adaptiv regulator för industrirobotar," (Implementation of a direct adaptive controller for an industrial robot). Master thesis ISRN LUTFD2/TFRT--5493--SE, December 1993.

Petersson, Mikael: "Minimum energy control applied to mechanical systems driven by introduction motors." Master thesis ISRN LUTFD2/TFRT--5494--SE, December 1993.

Ringdahl, Anders: "Simulering av adaptiva regulatorer i Matlab," (Simulation of adaptive controllers using Matlab). Master thesis ISRN LUTFD2/TFRT--5483--SE, September 1993.

Smakman, Henk: "Adaptive control of the radial servo of a compact disc player." Master thesis ISRN LUTFD2/TFRT--5498--SE, February

1994.

Tengvall, Anna: "Reglering och automatisk regulatorinställning för osymmetriska processer," (Control and automatic tuning for unsymmetrical processes). Master thesis ISRN LUTFD2/TFRT--5487--SE, November 1993.

Widell, Johan: "Control of hybrid vehicles." Master thesis ISRN LUTFD2/TFRT--5500--SE, March 1994.

Wiktorsson, Magnus: "Designbegränsning för stabil regulator vid polynomsyntes," (Design limitations for a stable controller using polynomial design). Master thesis ISRN LUTFD2/TFRT--5504--SE, May 1994.

Other Reports

Andersson, Leif: "Implementation of a real-time kernel." Report ISRN LUTFD2/TFRT--7511--SE, November 1993.

Åström, Karl Johan: "Nyquist's contributions to control and communication." Report ISRN LUTFD2/TFRT--7512--SE, September 1993.

Bernhardsson, Bo: "Simultaneous block-diagonalization of one hermitian and one symmetric form." Report ISRN LUTFD2/TFRT--7520--SE, June 1994.

Dagnegård, Eva, and Rolf Johansson: "Activity report 1992–1993." Report ISRN LUTFD2/TFRT--4021--SE, December 1993.

Gustafsson, Kjell: "An architecture for autonomous control." Report ISRN LUTFD2/TFRT--7514--SE, January 1994.

Hagander, Per, and Anders Hansson: "Discrete time LQ control in case of dynamically redundant inputs." Report ISRN LUTFD2/TFRT--7516--SE, January 1994.

Hagander, Per, and Anders Hansson: "Sufficient and necessary conditions for the existence of discrete-time LQG controllers." Report ISRN LUTFD2/TFRT--7517--SE, May 1994.

Hansson, Anders: "Fuzzy anti-reset windup for heater control." Report ISRN LUTFD2/TFRT--7515--SE, December 1993.

Hansson, Anders: "Travel report from London." Report ISRN LUTFD2/TFRT--8049--SE, May 1993.

Holmberg, Ulf: "Traveling in Japan." Report ISRN LUTFD2/TFRT--8048--SE, April 1993.

Johansson, Rolf, Lennart Andersson, and Ulf Jönsson: "Processidentifiering. Projektarbeten våren 1994," (Term papers in Process Identification—spring semester). Report ISRN LUTFD2/TFRT--7522--SE, May 1994.

Jönsson, Ulf: "Stability theory using Lipschitz and Dahlquist functionals, part II: Extended spaces and causality." Report ISRN LUTFD2/TFRT--7509--SE, July 1993.

Nielsen, Lars, Leif Andersson, Mats Andersson, and Karl-Erik Årzén: "A real-time kernel with graphics support modules." Report ISRN LUTFD2/TFRT--7510--SE, August 1993.

Pedersen, Lars Malcolm: "Plate thickness control of hot rolling mills." Report ISRN LUTFD2/TFRT--7513--SE, November 1993.

Ramos González, Juan José: "Object-oriented modelling of flows in process systems." Report ISRN LUTFD2/TFRT--7521--SE, jun 1994.

Rantzer, Anders, and Bo Bernhardsson: "Nonlinear control theory, the PhD course 1994." Report ISRN LUTFD2/TFRT--7519--SE, jun 1994.

Wittenmark, Björn, and M. Törngren: "Timing problems in real-time control systems: Problem formulation." Report ISRN LUTFD2/TFRT--7518--SE, May 1994.

Reports Available

Some abstracts and reports are available by anonymous FTP from

`ftp.control.lth.se` in directory `/pub/techreports`

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, S-581 83 Linköping
- UB 2, Svenska Tryckavdelningen, Box 1010, S-221 03 Lund
- Stockholms Universitetsbibliotek, Svenska Tryckavdelningen, S-106 91 Stockholm
- Kungliga Biblioteket, Box 5039, S-102 41 Stockholm
- Umeå Universitetsbibliotek, Box 718, S-901 10 Umeå
- Uppsala Universitetsbibliotek, Box 510, S-751 20 Uppsala

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F. Seminars at the Department

Seminars given at the department during the academic year 1993–1994, are summarized here. They are given both by the staff at the department and by invited lecturers.

1993

Aug 18	Michael Lekman: "A Matlab toolbox for QFT." MSc-thesis presentation.
Aug 20	Ola Johansson, Magnus A. R. Andersson: "Production planning using genetic algorithms and neural networks." MSc-thesis presentation.
Aug 20	Per Lantorp: "Test unit for a final folder." MSc-thesis presentation.
Aug 26	Stefan Vlachos, Johan Eker: "Classification of system dynamics using neural networks." MSc-thesis presentation.
Aug 27	Charlotta Johnsson: "Asymptotic continuous Petri nets." MSc-thesis presentation.
Sep 1	Doug Looze (Univ of Massachusetts): "Identification and control of GaAs crystal growth."
Sep 3	Michel Colombo (Grenoble): "Hybrid Petri Nets in G2." MSc-thesis presentation.
Sep 8	Anders Rantzer: "Optimization of robustness with respect to uncertain parameters in linear systems."
Sep 10	Henrik Nilsson, Tony Sandberg: "Self-tuning extremum control." MSc-thesis presentation.
Sep 15	Lennart Andersson: "Non-linear stochastic control of extreme values." MSc-thesis presentation.

Sep 22 Josef Böhm (Prague): "The development of adaptive controllers at UTIA: Theoretical basis, algorithms, experience."

Sep 24 Karl-Erik Årzén, Jörgen Malmborg: ""Fuzzy fever in Aachen"—Impressions from EUFIT '93."

Oct 6 Karl Henrik Johansson: "On market dependencies of agent's learning for a hyperinflation model."

Oct 8 Mats Carlsson: "User friendly systems—Rapid prototyping of graphical user interface." MSc-thesis presentation.

Oct 14 Wolfgang Marquardt (RWTH, Aachen): "On the representation of chemical process modeling knowledge."

Oct 15 Bernt Nilsson: "Object-oriented modeling of chemical processes." Doctoral dissertation defence.

Oct 19 Helen Nyquist-Weekes (Houston, Texas): "About my father Harry Nyquist."

Oct 22 Anders Helmersson: "Lyapunov technique for assuring global performance bounds."

Oct 25 Kenneth W. Goff (Performance Controls, Horsham, PA): "Some industrial applications of automatic control."

Oct 27 Doug Looze (Massachusetts): "Integral constraints for linear feedback systems."

Oct 29 Vincent Blondel (KTH): "Simultaneous stabilization: An unsolvable question in linear systems theory."

Nov 1 Ole Langeland (Statoil Research Centre, Trondheim): "Use of dynamic models in process industry, now and in future."

Nov 10 Karl Johan Åström: "Hot stuff from WPAB."

Nov 12 Magnus Akke: "Dynamical problems with transformation of high voltage direct current."

Nov 19 Anders Lindquist (KTH): "A complete parameterization of all positive rational extensions of a covariance sequence."

Nov 26 Mikael Petersson: "Minimum energy control applied to mechanical systems driven by induction motors." MSc-thesis presentation.

Nov 26 Pär Larsson, Niclas Olsson: "Adaptive robot control." MSc-thesis presentation.

Nov 29 Anders Rantzer: "Robustness conditions for nonlinear and time-varying systems."

Nov 30 Joe Armstrong (Ericsson): "Industrial usage of a declarative programmnig language."

Dec 1 Kjell Gustafsson: "Sensor array processing—A tutorial."

Dec 2 Anna Tengvall: "Control and automatic tuning." MSc-thesis presentation.

Dec 2 David Hill (Univ of Newcastle, Australia): "Dissipative systems: Basics, stability analysis and applications."

Dec 3 Kjell Gustafsson: "Mitigation of wing flexure induced errors in direction finding from airborne platforms."

Dec 7 Patrik Olofsson: "Optimization of available production resources in an electric power balance."

Dec 8 Jorge Mari (KTH), Jan Peter Axelsson (Pharmacia): "Design of optimal feed profiles for fedbatch production of human growth hormones using yeast."

Dec 10 Mikael Johansson: "Nonlinearities and interpolation in fuzzy control." MSc-thesis presentation.

Dec 13 Bo Bernhardsson: "A formula for computation of the real stability radius."

Dec 16 Magnus Ericsson, Patrik Östberg: "Dynamical testing of heat exchanger systems." MSc-thesis presentation.

Dec 16 Tor Göransson: "Introduction of adaptive active filters in HVDC systems." MSc-thesis presentation.

Dec 17 Rolf Johansson, Gunnar Bolmsjö, Gunnar Lindstedt, Klas Nilsson: "Lund research programme in autonomous robotics."

Dec 21 Anders Hansson: "Fuzzy anti-reset windup for heater control."

1994

Jan 19 Tord Björsne: "Passive optical distance estimation for robotic control." MSc-thesis presentation.

Jan 25 Carlos Canudas de Wit (LAG, Grenoble): "Direct adaptive impedance control,"

Jan 26 Stefan Larsson: "Simulation of a firing anti-aircraft gun." MSc-thesis presentation.

Feb 4 Rikard Hesslevik, Pehr Hjalmarsson: "Temperature control of a packaging machine." MSc-thesis presentation.

Feb 7 Edward Fadden (Applied Dynamics Int, Ann Arbor, Michigan): "Methods and tools for real-time simulations."

Feb 9 Torsten Söderström (Uppsala University): "High-order Youle-Walker methods for frequency estimation."

Feb 23 Johan Widell: "Control of hybrid vehicles." MSc-thesis presentation.

Feb 23 Björn Fälth: "State of charge observer for hybrid vehicles." MSc-thesis presentation.

Feb 25 Henk Smakman: "Adaptive control of the arm of a CD player." MSc-thesis presentation.

March 9 Alexander Kuznetsov (Univ of Oxford): "Some problems of constrained generalized predictive control."

March 23 Per Hagander: "LQG revisited."

March 30 Jonas Eborn: "Effets of friction on a pheumatic positioner." MSc-thesis presentation.

April 13 Karl Johan Åström: "Control paradigms."

April 20 Martin Hägerdal: "Bridging over FPGA computer tools with VHDL." MSc-thesis presentation.

May 18 Jesper Bergstrand: "Control of hydraulic valves." MSc-thesis presentation.

May 19 Torgny Holmström: "Feasibility study of a hold of device." MSc-thesis presentation.

May 20 Albert-Jan Baerveldt (ETH, Zurich): Video presentation: "Inverted pendulum on robot and a project oriented approach to robotics education at ETH, Zurich."

May 20 Lars Hermansson: "Investigation of Lewis' servomechanism." MSc-thesis presentation.

May 20 Rolf Johansson: Video presentation: "IEEE Robotics and Automation Conference video proceedings."

May 30 Jerzy W. Rozenblit (Univ of Arizona): "An integrative approach to engineering design."

June 3 Magnus Wiktorsson: "Design limitations for a stable controller using polynomial design." MSc-thesis presentation.

June 7 Michael Lundh (FFV Aerotech AB, Arboga): "A simplified flight state control for target adaptive dispenser systems."

June 28 David S. Bayard (Caltech, Pasadena): "Identification of high-order wideband stat-space models from frequency data."

June 29 David S. Bayard (Caltech, Pasadena): "A frequency domain approach to system identification, uncertainty characterization, and robust control design."

June 30 David S. Bayard (Caltech, Pasadena): "Zero annihilation methods for stable inversion of non-minimum phase systems,"

June 30 Alan E. Pearson (Brown University): "Parameter identification for differential systems in the frequency domain."

G. Lectures by the Staff

1993

July 12 Björn Wittenmark: "Practical issues and case studies in adaptive control," University of Melbourne, Australia.

July 14 Björn Wittenmark: "Adaptive control of a stochastic nonlinear system: An example," University of Melbourne, Australia.

July 19 Karl-Erik Årzén: "Grafcet for intelligent real-time systems," 12th IFAC World Congress, Sydney, Australia.

July 19 Bo Bernhardsson: "Sampling of state space systems with several time delays," 12th IFAC World Congress, Sydney, Australia.

July 19 Anders Hansson: "Minimum upcrossing control of ARMAX processes," 12th IFAC World Congress, Sydney, Australia.

July 19 Anders Hansson: "Fuzzy anti-reset windup for PID controllers," 12th IFAC World Congress, Sydney, Australia.

July 19 Karl Henrik Johansson: "On simultaneous H_2-optimization of several performance bounds," 12th IFAC World Congress, Sydney, Australia.

July 19 Björn Wittenmark: "A frequency domain adaptive controller," 12th IFAC World Congress, Sydney, Australia.

July 21 Bernt Nilsson: "Modeling of process control systems in Omola," 12th IFAC World Congress, Sydney, Australia.

July 22 Karl Johan Åström: "PID control revisited," 12th IFAC World Congress, Sydney, Australia.

July 22 Bo Bernhardsson: "Robust stochastic performance optimization," 12th IFAC World Congress, Sydney, Australia.

July 22 Anders Hansson: "Optimal modification of reference signals for critical processes using alarm signals," 21th IFAC

World Congress, Sydney, Australia.

July 22 Bernt Nilsson: "Modeling of combined discrete event and continous time Dynamical Systems," 12th IFAC World Congress, Sydney, Australia.

Aug 23 Karl Henrik Johansson: "On market dependencies of agents' learning for a hyperinflation model," International Institute of System Analysis, Laxenburg, Austria.

Aug 30 Karl Johan Åström: "Indirect measuring techniques," Astra/Draco, Lund, Sweden.

Sep 2 Karl Johan Åström: "Matching criteria for control and identification," Swedish-Italian Workshop on New Perspectives in Modelling and Identification with Applications, Stockholm, Sweden.

Sep 3 Björn Wittenmark: "Adaptive extremal control: an example," Swedish-Italian Workshop on New Perspectives in Modelling and Identification with Applications, Stockholm, Sweden.

Sep 8 Karl-Erik Årzén: "Expert systems in control engineering: State of the art," First European Congress on Fuzzy and Intelligent Technologies, Aachen, Germany.

Sep 9 Karl Johan Åström: "Nyquist's contribution to Automatic Control," Karlstad University College, Sweden.

Sep 9 Karl Johan Åström: "Harry Nyquist—A pioneer within engineering science," Karlstad University College, Sweden.

Sep 15 Karl Johan Åström: "Autonomous process control," invited lecture at the 2nd IEEE Conference on Control Applications, Vancouver, Canada.

Sep 29 Klas Nilsson: "Object oriented DSP programming," Fourth International Conference on Signal Processing Applications & Technology, Santa Clara, California.

Oct 5 Karl Johan Åström: "Relay feedback," IEEE Control System Society, Vancouver Section, Vancouver, Canada.

Oct 5 Klas Nilsson: "On the programming of industrial robots," McGill University, Centre for Intelligent Machines, Montreal, Canada.

Oct 7 Tore Hägglund: "Adaptive control," University of Aveiro, Portugal.

Oct 8 Tore Hägglund: "Supervision, detection, and safety," University of Aveiro, Portugal.

Oct 6 Karl Johan Åström: "Adaptive control," Department of Electrical Engineering, University of British Columbia, Vancouver, Canada.

Oct 7 Karl Johan Åström: "Unifying criteria for control and identification," Departments of Mechanical Engineering, University of British Columbia, Vancouver, Canada.

Oct 9 Karl Johan Åström: "Black boxes and white noise," The Vancouver Institute, University of British Columbia, Vancouver, Canada.

Oct 15 Anders Rantzer: "Robust control with structured uncertainty using linear matrix inequalities," Royal Institute of Technology, Stockholm, Sweden.

Oct 18 Karl Johan Åström: "Model development and simulation—A survey," a one-day-seminar on development of tools for simulation, supervision and analysis of power generating units, Sydkraft, AB, Malmö, Sweden.

Oct 18 Sven Erik Mattsson: "OmSim—An object-oriented environment for modelling and simulation," at a one-day-seminar on development of tools for simulation, supervision and analysis of power generating units, Sydkraft, AB, Malmö, Sweden.

Oct 19 Karl-Erik Årzén: "Using real-time expert systems for control system Prototyping," IEEE Systems, Man & Cybernetics Conference, Le Touquet, France.

Nov 2 Karl Johan Åström: "Practical aspects on implementation of adaptive systems," Wright Laboratory, Wright Patterson AFB, Dayton Ohio.

Nov 8 Karl Johan Åström: "Advances in control theory," European Science Foundation, Strassbourgh, France.

Dec 7 Anders Rantzer: "Robustness conditions for nonlinear time-varying structured uncertainty," Massachusetts Institute of Technology, USA.

Dec 8 Anders Rantzer: "Rank one robust synthesis," Massachusetts Institute of Technology, USA.

Dec 10 Anders Rantzer: "A formula for computation of the real stability radius," Iowa State University, USA.

Dec 13 Anders Rantzer: "Robustness conditions for nonlinear time-varying structured uncertainty," Honeywell Technology Center, Minneapolis, USA.

Dec 15 Anders Rantzer: "Linear matrix inequalities for rank one synthesis," CDC-93, San Antonio, Texas, USA.

1994

Jan 10–14 Bernt Nilsson: "Matlab—A basic course for Chemical Engineers," Department of Chemical Engineering, LTH, Sweden, 1994.

Jan 14 Mats Andersson: "Modelling and simulation of hybrid dynamical systems in Omola," Department of Automatic Control, Chalmers Technical University, Gothenburg, Sweden.

Jan 19 Karl-Erik Årzén: "Models in on-line monitoring and diagnosis," Jernkontoret, Stockholm, Sweden.

Feb 4 Sven Erik Mattsson: "Simulation of object-oriented continuous time models," IMACS 1. MATHMOD, Technical University Vienna, Austria.

March 7 Mats Andersson: "OmSim—An integrated interactive environment for object-oriented modeling and simulation," IEEE/IFAC Joint Symposium on Computer-Aided Control System Design, Tucson, Arizona.

March 9 Anders Rantzer: "On real perturbation values," invited lecture at the conference Interval '94, St. Petersburg, Russia.

March 10 Anders Rantzer: "Systems analysis via integral quadratic constraints," St.Petersburg University, Russia.

March 11 Anders Rantzer: "Systems analysis via integral quadratic constraints," Royal Institute of Technology, Stockholm, Sweden.

March 15 Karl Johan Åström: "Industry-university cooperation—A grassroot's view," invited lecture at Crossing Frontiers and Bridging Gaps, a seminar on Swedish Experiences from Industry-University Cooperation, Brussels.

March 16 Karl Johan Åström: "Människans roll i automationssystem," Kognitionsforskning i Lund, Institutionen for Kognitionsforskning, Lunds Universitet.

March 29 Bernt Nilsson: "Dynamic modeling of chemical processes using Omola," European Symposium on Computer Aided Process Engineering—ESCAPE 4, Dublin, Ireland, 1994.

April 1 Karl Johan Åström: "Tune in the future of control," Vistas in Systems Control. Center for Control Engineering and Computation. UCSB, Santa Barbara.

April 8 Bo Bernhardsson: "Improved evaluation of asthma medicines," Lund, Sweden.

April 12 Karl Johan Åström: "Control paradigms," ABB Corporate Research, Zurich.

April 12 Anders Rantzer: "Systems analysis via integral quadratic constraints," Cambridge University, UK.

April 13 Anders Rantzer: "On the real stability radius," Cambridge University, UK.

April 19 Bo Bernhardsson: "Fractional calculus," Seminar at Lunds Matematiska Sällskap, Lund, Sweden.

April 29 Rolf Johansson: "Conditions of human postural control and measurements," Dept. Physical Therapy, Lund University Hospital, Sweden.

May 5 Karl Johan Åström: "New methods for tuning PID controllers," Satt Control, Malmö, Sweden

May 9 Bernt Nilsson: "Object-oriented modeling of process engineering systems," Annual Sydkraft seminar at Lund Institute of Technology, Lund, Sweden, 1994.

May 10 Rolf Johansson: "Quadratic optimization of impedance control," IEEE Int. Conference on Robotics and Automation, San Diego, California.

May 24 Karl Johan Åström: "What information is required to tune a PID controller," Faculty of Engineering, Singapore National University.

May 27 Rolf Johansson: "Topics in system identification," ERASMUS lecture at ENSEEIHT, Toulouse, France.

May 30 Rolf Johansson: "System identification: Linear regression problems," ERASMUS lecture at ENSEEIHT, Toulouse, France.

May 31 Rolf Johansson: "System identification: Application of nonlinear optimization methods," ERASMUS lecture at ENSEEIHT, Toulouse, France.

May 31 Sven Erik Mattsson: "Automatic Control, Lund Institute of Technology," Institut de Cibernetica, Universitat Politecnica de Catalunya, Barcelona, Spain.

June 2 Tore Hägglund: "Automatic monitoring of control loop performance," Control Systems 94—Conference on control systems in the pulp and paper industry, Stockholm, Sweden.

June 2 Sven Erik Mattsson: "An object-oriented model of a heat-exchanger unit," European Simulation Multiconference (ESM'94), Barcelona, Spain.

June 2 Bernt Nilsson: "Guidelines for process model libraries using an Object-oriented approach," European Simulation Multiconference (ESM'94), Barcelona, Spain, 1994.

June 3 Sven Erik Mattsson: "Object-oriented modelling and simulation of continuous time models," 2 hours tutorial sponsored by the Universitat Politecnica de Catalunya, European Simulation Multiconference (ESM'94), Barcelona, Spain.

June 6 Rolf Johansson: "Discrimination of patients with acoustic neurinoma and peripheral vestibular lesions with human posture dynamics," Bárány Society Int. Meeting, Uppsala, Sweden.

June 8 Bo Bernhardsson: "Topics in digital and robust control of linear systems," Linköping, Sweden.

June 8 Bo Bernhardsson: "Computation of the real stability radius," Linköping, Sweden.

June 10 Bo Bernhardsson: "Fractional calculus," Linköping, Sweden.

June 10 Rolf Johansson: "Conditions of human postural control and measurements," Dept. Physical Therapy, Lund University Hospital, Sweden.

June 10 Sven Erik Mattsson: "Object-oriented modelling and simulation of continuous time models," Department of Electrical and Electronic Engineering and Computer Science Department, University College of Swansea, Wales, UK.

June 14 Tore Hägglund: "Automatic supervision of control valves," IFAC symposium on fault detection, supervision and safety for technical processes, Helsinki, Finland.

June 16 Karl Johan Åström: "Adaptation—A control engineering perspective," invited lecture at the Workshop on Approaches to Modeling the Evolution and Breakdown of Adaptive Systems, Werner Reimers Foundation, Bad Homburg, FRG.

June 30 Karl Johan Åström: "Information and control," invited plenary lecture, IEEE Int Symposium on Information Theory, Trondheim, Norway.

H. Miscellaneous

On September 28 – October 1 the 1993 Secretary Congress was held in London, UK. The congress was arranged by the journal *Dagens Sekreterare* and had about 200 Swedish participants. From the Department **Eva Dagnegård**, **Britt-Marie Mårtensson**, **Eva Schildt**, and **Agneta Tuszynski** attended.

Mats Andersson visited Chalmers Technical University in Gothenburg where he gave a seminar on modelling and simulation of hybrid systems in Omola. He also participated in the IEEE/IFAC Joint Symposium on Computer-Aided Control System Design in Tucson, Arizona, in March.

Karl-Erik Årzén participated at the IFAC World Congress in Sydney, Australia in July 1993. He participated in the FALCON meeting and the EUFIT 93 conference in Aachen, Germany in September 1993. In October 1993 he attended the IEEE Conference on Systems, Man & Cybernetics in Le Touquet, France. In April 1994 he visited Delft Institute of technology and participated in a FALCON meeting in Bruges, Belgium.

Karl Johan Åström participated in the IFAC World Congress in Sydney, Australia in July 1993, where he was Organizer for Target Area T-3 on Intelligent Control. He also coauthored three papers. In September he participated in the Swedish-Italian Workshop on New Perspectives in Modelling and Identification with Applications in Stockholm and in 2nd IEEE Conference on Control Applications, Vancouver, Canada. He was a Cecil H. and Ida Green Visiting Professor at University of British Columbia, Vancouver, Canada, in October. In November he was invited to Wright Laboratories at the Wright Patterson AFB to discuss theory and applications of adaptive control technology.

In February 1994 he visited Canada as a member of the Mathematical Sciences Review Panel University of Toronto and in May he visited Singapore to serve on the International Advisory Panel for Singapore National University.

Bo Bernhardsson visited the IFAC conference in Sydney in July 1993, where he presented four articles. He also visited Professor Rod Bell at Macquarie University in New South Wales. In June 1994 he visited Linköping where he was external examiner for a licentiate thesis and gave two talks. During 1993 he was on leave four months to take care of his son Albin.

Tore Hägglund visited the paper mill Gruvön and performed controller field tests in September 1993. In October he gave a short industrial course in Aveiro, Portugal. He participated and presented papers at the conferences "Control Systems 94 – Conference on control systems in the pulp and paper industry" in Stockholm, and "IFAC Symposium on fault detection, supervision and safety for technical processes" in Helsinki, both in June 1994. Tore Hägglund has also lectured on industrial courses at SattControl AB in Stockholm.

Anders Hansson visited in July the IFAC World Congress held in Sydney, Australia, where he presented three papers.

Karl Henrik Johansson participated in Young Scientist's Summer Program at the International Institute of Applied System Analysis in Vienna from June to 1 August 31, 1993. In July 1993 he participated in the 12th IFAC World Congress in Sydney, where he presented a paper.

Rolf Johansson participated in IEEE Int. Conf. Robotics and Automation, San Diego, California, May 1994. He visited Departement de Mathematique Appliquée (Prof. P. Berger and Prof. J. Noailles) at E.N.S.E.E.I.H.T., Toulouse, France as a part of a faculty exchange within the framework of the ERASMUS program. In June 1994 he participated in the Bárány Society Int. Meeting, Uppsala.

Per-Olof Källén participated in the 12th IFAC World Congress in Sydney, Australia, in July 1993, where a paper was presented.

Sven Erik Mattsson participated in February 1994 in IMACS 1. MATHMOD at the Technical University Vienna, Austria and presented a paper. In March he participated in the IEEE/IFAC Joint Symposium on Computer-Aided Control System Design, CACSD'94 in Tucson, Arizona, where he was Program Co-Chairman. In June he participated in the European Simulation Multiconference, ESM'94 in Barcelona to present a paper and to give a tutorial. He was also the chairman of the Object-Oriented Modeling and Simulation Conference track. In June he also went to the University College of Swansea, Wales to act as an external examiner for a MPhil thesis and a PhD thesis.

Klas Nilsson visited The International Conference on Signal Processing Applications & Technology in Santa Clara, USA, in September and October 1993. While being in California, Klas also visited HP Labs in Palo Alto and Silma in Cupertino for discussions about robot programming. In October, he also visited McGill University, Centre for Intelligent Machines, Montreal, Canada, where he gave a seminar with the title On the Programming of Industrial Robots.

Anders Rantzer visited Royal Institute of Technology in October 1993 to give a seminar. In connection to CDC in San Antonio 1993 he was invited to give seminars at MIT, Iowa State University and Honeywell Technology Center. Based on research exchange during this trip Rantzer organized an invited session for the next CDC in Florida 1994. In March 1994, he was invited to give a lecture at the conference Interval'94 in St. Petersburg, Russia. After that he also gave a seminar at St.Petersburg University. One month later he was invited to Cambridge University, England to give seminars on Robust Control.

Bernt Nilsson participated in the IFAC World Congress of in Sydney, Australia, in July 1993. He also participated in ESCAPE 4, 4th European Symposium on Computer Aided Process Engineering. The symposium were held in Dublin, Ireland, in March 1994. In June he

participated in European Simulation Multiconference on Modeling and Simualtion in Barcelona, Spain.

Björn Wittenmark participated in the IFAC World Congress in Sydney, Australia, the Swedish-Italian workshop at KTH, and in a meeting in Compiegne within the network "Nonlinear and adaptive control" within the Human Capital and Mobility program.