Activity Report: Automatic Control 1989-1990

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1989–1990

Department of

Automatic Control

Lund Institute of Technology

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Abstract

The report surveys the activities during the academic year 1989/90 (1 July 1989 – 30 June 1990) at the Department of Automatic Control, Lund Institute of Technology, Lund, Sweden.

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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 1989 – 30 June 1990, which is the academic year 1989/90.

During this academic year, professor Karl Johan Åström was visiting professor at the Department of Electrical and Computer Engineering at The University of Texas at Austin. One PhD thesis and two Lic Tech theses were completed during the period (see Section 4).

In the development of the undergraduate curriculum, much effort has been made in revising the laboratory exercises. Three of our courses; "Computer controlled systems", "Process identification" and "Adaptive control", are prepared to suit foreign guest students. The course material in these courses has now been translated to English. In summary 518 students have attended and passed the courses of the department (see Section 2).

Research has continued in established areas such as adaptive control, expert control, computer aided control engineering, robotics, and information technology, (see Section 3). The old VAX-11/780 computer has finally been replaced by a Sun network, wich is now the basic computer environment for the department staff as well as the students. The computational environment is described in Section 5.

We want to thank our sponsors, the Swedish Board for Technical Development (STU), the Swedish Council for Planning and Coordination of Research (FRN), the National Energy Administration (Statens energiverk), the Swedish Medical Research Council (MFR), SAGEM, Sydkraft, Vattenfall, and the Knut and Alice Wallenberg Foundation, for their support to our projects.

Certain reports and theses are available for sale from the Department, see further Appendix D.

2. Education

Undergraduate Courses

Automatic control courses are taught as a part of the engineering curricula in Engineering Physics (F), Electrical Engineering (E), Computer Engineering (D), Mechanical Engineering (M), and Chemical Engineering (K).

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

Name of the course (Section)	Number of students
Reglerteknik AK (F, E, D) (Automatic control, linear systems)	209
Reglerteknik AK (M) (Automatic control, linear systems)	91
Processreglering (K) (Automatic Process control)	99
Digital reglering (F, E, D) (Computer controlled systems)	54
Datorimplementering av reglersystem (F, E, D) (Computer implementation of control systems)	42
Processidentifiering (F, E, D) (Process identification)	8
Adaptiv reglering (F, E, D) (Adaptive control)	15

The figures give the number of students that have passed the courses during 1989/90, totally 518 students.

Master Theses

Twenty-nine students completed their master theses during the year. A list is given in Appendix D.

The theses concerned the following application areas: Adaptive control (3), Biomedical engineering (2), Computer aided design and computer graphics (2), Controller implementation (1), Image processing (4), Knowledge-based systems (2), Man-machine interaction (3), Power systems (4), Process control (4), Robotics and servo mechanisms (4).

Graduate Courses

One PhD thesis and two Lic Tech theses were completed during the period. The abstracts of these are given in Chapter 4. One new PhD student (Anders Hansson) was admitted to the department.

The following PhD courses have been given:

Linear Systems, 10 p (Per Hagander)	fall 1989
Nonlinear Systems, 4 p (Björn Wittenmark)	spring 1990
H_∞-Control, 2 p (Michael Green)	March 1990

Extension Courses

The extension program in automatic control offers courses for extended education of engineers in industry. The courses given by the department are:

Introduction to automatic control
Digital control
Simulation and modeling
Process identification
Adaptive control
Knowledge-based process control

A course demands 3–4 days of attendance and takes 16–20 participants. Each course day usually consists of two or three lectures and a laboratory session of about four hours. The following course has been given during the period:

Knowledge-based process control	9–12 January 1990

On the 4–7 September 1989, Andrew R. Koenig from AT & T Bell Laboratories gave the course "Effective Use of C++" at the department. The participants were the department staff and externals from universities and industry.

3. Research

Research at the department concerns theory and applications. The main research areas have been:

Adaptive control
Computer aided control engineering
Expert control
Robotics and sensory control
Power systems
Control of biotechnology processes
Modeling and control of medical systems
Control in ODE-solvers

The areas are highlighted below.

Adaptive Control

Researchers: Karl Johan Åström, Björn Wittenmark, Rolf Johansson, Tore Hägglund, Mats Lilja, Michael Lundh, Bo Bernhardsson, Per-Olof Olsson, Ulf Holmberg

During the last year the following problem areas in adaptive control have been investigated:

- Analysis of robustness of adaptive systems
- Analysis of auto-tuning
- Multivariable adaptive control

The development in adaptive control is summarized in the text book Åström and Wittenmark (1989). New emerging research problems have also arisen. In this context we would in particular like to mention robust adaptive control and the relations between adaptive control and AI. An idea is to investigate if robust design methods (H_∞) can increase the performance of adaptive controllers.

Adaptive control research is currently focused on the use of parametric models. The parameters can typically be coefficients in a transfer function model. This approach has proven very successful. It is easy to generate recursive parameter estimators, and there are control design techniques available. The approach has, however, two significant drawbacks, first it is necessary to assume a model structure, secondly the parametric approach is not well suited to capture model uncertainty. A nonparametric approach can be developed using frequency domain concepts. This has been pursued for simple systems. The key idea is to determine and track critical points on the Nyquist curve of the process.

The main thrust of the research is now to develop frequency response approaches to adaptive control. A key problem is to develop suitable design methods that can be used on line. A first step in this direction is methods based on measurements of the transfer function for a low number of frequencies. This knowledge can be used to design a low order controller based on approximation theory.

Some work on multivariable adaptive control has been done. Adaptive control of a robot manipulator motion designed by methods of optimization and Lyapunov theory has been developed. The methods exploits the physical structure of the system as well as the natural energy interpretations of the Lyapunov functions used in the design.

Computer Aided Control Engineering (CACE)

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

Mathematical models are important in all kinds of engineering and particularly in Computer Aided Control Engineering (CACE). Model development is often a time consuming and difficult task. The CACE project aims to provide better computer support to facilitate development of new models and reuse of old ones.

Model development is facilitated by tools providing a proper set of high-level concepts for describing models of dynamic systems. The concepts

must include ways to describe the models in a modular fashion to ease reuse of model components. The models should also be described in a problem independent way. We claim that most modeling and simulation languages in use today fail to meet these basic requirements.

We have proposed a new universal modeling language, based on ideas from object-oriented programming, called Omola. The language provides concepts for defining models in a structured and modular way. It also allows models and model components to be defined as specializations of previously defined models by using the inheritance concept adopted from object-oriented programming. Inheritance will facilitate model reuse. The mathematical framework currently considered for representing model behaviour is based on differential and algebraic equations. However, the Omola language permits a wide variety of other formalism to be used.

Many of the new modeling concepts have been experimented with in a prototype implementation based on Common Lisp and KEE. A currently on-going project will implement a kernel for model representation based on Omola. The implementation is done in C++ and it will include a simulator for continuous time and sampled data models as well as some basic tools for defining and manipulating models interactively and for checking model consistency. The kernel will serve as a work-bench and a framework for further experiments in advanced user interfaces, symbolic model manipulation, design tool integration, etc.

Future research will be directed towards modeling and simulation of combined continuous time and discrete event models and symbolic manipulation to reduce the index of high index problems. Further research is also needed in object-oriented modeling methodology and in tool integration, i.e., how a set of tools should cooperate in an integrated environment in order to aid the user solving advanced problems in control and process design.

Expert System Applications in Automatic Control

Researchers: Karl-Erik Årzén, Jan Eric Larsson, Per Persson, Stéphane Sallé

Expert Control. Research on expert control has been funded by STU since 1985. The goal of expert control is to extend the range of conventional controllers by encoding general control knowledge and heuristics concerning tuning and adaptation in a supervisory expert system. An important part of the project is architectures for real-time, on-line expert systems. The work during the last year has concentrated on dominant pole design methods and an implementation of an expert controller based on the Muse expert system tool.

Knowledge-Based Control Systems. The department is a part of the IT4 project "Knowledge-based real-time control systems" together with ABB and SattControl. The aim of the project is to specify and verify a system architecture that integrates knowledge-based techniques with conventional distributed control systems. The concept is based on a common knowledge base containing an object-oriented multi-level, multi-view model of the process and the control system. The UHT sterilization process Steritherm from Alfa Laval is used as a demonstrator.

Two prototypes have been developed. One uses hypermedia techniques to emulate the operator interface of a knowledge-based control system. This prototype is implemented in the hypermedia tool Plus on an Apple Macintosh II computer. The second prototype uses the real-time expert system tool G2 to explore the internal structure of the knowledge base. The G2 prototype consists of two main parts: a real-time Steritherm simulator and a model of a knowledge-based control system that controls and monitors the simulation model. The control system includes continuous PID control, sequential control, alarm logic, rule-based monitoring, model-based on-line diagnosis based on quantitative governing equations, fault tree based off-line alarm analysis, and a product following system. The model-based diagnosis part was developed by Thomas F. Petti from the University of Delaware who participated in the project between October–December 1989. The use of the functional

modelling methodology Multi-level Flow Models (MFM) developed by Morten Lind as a base for diagnosis schemes is being explored by Jan Eric Larsson.

Robotics and Sensory Control

Researchers: Lars Nielsen, Ola Dahl, Klas Nilsson

A laboratory for robotics and sensory control has been initiated. The responsible researcher is Lars Nielsen. The experimental work is centered around an Asea Irb-6 robot. Hardware interfaces have been developed to create an open system suitable for control experiments. Other experimental setups are a separate Asea Irb-6 DC-servo motor with the same interfaces, and setups around different versions of a DC-servo developed at the department. Among these setups there is a robot simulator based on two such DC servos connected via a signal processor. The computer hardware is a VME-based system connected to a SUN workstation. We use software based on the language Modula-2 and on a real time programming environment developed at the department.

Using this environment a number of projects and prototype systems have been tested in research, education and master theses work. 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. Typical applications are gluing, arc welding and laser cutting. Control algorithms for adjustment of a nominal velocity profile along the path have been developed and tested in simulations and experiments. Other projects include identification of robot parameters from real data, experiments with adaptive control of the Asea Irb-6 robot, calibration of both robot and sensors with emphasis on autonomous calibration, implementation of robot control programs, and automatic generation of code for control algorithms.

Power Systems

Researchers: Brian Surgenor, Magnus Akke, Bo Eliasson, Karl Johan Åström, Björn Wittenmark

A guest professor in power systems has been supported by Sydkraft and Vattenfall. During spring 1990 the position was help by professor Brian Surgenor from Queen's University, Kingston, Canada. Special focus was given to the area expert systems in power generation. The aim of the project was to demonstrate the application of an expert system software tool to thermal performance analysis. A prototype was written using G2 for application to Sydkraft's Barsebäck nuclear power plant.

A second research area in power systems is power system stabilization. Self-excited low frequency power oscillations in large power systems may jeopardize the operation of the systems. The problem is to model the large systems and to decide where to place the damping equipment. The design methods are tested on models of the Nordic power system. The load model has a great influence on the resulting controller. Voltage dependent loads have been investigated in cooperation with professor David Hill, University of Newcastle, Australia. Further work on siting and tuning of power system stabilizers has been done and the methods are demonstrated on a 244 machine model of the Nordic power system.

Control of Biotechnology Processes

Researchers: Per Hagander in cooperation with O. Holst and B. Mathiasson (Biotechnology, Lund)

A joint project with the Division of Biotechnology, Chemical Center, Lund, on control in biotechnology processes has been funded by STU since 1983. The purpose of the work is to investigate the possibilities for process control using direct measurements of substrate, product and intermediates in the processes. Newly developed biosensors have been applied to fed-batch production of baker's yeast. Here measurement of ethanol concentration gives a sensitive indication of the metabolic state

of the cells. Identification experiments are performed in closed loop, and parameter estimation is done for models with partially known dynamics. The process dynamic changes during a batch, but the main control problem is to follow the increasing with the exponential growth rate μ. It is found advantageous to substitute the I-part of a PID-regulator with an unstable part with a pole at μ using a reduced order observer. The D-part can be tuned for robustness. In certain situation μ may change, and an adaptive observer tracking such changes is shown to improve the control. Some optimal control problems are also formulated and investigated using nonlinear control theory.

The bacteria *Pseudomonas Cepacia* is grown on the toxic substrate salicylate to produce the enzyme salicylate hydroxylase. The enzyme is, e.g., used in clinical chemistry to determine salicylate in blood samples. The purpose of the work is to control the substrate addition to be enough for growth without any adverse effect from its toxicity. A spectrophotometric sensor is developed, and experiments are performed using PI-control around a basic substrate flow scheme. The growth rate is quite high provided that a high oxygen concentration can be maintained.

Modeling and Control in Medical Systems

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

Two projects treat estimation of parameters and modeling of human posture dynamics. The work is sponsored by the Swedish Medical Research Council (MFR) and Söderbergs Foundation. The stability investigation is made with induced body sway by galvanic or vibratory stimuli followed by analysis with application of methods from signal processing and control theory. The goal is to find parameters that describe the human ability to maintain posture. The methods developed are intended for use in diagnosis and rehabilitation of human balance disorders.

Error and Convergence Control in ODE-solvers

Researchers: Kjell Gustafsson in cooperation with Gustaf Söderlind (ITM, Stockholm)

When implementing a numerical algorithm it has to be equipped with supervisory code that acts as a safety net. This code chooses parameters and handles exceptional cases in such a way that the algorithm runs smoothly and produces a correct result. Using analogies from automatic control the supervisory code can be regarded as a controller with the numerical algorithm as the controlled process.

In the case of numerical integration of ordinary differential equations the control objective is to produce a sufficiently accurate solution with the least amount of computation. An important control variable is the stepsize which directly affects the integration error. Traditionally, the same stepsize selection rule is used for all integration methods. However, different methods have different properties and using the insight provided by the control analysis it is possible to improve on the stepsize controller.

Recently, the research has been aimed at control of implicit methods. An implicit method includes an equation solver, which the controller has to supervise. The interaction between the different loops complicates the control design.

4. Dissertations

One PhD thesis and two Lic Tech theses were defended during the year. The abstracts are presented below.

Controller Design by Frequency Domain Approximation

Mats Lilja
PhD dissertation, 27 October 1989

Approximation is important in many areas of applied mathematics. It enters in a natural way in control systems design, where a controller of a specified order is computed such that a certain closed loop performance or robustness is achieved. Some different approximation methods are reviewed in the thesis and a new method for computing controllers from frequency response data, is proposed.

In the thesis a new method for Hankel norm approximation of rational functions is presented where the coefficents of the (SISO) rational function is used directly without any transformation to state space. Least squares approximation of transfer functions is treated in the form of Nyquist curve fitting at a finite number of frequencies. A new method for least squares fitting to a rational function times an exponential, is demonstrated.

The polynomial version of pole placement is reviewed and some examples show the bad robustness in the case where the closed loop bandwidth is chosen much higher than the bandwidth of the plant. A new design method is presented, where the controller has the same two degree of freedom structure as in the pole placement method. In this method, least squares fitting is used to calculate a controller of speci-

fied order so that the closed loop transfer function is close to a specified function at certain frequencies.

Loop shaping by least squares approximation is used to obtain robustness against variations in loop gain. A controller of specified order is calculated such that the loop transfer function approximates a non-rational transfer function with constant phase.

Structured Modelling of Chemical Processes —An Object-Oriented Approach

Bernt Nilsson
Lic Tech dissertation, 20 October 1989

Models and modelling are gaining more and more interest in process industry. Important tasks are model development, model reuse, model refinement and model maintenance. Systems for modelling and simulation of today do not support these tasks in a wider extent. A process modelling environment supporting these tasks will make it possible to distribute the modelling efforts to different model developers and end users. It will also increase the speed of model development. Modelling of a typical continuous chemical process based on an object-oriented approach is investigated.

The study uses recently developed tools for model development and simulation. The chemical plant is used to illustrate ideas and benefits of the new object-oriented modelling methodology. In the case study the aim is to develop a process model of reusable and adaptable process objects. Modularization of large process models into encapsulated smaller submodels in a hierarchical submodel description is one of the major concepts that facilitates development and reuse. Inheritance is another concept, which also facilitates model development and reuse.

Models and model components are represented as objects in single inheritance object class hierarchies. The power of inheritance in process

modelling is shown and discussed. To further facilitate reuse and development of generic process submodels, a number of methods for process model decompositions and parametrizations are presented. Reusable and adaptable process models are stored in process model libraries, which can be used and modified by the user.

Omola—An Object-Oriented Language for Model Representation

Mats Andersson
Lic Tech dissertation, 5 June 1990

Models are essential in all kinds of control and process engineering. Computer based tools for control and process engineering are available but different tools do not communicate easily. This thesis presents a new language for structured dynamic models. The language, called Omola, is inteded to function as a common representation in an integrated environment of cooperating control engineering tools.

The thesis discusses the basic requirements on a new modeling languages and it presents the fundamental model structuring concepts and the design of Omola. Some basic algorithms for checking model consistency are outlined. Finally, as an example, an Omola model of a chemical reactor is presented.

Models can be decomposed into a multi-level hierarchy of submodels with abstract interfaces based on terminals and parameters. Models may have multiple descriptions of behaviour and terminals may be structured to model physical interaction. The framework for describing model behaviour is based on differential and algebraic equations but also more special descriptions of behaviour are considered.

Omola is based on ideas from object-oriented programming. Models are represented as classes with attributes. Inheritance and hierarchical submodel decomposition improves model structure and facilitates reuse

of models. The language is designed to be general and extendible in order to represent future, yet unpredicted, model representation concepts.

5. Computer Facilities

During the year the old VAX-11/780 has finally been decommissioned after ten years of service, and the Iris Workstation has been exchanged for a SPARCstation. The Sun network has been expanded with a new file server (Sun 4/390) and a number of SPARCstations. The basic computer environment for the department staff and students is thus a Sun network, except for a few Macs.

An important new acquisition to the undergraduate lab is a number of lab computers with Motorola 68020 as CPU, based on the VME bus. They have a process interface with analog and digital input and output and ethernet for communication. There are also a number of Sun workstations available to the students, and the idea is that all program development should be made on the workstations and the finished code downloded to the lab computers.

The total computer capabilities of the department are as follows:

- A **Sun Workstation** network with two file servers, a Sun 3/180 with 400 MB disk and a Sun 4/390 with 1.6 GB disk. There are 8 SPARCstations and 12 older workstations of type Sun3. Two of the workstations have color monitors.
- Four **Macintoshes**, used for text processing and for creating figures and drawings for the technical reports. A special program enables the inclusion of drawings produced on the Macintosh directly into TEX documents produced on the Suns.
- Four **Macintosh II** intended for development of control engineering software in a Macintosh environment. All Macintoshes are connected together in an Apple Local Talk network, and some of them also have Ethernet. The two networks are connected via special bridge software running in one of the more powerful Macs.

- An **Undergraduate Computer Lab** with 5 Sun 3/80 workstations and lab computers with 68020:s as indicated above. The basic software for the lab computers is in a build-up phase, but the systems have nonetheless been used in successful undergraduate projects in a limited scale. The programming is done in Modula-2, which is cross-compiled and linked on the Suns using a compiler from Oregon Software. The intention is that these computers will take over most of the more advanced real-time work from the IBM-AT:s mentioned below.

  The workstations are also used in undergraduate courses for Matlab, Simnon and other program packages. They are freely available to the students any time of day.

- Fourteen **IBM-AT** or compatibles with 640 kB memory and 20 MB disk. They have analog input and output channels (4 or 16 channels in and 2 or 8 channels out) and also some digital I/O. The main use of these computers is for real time control, both in formal lab exercises and projects in the undergraduate courses, and also in research projects by graduate students and faculty. The programming is done almost exclusively in Modula-2, and a library containing a real time kernel and real time graphics has been developed. This library has reached such a state of maturity that researchers wishing to perform a control experiment can concentrate on the control algorithm and let the library take care of the problems of real-time programming. The achievable sampling rates is up to 100 Hz.

  The same computers are also used for control design. A real-time version of PC-Simnon has been developed so that control experiments can be performed directly with the Simnon code. Alternatively parameters obtained in a design can be transferred to the Modula-2 system for control of the real process.

  The PC-Simnon is very easily available and has grown to a great success.

A. List of Personnel

The following list shows the status of June 1990 if nothing else is mentioned.

Professorer (Professors)

Karl Johan Åström (on leave 1989/90)
Björn Wittenmark

Högskolelektorer (Associate professors)

Per Hagander
Tore Hägglund
Rolf Johansson
Lars Nielsen

Forskarassistent (Research associate)

Sven Erik Mattsson

Forskningsingenjörer (Research engineers)

Leif Andersson
Anders Blomdell
Rolf Braun
Tomas Schönthal

Forskningsassistenter (Research assistants)

Magnus Akke (till January 1990)
Mats Andersson
Karl-Erik Årzén
Jan Peter Axelsson (till January 1990)
Dag Brück
Anders Hansson

Per-Olof Källén
Mats Lilja
Bernt Nilsson
Klas Nilsson
Lars Rundqwist

Doktorandtjänster (Teaching assistants)

Bo Bernhardsson
Ola Dahl
Kjell Gustafsson
Ulf Holmberg
Jan Eric Larsson
Michael Lundh
Per Persson

Institutionssekreterare (Secretaries)

Eva Dagnegård (part time)
Eva Schildt
Agneta Tuszynski (part time)

Assistent (Technical drawings)

Britt-Marie Mårtensson

Visiting Scientists

Professor Carlos Canudas
Laboratoire d'Automatique de Grenoble
ENSIEG, Grenoble, France
(20 July – 4 Sept 1989, 19–23 Febr 1990)

Professor Ibrahim Eksin
Istanbul Technical University
Maslak/Istanbul, Turkey
(30 Nov 1989 – 12 Jan 1990)

Professor Michel Gevers
Université Catholique de Louvain, Belgium
(4–12 April 1990)

Dr Michael Green
Dept of Electrical Engineering, Imperial College
London, UK
(26–30 March 1990)

Mr Tom Petti
Dept of Chemical Engineering, University of Delaware
Newark, Delaware
(3 Oct – 22 Dec 1989)

Mr Stéphane Sallé
Laboratoire d'Automatique de Grenoble
ENSIEG, Grenoble, France
(13 February 1989 – 24 May 1990)

Mr Javier Serrano
Universitat Autonoma de Barcelona, Spain
(From 10 Jan 1990)

Dr Brian Surgenor
Dept of Mechanical Engineering, Queens University
Kingston, Canada
(5 Febr – 15 June 1990)

Ms Claire Valentin
Laboratoire d'Automatique de Grenoble
ENSIEG, Grenoble, France
(31 March – 15 Sept 1989)

Mr Kirthy Walgama
Institute of Technology, Luleå, Sweden
(9–20 Oct 1989)

B. Awards

Karl Johan Åström received the *IEEE Field Award 1990 in Control Systems Science and Engineering* for "fundamental contributions in control theory with emphasis on its practical applications". He also received the *Donald G. Fink Prize Paper Award* for his paper "Adaptive feedback Control," *Proc. IEEE,* **75** (1987) 185–217.

Tore Hägglund received the award *Innovation Cup 1989* sponsored by Skandia and Dagens Industri. His contribution was "A predictive PI controller for processes with long dead time."

Bo Bernhardsson and **Bernt Nilsson** both received Saab-Scania awards for graduate students in Automatic Control at the annual meeting of shareholders in Linköping.

C. External Publications

Books

Åström, K. J., and B. Wittenmark (1989): *Adaptive Control*, Addison-Wesley, Reading, Massachusetts.

Åström, K. J., and B. Wittenmark (1990): *Computer Controlled Systems – Theory and Design*, Second edition, Prentice-Hall, Englewood Cliffs, NJ.

Hägglund, T. (1990): *Praktisk Processreglering (Applied Process Control)*, Studentlitteratur, Lund, Sweden.

Papers

Årzén, K-E. (1989): "An architecture for expert system based feedback control," *Automatica*, **25**, No 6, 813–829.

Åström, K. J. (1990): "Application of robust and adaptive pole placement," *Int. J. of Adaptive Control and Signal Processing*, **4**, 99–111.

Åström, K. J. (1990): "Automatic tuning and adaptive control – Past accomplishments and future directions," in D. M. Prett and C. E. Garcia (Eds.): *The Second Shell Process Control Workshop*, Butterworths, Stoneham, MA, pp. 1–24..

Bernhardsson, B., L. Ljung and K. Wang (1990): "Corrections to 'A discussion of adaptive stabilization and robust adaptive control'," *Systems and Control Letters*, **14**, 183.

Brück, Dag M. (1989): "Useful use counts in C++," *The C++ Report*, **1**, No 10, November/December.

Brück, Dag M. (1990): "Debugging C++ programs with xdbx," *The C++ Report*, **2**, No 5, May.

Johansson, R. (1989): "Global Lyapunov stability and exponential convergence of direct adaptive control," *Int. J. Control*, **50**, 859–869.

Johansson, R., and M. Magnusson (1989): "Determination of characteristic parameters of human postural dynamics," *Acta Otolaryngologica*.

Larsson, J. E. (1989): "AILU?," Teknologkåren vid Lunds Tekniska Högskola, Lund, *ORDO*, **3/89**, årgång 23.

Larsson, J. E. (1989): "A Chess Font for TEX," *TUGboat*, **10**, No 3, p. 351.

Magnusson, M., and R. Johansson (1989): "Dynamic performance of vibration induced body sway during upright posture in normal subjects," *Acta Otolaryngologica*.

Sparr, G., A. Hansson and L. Nielsen (1990): "Discontinuity preserving visual reconstruction by means of potential theory," *Pattern Recognition Letters*, **11**, 117–122.

Conference Contributions

Andersson, M. (1989): "An object-oriented language for model representation," *1989 IEEE Control Systems Society Workshop on Computer-Aided Control System Design (CACSD)*, Tampa, Florida.

Årzén, K-E. (1990): "Knowledge-based control systems," *American Control Conference (ACC '90)*, San Diego, CA.

Åström, K. J., and T. Hägglund (1990): "Practical Experiences of Adaptive Techniques," *American Control Conference (ACC '90)*, San Diego, California.

Åström, K. J., C. C. Hang and P. Persson (1989): "Towards intelligent PID control," *IFAC Workshop on Artificial Intelligence in Real Time Control*, Shenyang, P. R. China.

Axelsson, J. P., and P. Hagander (1989): "Flow-rate control of a continuous stirred tank reactor – Start-up and large disturbances," *Annual AIChE Meeting,* San Francisco, California.

Bernhardsson, B. (1990): "Does computer technology change the education in mathematics?," *Conference on Mathematics in the New Engineering Education,* Växjö, Sweden.

Brück, Dag M., "Experiences of Object-Oriented Development in C++ and InterViews," *Proc. TOOLS'89,* Paris, France, pp. 123–127.

Dahl, O., and L. Nielsen (1990): "Stability analysis of an on-line algorithm for torque limited path following," *IEEE Int. Conference on Robotics and Automation,* Cincinnati, Ohio.

Dahl, O., and L. Nielsen (1990): "Torque limited path following by on-line trajectory time scaling," *Nordisk doktorgradsforskning innen Robotteknikk,* Trondheim, Norge.

DeWeerth, S., L. Nielsen, C. Mead and K. J. Åström (1990): "A neuron-based pulse servo for motion control," *IEEE Int. Conference on Robotics and Automation,* Cincinnati, Ohio.

Gustafsson, K., and Söderlind, G. (1990): "Towards a New Strategy for Stepsize and Convergence Control in Implicit RK," *The 1990 Conference on the Numerical Solution of Ordinary Differential Equations,* Helsinki, Finland.

Johansson, R. (1990): "Quadratic optimization of motion coordination and control," *Proc. IEEE Int. Conf. Robotics and Automation,* Cincinatti, Ohio.

Johansson, R. (1990): "Quadratic optimization of motion coordination and control," *Proc. American Control Conference (ACC '90),* San Diego, California.

Johansson, R., and M. Magnusson (1990): "Lateral posture stability during galvanic stimulation," *Barany Society Int. Meeting,* Tokyo, Japan.

Larsson, J. E. (1990): "A multilevel flow model of steritherm," *Proceedings of the SAIS '90 Workshop,* Dept of Computer and System Sciences, University of Stockholm/Royal Institute of Technology, Stockholm, Sweden.

Magnusson, M., S. Padouan, M. Karlberg and R. Johansson (1990): "Delayed onset of ototoxic effects of gentamicin in treatment of Ménière's disease.," *Barany Society Int. Meeting,* Tokyo, Japan.

Magnusson, M., R. Johansson and J. Wiklund (1990): "Galvanically induced body sway in the anterior-posterior plane," *Barany Society Int. Meeting,* Tokyo, Japan.

Mattsson, S. E., and G. Söderlind (1990): "A new technique for solution of high index differential-algebraic equations," *The 1990 Conference on the Numerical Solution of Ordinary Differential Equations,* Helsinki, Finland.

Nilsson, B. (1989): "Structured modelling of chemical processes with control systems," *Annual AIChE Meeting 1989,* San Francisco, California.

Sallé, S. E., and K-E. Årzén, "A comparison between three development tools for real-time expert systems: Chronos, G2, and Muse," Proc. of Workshop on Computer-Aided Control Systems Design CACSD'89, Florida.

Sparr, G., and L. Nielsen (1990): "Shape and mutual cross-ratios with applications to different orientation problems," *Symposium SSAB (Svenska Sällskapet för Automatiserad Bildanalys),* (Swedish APR (Association for Pattern Recognition)), Linköping, Sweden.

Sparr, G., and L. Nielsen (1990): "Shape and mutual cross-ratios with applications to exterior, interior, and relative orientation," in O. Faugeras (Ed.): *Computer Vision – ECCV 90,* Proceedings of First European Conference on Computer Vision, Antibes, France. Lecture Notes in Computer Science no 427, Springer-Verlag, pp. 607–609.

Sparr, G., L. Nielsen and C-G. Werner (1990): "Analytic and geometric image modelling," *Symposium SSAB (Svenska Sällskapet för Automatis-*

erad Bildanalys), (Swedish APR (Association for Pattern Recognition)), Linköping, Sweden.

Verbruggen, H. B., and K. J. Åström (1989): "Embedded rule-based systems," invited lecture, *IFAC Workshop on Artificial Intelligence in Real Time Control*, Shenyang, P. R. China.

Wittenmark, B. (1989): "Theory of low cost automation," *Preprints 2nd IFAC Symp. on Low Cost Automation*, Milano, Italy.

Wittenmark, B. (1990): "Prediction and adaptation in stochastic systems," *Preprints 5th Annual Conference of the European Consortium for Mathematics in Industry*, Lahti, Finland.

Technical Reports

ABB, SattControl, and Department of Automatic Control (1990): "Knowledge-based real-time control systems: IT4 project – Phase I," Lund, Sweden.

Larsson, J. E. (Ed.) (1990): "Projekt i Tillämpad AI 1989, (Projects in Applied AI 1989)," Internal report, LU-CS-IR: 90.1, Dept of Computer Science, Lund Institute of Technology, Lund, Sweden.

Sparr, G., and L. Nielsen (1990): "Shape and mutual cross-ratios with applications to orientation problems," Report 1990:3, Department of Mathematics, Lund Institute of Technology, Lund, Sweden.

D. Reports

The reports listed in this appendix are numbered with "TFRT-" and four numerals. This number is part of the complete report number CODEN: LUTFD2/(TFRT-0000).

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:

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Svenska Tryckavdelningen, S-106 91 Stockholm

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Lund Institute of Technology
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Please be certain to include both the report number and the title.

PhD Theses

Eliasson, B., "Damping of power oscillations in large power systems," TFRT-1032, May 1990. To be defended in September.

Lilja, M., "Controller design by frequency domain approximation," TFRT-1031, August 1989.

Lic Tech Theses

Andersson, M., "Omola – An object-oriented language for model representation," TFRT-3208, May 1990.

Nilsson, B., "Structured modelling of chemical processes – An object-oriented approach," TFRT-3203, September 1989.

Final Reports

Åström, K. J., "Computer aided tools for control system design," TFRT-3207, December 1989.

Mattsson, S. E., and M. Andersson, "An environment for model development and simulation. STU project 87-02503, 87-02425," TFRT-3205, September 1989.

Wittenmark, B., and K. J. Åström, "Automatic control, LTH – Past, present and future," TFRT-3206, February 1990.

Activity Report

Dagnegård, E. and R. Johansson, "Activity report 1988–89," TFRT-4017, December 1989.

Master Theses

Ahlgren, M., and F. Lönegård, "Reglering av lödda värmeväxlare för ångapplikationer," (Control of brased heat exchanger in steam applications), TFRT-5418, October 1989.

Åkeson, M., "Adaptive polplacering med automatiskt val av specifikationer," (Adaptive pole placement with automatic choice of specifications), TFRT-5405, July 1989.

Andersson, U., "Implementering av en fuzzyregulator," (Implementation of a fuzzy controller), TFRT-5415, October 1989.

Bengtsson, H., and A. Söderstjärna, "Automatisk viktreglering av ubåt med olinjära systemkomponenter," (Automatic weight control of submarine with nonlinear system components), TFRT-5420, January 1990.

Bergstrand, M., "Service restoration in electric power distribution networks," TFRT-5412, October 1989.

Christiansson, M., and P. Ericsson, "Knowledge-based control and modelling with G2," TFRT-5411, October 1989.

Edler, M., and F. Holst, "Farkoststyrning och förarmiljö," (Man-machine adaptation of the steering gear in a submarine), TFRT-5417, October 1989.

Eneberg, J., "Användande av a priori-kunskap i adaptiva regulatorer," (A priori knowledge in adaptive controllers), TFRT-5408, September 1989.

Ericsson, T., "Window based handling of image hardware," TFRT-5416, October 1989.

Ericsson, T., and M. Andersson, "Bildbehandling för bestämning av detaljers position och orientering," (Determination of position and orientation using image processing), TFRT-5413, October 1989.

Fredriksson, H., and J. Nilsson, "Gasturbinmodell för gaskombikraftverk," (Gas turbine model for a combined cycle power plant), TFRT-5409, September 1989.

Halling, L., and T. Zeidler, "Modellbygge och simulering av värmebatteri," (Modelling and simulation of a crossflow heat exchanger), TFRT-5424, June 1990.

Hedlund, H., "Automatisk regulatorinställning på kontinuerlig pappersmassakokare," (Automatic controller tuning on a continuous pulp digester), TFRT-5423, April 1990.

Höjerback, P., "Designing a process operator interface – A hypermedia model," TFRT-5414, October 1989.

Höskuldsson, G., "Sensorimotor integration in oculomotor control," TFRT-5405, August 1989.

Klinghult, G., "Adaptiv parameterstyrning av förbränningsmotorer," (Adaptive gain scheduling of a combustion engine), TFRT-5419, December 1989.

Lönnell, K., "PostScript images generated from InterViews," TFRT-5421, January 1990.

Pålsson, M., "Investigations of the potential theory model for image interpolation," TFRT-5422, February 1990.

Persson, A., "Stability of gain scheduled systems," TFRT-5406, August 1989.

Persson, J., "Vattenkraftens bidrag till dämpningen av långsamma effektpendlingar i stora elkraftsystem," (Hydroelectric power plants contribution to the damping of low frequency power oscillations in large power systems), TFRT-5407, October 1989.

Wilhelmsson, G., and M. Hansson, "Utbytbarhetsproblemet för robotar," (The exchange problem for industrial robots), TFRT-5410, September 1989.

Internal Reports

Åström, K. J., "Adaptive control – A perspective," TFRT-7427, August 1989.

Åström, K. J., "Projekt i adaptiv reglering," (Projects in adaptive control), TFRT-7444, January 1990.

Åström, K. J., "Adaptation, auto-tuning and smart controls," TFRT-7445, December 1989.

Åström, K. J., C. C. Hang and P. Persson, "Intelligence PID control," TFRT-7434, October 1989.

Axelsson, J. P., P. Hagander and O. Holst, "Substrate control of biotechnical fedbatch processes and the role of adaptivity," TFRT-7424, August 1989.

Bernhardsson, B., "Geometric theory for multivariable linear systems with MATLAB examples," TFRT-7447, March 1990.

Bernhardsson, B., and P. Hagander, "Exercises in linear system theory," TFRT-7448, March 1990.

Brück, D., "C++ committee meeting December 15, 1989," TFRT-7421, January 1990.

Brück, D., "Scones – An interactive block diagram editor for Simnon," TFRT-7423, July 1989.

Brück, D., "ANSI C++ committee meeting March 12–16, 1990," TFRT-7450, April 1990.

Brück, D., "ANSI C++ Committe meeting March 12–16, 1990," TFRT-7452, April 1990.

Dagnegård, E., "Emacs på Sun," (Emacs on Sun), TFRT-7430, September 1989.

Dahl, O., "SIM2DDC – User's manual," TFRT-7443, January 1990.

Dahl, O., and L. Nielsen, "Stability analysis of an on-line algorithm for torque limited path following," TFRT-7449, March 1990.

DeWeerth, S., L. Nielsen, C. Mead and K. J. Åström, "A neuron-based pulse servo for motion control," TFRT-7446, March 1990.

Eliasson, B. E., and D. J. Hill, "Damping structure in power systems," TFRT-7460, December 1989.

Ericsson, T., and L. Nielsen, "Window based interactive image processing," TFRT-7440, December 1989.

Hägglund, T., "A predictive PI controller for processes with long dead time," TFRT-7435, October 1989.

Hägglund, T., and K. J. Åström, "An industrial adaptive PID controller," TFRT-7426, August 1989.

Johansson, R., O. Dahl and K. Gustafsson, "Processidentifiering – Projektarbeten hösten 1989," (Process identification – Project work autumn 1989), TFRT-7451, April 1990.

Lundh, M., "Hermite forms in algebraic system theory," TFRT-7432, October 1989.

Lundh, M., "Optimization based robust design of uncertain SISO systems," TFRT-7442, January 1990.

Mattsson, S. E., "The CACE project – Steering committee meeting 1989-09-08," TFRT-7437, November 1989.

Mattsson, S. E. (Ed.), "New tools for model development and simulation. Proceedings of a full-day seminar, Stockholm, 24 October 1989," TFRT-7438, November 1989.

Mattsson, S. E., and M. Andersson, "A kernel for system representation," TFRT-7429, August 1989.

Nielsen, L., and G. Sparr, "Projective area-invariants as an extension of the cross-ratio," TFRT-7441, December 1989.

Nilsson, B., "Object-oriented modelling of a controlled chemical process," TFRT-7428, August 1989.

Nilsson, B., "Structured modelling of chemical processes with control systems," TFRT-7439, November 1989.

Sallé, S., and K. E. Årzén, "A comparison between three development tools for real-time expert systems: CHRONOS, G2 and MUSE," TFRT-7436, November 1989.

Surgenor, B., "Thermal performance analysis: An expert systems approach," TFRT-7453, June 1990.

Valentin, C., "Combining auto-tuning and adaptation," TFRT-7431, September 1989.

Verbruggen, H. B., and K. J. Åström, "Artificial intelligence and feedback control," TFRT-7433, October 1989.

Travel Report

Akke, M., "Travel report from Australia, Singapore and Korea," TFRT-8047, November 1989.

E. Seminars at the Department

Seminars given at the department during the academic year 1989–1990, are summarized here. They are given both by the staff at the department and by invited lecturers.

1989

July 3	A. M. Annaswamy (Boston University): "Direct and indirect adaptive control."
July 15	Anders Rantzer (KTH, Stockholm): "Test of Hurwitz stability of families of polynomials and the SPR condition of families of rational functions."
July 10	Mårten Åkesson: "Adaptive systems with automatic choice of specifications." MSc-thesis presentation.
Aug 15	Anders Persson: "Stability of gain scheduled systems." MSc-thesis presentation.
Aug 18	A. Cinar (Illinois Inst. Tech.): "Real-time expert systems for supervisory control of chemical processes."
Aug 23	Carlos Canudas de Wit (Grenoble): "Nonlinear observers for rigid robots."
Aug 23	Gauti Höskuldsson: "A model for visual-vestibular interaction." MSc-thesis presentation.
Sep 13	Håkan Wassgren (IBM, Sundsvall): "New ideas for managing process data."
Sep 15	Claire Valentin (ENSIEG, Grenoble): "Auto-tuned adaptive controller based on pole placement design."
Sep 19	Fredrik Lönegård, Magnus Ahlgren: "Control of brased heat exchanger in steam applications." MSc-thesis presentation.

Sep 21 Håkan Fredriksson, Jörgen Nilsson: "Gas turbine model for a combined cycle power plant." MSc-thesis presentation.

Sep 22 Bo Eliasson (Sydkraft, Malmö): "Coordinated tuning and siting of damping equipment in power systems."

Sep 26 Jerker Persson: "Hydroelectric power plants contribution to the damping of low frequency power oscillations in large power systems." MSc-thesis presentation.

Sep 29 Thomas Kronhamn (Ericsson Radar Systems): "Serial connected Kalman filters – How and why."

Sep 29 Michael Andersson, Ted Ericsson: "Determination of position and orientation of details." MSc-thesis presentation.

Oct 10 Greta Wilhelmsson, Maria Hansson: "The exchange problem for industrial robots." MSc-thesis presentation.

Oct 11 Bo Bernhardsson: "Construction of Runge-Kutta methods for differential-algebraic equations."

Oct 11 Kjell Gustafsson: "Stepsize selection in and properties of implicit Runge-Kutta methods."

Oct 12 Michael Christiansson, Pär Ericsson: "Knowledge-based control and modelling with G2." MSc-thesis presentation.

Oct 12 Peter Höjerback: "Designing a process operator interface – a hypermedia model." MSc-thesis presentation.

Oct 13 Tore Hägglund: "Adaptive process control with the ECA400 controller." Docent lecture.

Oct 16 Magnus Bergstrand: "Service restoration in electric power distribution networks." MSc-thesis presentation.

Oct 17 Michael Nevins (Management Analysis): "Decision support system for nuclear power using G2."

Oct 18 Mats Andersson: "Omola – An object-oriented language for model representations."

Oct 20 Henrik Bengtsson, Andreas Söderstierna: "Automatic weight control of submarines." MSc-thesis presentation.

Oct 20 Bernt Nilsson: "Structured modelling of chemical processes." Lic Tech dissertation seminar.

Oct 23 Sven Erik Mattsson: "CACE presentation: Support for model development and simulation."

Oct 26 Keith Glover (Univ. of Cambridge, UK): "State space approach to H_∞ control."

Oct 27 Mats Lilja: "Controller design by frequency domain approximation." Doctoral dissertation defence.

Nov 1 Tom Petti (Univ of Delaware): "The diagnostic model processor – A method of model-based fault diagnosis."

Nov 1 Michael Edler, Fredrik Holst: "Man-machine adaptation of the steering gear in a submarine." MSc-thesis presentation.

Nov 3 Laurent Dube (Portland, Oregon): "Models: System description and dynamic simulation program."

Nov 6 Magnus Bergstrand: "Service restoration in electric distributional networks." MSc-thesis presentation.

Nov 24 Karl-Erik Årzén: "IT4 – Knowledge based real time control systems – Status and the future."

Dec 1 Magnus Akke: "Magnus' World Tour 1989."

Dec 1 Björn Wittenmark: "Computer facilities for education."

Dec 15 Hilding Elmqvist (SattControl): "SattLine – An integrated architecture for automation."

Dec 15 Ulf Andersson: "Implementation of a fuzzy controller." MSc-thesis presentation.

Dec 20 Karl-Erik Årzén: "Travel report from Japan."

1990

Jan 18	Sven Erik Mattsson: "Simulation of DAE problems with large index – The research and results of the decade."
Jan 23	Dag Brück: "Travel report ANSI C++, C++ at Bell Labs."
Jan 25	Andrew Mears (Univ Newcastle, Australia): "CICS Centre."
Jan 30	Michael Lundh: "The program ToolBox for laboratory lessons."
Feb 6	Ola Dahl: "SIM2DDC – Manual and an example."
Feb 6	Per Persson: "Library routines for graphic programming."
Feb 13	Brian Surgenor (Queens University, Kingston, Canada): "Intelligent versus conventional control for industrial systems."
March 1	Sten Bergman (Technical Attachés of Sweden, Tokyo): "Research and development in Japan."
March 1	Martin Pålsson: "Investigations of the potential theory model for image interpolation." MSc-thesis presentation.
March 2	Klas Lönell: "PostScript images generated from InterViews." MSc-thesis presentation.
March 8	Leif Andersson: "X-windows."
March 15	Kjell Gustafsson, Michael Lundh: "Matlab-macros for simulation, pole-placement, plot and manipulation of root locus and frequency responses."
March 20	Mats Lilja: "Matlab-macros for frequency response approximation."
March 21	Mats Lilja: "Matlab-macros for design in the frequency domain."
March 26	Michael Green (Imperial College, London): "Introduction to H_∞ control – Singular value analysis of feedback systems."

March 27 Michael Green: "H_∞ norm specification of control objectives – The generalized regulator problem."

March 28 Michael Green: "A game theoretic approach to finite horizon H_∞ synthesis."

March 29 Michael Green: "Internal stability and parameterization theory."

March 30 Michael Green: "H_∞ synthesis theory."

April 5 Michel Gevers (Université Catholique de Louvain, Belgium): "Persistence of excitation."

April 6 Michel Gevers: "Generalized predicitive control and LQG control: Stability issues."

April 10 Michel Gevers: "Bias and variance of estimated transfer functions."

April 11 Håkan Hedlund: "Automatic controller tuning on a continuous pulp digester." MSc-thesis presentation.

April 19 Björn Wittenmark, Rolf Johansson: "Information seminar."

April 26 Gunnar Klinghult: "Adaptive gain scheduling of a combustion engine." MSc-thesis presentation.

May 2 Keisuke Kurihara (Swedish Embassy, Tokyo): "Japanese strategy of reseach and industrial development."

May 3 Lars Rundqwist: "Anti-reset windup for PID controllers."

May 4 Stéphane Sallé (Grenoble): "On the use of an asymmetrical relay in a relay experiment."

May 8 Anders Hansson: "Integration of control and supervision – a Petri-net model."

May 8 Rolf Johansson: "Quadratic optimization of motion coordination and control."

May 10 Ulla Holst, Anders Holtsberg (Dept of Mathematical Statistics, Lund): "Information seminar: Splus, statistical software in the education."

May 29 Bo Bernhardsson: "The predictive first order hold circuit."

May 29 Björn Wittenmark: "Travel report."

May 31 Kjell Gustafsson: "Some comments on a control design for the flexible servo."

May 31 Lars Nielsen: "A neuron-based pulse servo for motion control."

June 5 Mats Andersson: "OMOLA – An object oriented language for model representation." Lic Tech dissertation seminar.

June 7 Kjell Gustafsson: "A new strategy for stepsize and convergence control in implicit Runge-Kutta methods."

June 14 Brian Surgenor (Canada): "Thermal performance analysis: An expert system approach."

June 18 David Wilson (Institute of Technology, Karlstad): "Advanced control of a batch raw sugar crystalliser."

F. Lectures by the staff

1989

Aug 9	Karl Johan Åström: "Automatic feedback control," The international study conference Analysis of Dynamical Systems, Huddinge, Sweden.
Sept 28	Michael Lundh: "Design for robust performance of uncertain SISO systems," G. R. Automatique/SARTA, Grenoble, France.
Sept 29	Kjell Gustafsson: "Stepsize Selection in ODE-Solvers," Department of Numerical Mathematics, Technical University of Norway, Trondheim, Norway.
Oct 2–5	Karl Johan Åström and Björn Wittenmark: "Adaptive control," Industrial course, Davos, Switzerland.
Oct 5	Rolf Johansson: "Applications of Petri Nets," Department of Electrical Engineering and Computer Sciences, Lund Institute of Technology, Lund, Sweden.
Oct 12	Tore Hägglund: "Adaptive PID Control," DTH, Lyngby, Denmark.
Oct 18	Björn Wittenmark: "Reglerteknik–Idéer om påverkan (Automatic control–Ideas for influence)," Lund University Faculty Club
Oct 19	Karl-Erik Årzén: "AI in Medicine," the annual meeting of the Society for Medical Technology (Medicintekniska föreningens årsmöte), Lund, Sweden.
Oct 19	Rolf Johansson: "Applications of Petri Nets," Department of Electrical Engineering and Computer Sciences, Lund, Sweden.

Oct 24 Sven Erik Mattsson: "The CACE project — a survey," The full-day seminar "New tools for model development and simulation" at STU, Stockholm.

Oct 24 Sven Erik Mattsson and Mats Andersson: "An object oriented environment for model development," The full-day seminar "New tools for model development and simulation" at STU, Stockholm.

Oct 24 Bernt Nilsson: "Modelling of chemical processes," The full-day seminar "New tools for model development and simulation" at STU, Stockholm.

Oct 25 Lars Nielsen: "Robotutbytbarhet (Robot exchangeability)," STU-seminar (Swedish Board for Technological Development), Gothenburg, Sweden.

Nov 7 Karl-Erik Årzén: "Expert system applications in process control," the Finnish Chemical Society's symposium, Helsinki, Finland.

Nov 8 Björn Wittenmark: "Theory of low cost automation," 2nd IFAC Symp. on Low Cost Automation, Milano, Italy.

Nov 10 Bernt Nilsson: "Structured Modelling of Chemical Processes with Control Systems," the Annual AIChE meeting, San Francisco, California.

Nov 15 Dag Brück: "Experiences of Object-Oriented Development in C++ and InterViews," TOOLS'89, Paris, France.

Nov 18 Karl Johan Åström: "Averaging analysis of adaptive systems," Texas Systems Day, Rice University, Texas.

Nov 20 Lars Nielsen: "A robot laboratory for control experiments," European Laboratory Network, meeting in Grenoble, France.

Nov 20 Ola Dahl: "Torque limited path following by on-line trajectory time scaling," European Laboratory Network, meeting in Grenoble, France.

Nov 20 Ola Dahl: "An interactive environment for controller implementation," European Laboratory Network, meeting in Grenoble, France.

Nov 24 Ola Dahl: "Torque limited path following by on-line trajectory time scaling," The conference "Nordisk doktorgradsforskning innen Robotteknikk" in Trondheim, Norway.

Dec 11 Karl-Erik Årzén: "A G2 model of a knowledge-based control system," the First Japanese G2 User's Meeting, Tokyo, Japan.

Dec 13 Dag Brück: "Classdoc – A C++ to man-page translator," AT&T Bell Laboratories, Liberty Corner, New Jersey.

Dec 13 Dag Brück: "Experiences of object-oriented development in C++ and InterViews," AT&T Bell Laboratories, Liberty Corner, New Jersey.

Dec 16 Mats Andersson: "An Object-oriented language for model representation," the IEEE Computer Aided Control System Design Conference CACSD '89, Tampa, Florida.

1990

Jan 16 Dag Brück: "ANSI C++ Committee — Travel report," Ericsson Telecom AB, Stockholm, Sweden.

Jan 30 Karl-Erik Årzén: "Fuzzy control," ABB Västerås, Sweden.

Jan 31 Karl-Erik Årzén: "Knowledge-based real-time control systems," IT4 conference, Stockholm, Sweden.

Feb 5 Karl Johan Åström: "Automatic tuning of simple controllers," Department of Electrical and Computer Engineering, University of Texas at Austin, Texas.

Feb 12 Lars Nielsen: "Computer science aspects of robot control," STU-evaluation (Swedish Board for Technological Development), Stockholm, Sweden.

March 6 Karl Johan Åström: "Averaging analysis of adaptive systems," University of Notre Dame, Illinois.

March 6 Bernt Nilsson: "The CACE project," Kamyr, Karlstad, Sweden.

March 7 Jan Eric Larsson: "Computers and mind—A criticism of searle and the chinese room argument," Cognitive Research, Lund University, Lund.

March 8 Karl Johan Åström: "Adaptive control," University of Illinois, Urbana.

March 8 Karl Johan Åström: "Relay oscillations," University of Illinois, Urbana.

March 8 Dag Brück: "Generating PostScript from InterViews," AT&T Bell Laboratories, Murray Hill, New Jersey.

March 8 Bernt Nilsson: "The CACE project," Cromator, Helsingborg, Sweden.

March 15 Karl-Erik Årzén: "Real-time aspects of expert systems," The Nordic Meeting on Expert Systems in the Power Industry, Stockholm, Sweden.

March 19 Karl Johan Åström: "Control technology," IBM Manufacturing Seminar, Austin, Texas.

March 22 Rolf Johansson: "Grafcet and Petri nets in automation," Department of Industrial Electronics and Automation, Lund Institute of Technology, Lund, Sweden.

April 5 Lars Nielsen: "Visual control," STU-evaluation (Swedish Board for Technological Development), Linköping, Sweden.

April 7 Karl Johan Åström: "Self-tuning control based on relay feedback," NSF-UC-NASA Workshop on Nonlinear Control, University of California, Santa Barbara.

April 10 Bo Bernhardsson: "Does computer technology change mathematical education?," conference on Mathematics in the new Engineering Education, Växjö, Sweden.

April 24 Dag Brück: "X3J16 – ANSI C++," SIS/AG-22, Stockholm, Sweden.

April 24 Jan Eric Larsson: "A multilevel flow model of steritherm," SAIS '90 Workshop, Department of Computer and System Sciences, University of Stockholm/Royal Institute of Technology, Stockholm, Sweden.

Apr 24 Lars Nielsen: "Shape and mutual cross-ratios with applications to exterior, interior, and relative orientation," First European Conference on Computer Vision, Antibes, France.

April 25 Dag Brück: "Exception handling in C++ — April 1990," Ericsson Telecom AB, Stockholm, Sweden.

April 25 Björn Wittenmark: "Styrning och reglering i livsmedelsprocesser (Control of food industry processes)," Food Industry -90, Gothenburg, Sweden.

May 7 Ola Dahl: "Path following for robots with bounded torques – algorithm design and experimental environment," University of Illinois at Urbana-Champaign, USA.

May 8 Karl-Erik Årzén: "Expert system applications in the process industry," Modo, Örnsköldsvik, Sweden.

May 9 Ola Dahl: "Torque limited robot path following by on-line time scaling," RPI, Troy, New York.

May 10 Tore Hägglund: "Trends in Automatic Control," SattControl Instruments, Solna, Sweden.

May 16 Ola Dahl: "Stability analysis of an on-line algorithm for torque limited path following," 1990 IEEE Int. Conference on Robotics and Automation, Cincinnati, Ohio.

May 16 Rolf Johansson: "Quadratic optimization of motion coordination and control," IEEE Int. Conference on Robotics and Automation, Cincinatti, Ohio.

May 17 Lars Nielsen: "A neuron-based pulse servo for motion control," 1990 IEEE Int. Conference on Robotics and Automation, Cincinnati, Ohio.

May 22 Lars Nielsen: "Kamerakalibrering (Camera calibration)," STU-seminar (Swedish Board for Technological Development), Västerås, Sweden.

May 22 Karl Johan Åström and Björn Wittenmark: "Adaptive control," Tutorial workshop in connection with the 1990 American Control Conference, ACC'90, San Diego, California.

May 23 Rolf Johansson: "Quadratic optimization of motion coordination and control," American Control Conference, ACC'90, San Diego, California.

May 24 Karl Johan Åström: "Practical experiences of adaptive techniques," American Control Conference, ACC'90, San Diego, California.

May 24 Karl Johan Åström: "Where is the intelligence in intelligent control?," introduction to round table discussion, American Control Conference, ACC'90, San Diego, California.

May 30 Sven Erik Mattsson: "Computer Aided Control Engineering – the CACE project," SIMS 90, Scandinavian Simulation Society 32nd Annual Meeting, Lund, Sweden.

June 4 Karl Johan Åström: "Computer use in control and systems education," Department of Electrical and Computer Engineering, University of Texas at Austin, Texas.

June 6? Björn Wittenmark: "Prediction and adaptation in stochastic systems," 5th Annual Conference of the European Consortium for Mathematics in Industry, Lahti, Finland.

June 8 Rolf Johansson: "Quadratic optimization of motion coordination and control," Department of Electrical Engineering, Linköping University, Linköping, Sweden.

June 11 Jan Eric Larsson: "Knowledge-based control systems: A Steritherm example," the meeting of the Nordic Aseptic Society, Lund, Sweden.

June 12 Dag Brück: "C++ as a research tool," AT&T's C++ Seminar, London, England.

June 18 Kjell Gustafsson: "Towards a new strategy for stepsize and convergence control in implicit RK," The 1990 Conference on the Numerical Solution of Ordinary Differential Equations, Helsinki, Finland.

June 18 Sven Erik Mattsson: "A new technique for solution of high index differential-algebraic equations," The 1990 Conference on the Numerical Solution of Ordinary Differential Equations, Helsinki, Finland.

June 28 Karl Johan Åström: "Digital and optimal control systems," Servomechanism and Control System Design Course, The University of Texas at Arlington, Texas.

June 28 Karl Johan Åström: "Adaptive control systems," Servomechanism and Control System Design Course, The University of Texas at Arlington, Texas.

G. Travels

Mats Andersson attended the "IEEE Conference on Decision and Control" in Tampa, Florida, 13–15 December 1989. He also participated in the following "Workshop on Computer-Aided Control System Design (CACSD)" on 16 December.

Karl-Erik Årzén visited Finland in November 1989. He gave a presentation at the Finnish Chemical Society's yearly symposium and visited Arto Martinen at the Control Engineering Lab, Helsinki University of Technology.

As a part of the IT4 project he visited Japan in 2–12 December 1989 together with Claes Rytoft (ABB), Christer Gerding and Hilding Elmqvist (SattControl), and Arne Otteblad (STU). In Japan they visited Yokogawa, Nippon Kokan Steel, Toshiba, Laboratory for International Fuzzy Engineering Research (LIFE), Japan Atomic Energy Research Institute (JAERI), Hitachi, Tokyo Institute of Technology, Japanese Gas Company, Petroleum Energy Center, and C. Itoh Techno-Science Co. – all in the Tokyo area.

On Januari 31 – February 1, 1990, he gave a presentation at the IT4 conference in Stockholm. Also in Stockholm he gave a presentation at the Nordic Meeting on Expert Systems in the Power Industry on 15–16 March 1990.

Karl Johan Åström was visiting professor at the Department of Electrical and Computer Engineering during the academic year 1989/90. He participated in Texas System Day at Rice university, the IEEE Decision and Control Conference, where he received the Donald G. Fink Prize Paper Award, the NSF-UC-NASA workshop on Nonlinear Control at UCSB, and the American Control Conference in San Diego, where he gave a tutorial on Adaptive Control with B. Wittenmark. He also visited MIT, University of Notre Dame and the University of Illinois.

Bo Bernhardsson attended a course "Advanced Control System Design" in Glasgow in September 1989. Also in September he visited and worked together with Prof. Syvertt Nørsett and Gustaf Söderlind at the mathematics department in Trondheim for a week. In January 1990 he visited Göteborg where he was opponent for a licentiate thesis by Dag Wedelin. In April he was invited speaker at a conference in Växjö about mathematics in the new engineering education.

Dag Brück attended the TOOLS '89 conference in Paris (Techniques for Object-Oriented Languages and Systems), November 1989, and presented a paper. On 11–14 December he visited AT&T Bell Laboratories in Liberty Corner and Murray Hill, New Jersey, USA. He discussed the future of C++ and presented some of the departments work. On 15 December he attended the organizational meeting of the ANSI C++ committee (X3J16).

On 16 January 1990, Dag Brück visited Ericsson Telecom AB, Stockholm, Sweden. He gave a talk on C++ standardization issues and C++ development at AT&T Bell Laboratories. In March 1990, Dag Brück again visited AT&T Bell Laboratories in Liberty Corner and Murray Hill, New Jersey, USA. He discussed the future of C++ and presented some of the departments work. He also attended the first technical meeting of the ANSI C++ committee (X3J16). On 24–25 April 1990, Dag Brück visited SIS/AG-22 and Ericsson to report on C++ standardization and developments. On 11 May, Dag Brück visited Ellemtel, Stockholm, to attend a seminar with Bjarne Stroustrup and to discuss the future of C++. On 12 June 1990, Dag Brück participated as speaker and panel member at the C++ Seminar arranged by AT&T Unix Software Operation Europe, in London, England.

Eva Dagnegård attended a 5-day course "Advanced TEX/Macro Writing" in Exeter, UK, in September 1989. The course was arranged by the TEX Users Group.

Ola Dahl participated in a European Laboratory Network meeting in Grenoble, France, 20–21 November. The meeting was hosted by

Prof. Carlos Canudas de Wit. On 23–24 November he participated and presented a paper in the conference "Nordisk doktorgradsforskning innen Robotteknikk" in Trondheim, Norway.

Ola Dahl visited USA during 6–22 May, 1990. He participated and presented a paper at the IEEE International Conference on Robotics and Automation, 13–18 May, in Cincinnati, Ohio. He visited and gave seminars at University of Illinois at Urbana-Champaign and RPI, Troy, New York. He also visited CMU in Pittsburgh and the University of Texas at Austin.

Kjell Gustafsson visited the department of Numerical Mathematics in Trondheim, Norway, from 25 September to 4 October 1989. On 18–22 June 1990 he participated in the 1990 Conference on the Numerical Solution of Ordinary Differential Equations, Helsinki, Finland, where he also presented a paper.

Tore Hägglund visited DTH in Lyngby, Denmark, in October for the supervision of a licentiate project. He received the diploma of "Innovation Cup 1989" in Gothenburg in January. In May he gave a talk at SattControl Instruments AB in Stockholm.

Rolf Johansson participated in a delegation financed by UHÄ to establish contacts with universities in the European community. The following universities were visited in Germany: Technische Univ. München (Munich), Ludwig-Maximilian-Universität (Munich), Univ. des Saarlandes (Saarbrücken), and Univ. Dortmund.

In May 1990 Rolf Johansson participated and lectured at the following conferences: IEEE Int. Conf. Robotics and Automation, Cincinnati, Ohio; American Control Conference, San Diego, California; Barany Society Int. Meeting, Tokyo, Japan. Also in May he visited Prof. H. J. Chizeck, Case Western Reserve University, Cleveland, Ohio, USA and participated in the 5th Annual Applied Neural Control Research Day, Cleveland, Ohio.

He acted as an external examiner of the licentiate degree thesis by I. Klein at Linköping University, Linköping, Sweden, 8 June, 1990.

Per-Olof Källén attended a course "Advanced Control System Design" in Glasgow in September 1989.

Jan Eric Larsson participated in the Nordic Research Symposium "The Dynamics of Knowledge and Belief," Department of Philosophy, Lund University, 24–26 August, 1989. On 14 September he visited Linköping, where he was the opponent on Henrik Eriksson's licentiate thesis at the department of Computer Science, University of Linköping. On 24 October he participated in a one-day workshop "Nya verktyg för modellutveckling och simulering," Swedish Board for Technical Development (STU), Stockholm. He participated in the SAIS '90 Workshop, Institutionen för Data- och Systemvetenskap, Stockholms Universitet/Kungliga Tekniska Högskolan, Stockholm, 23–24 April 1990.

He was the opponent on Henrik Eriksson's licentiate thesis, 14 September 1990, at Linköping University, Linköping, Sweden.

Michael Lundh visited Grenoble in France in September 1989.

Sven Erik Mattsson participated in the 1990 Conference on the Numerical Solution of Ordinary Differential Equations, 18–22 June in Helsinki, Finland, where he presented a paper.

Lars Nielsen visited Grenoble, France, in November 1989. During this visit the European Laboratory Network in adaptive and non-linear control applied to robotics was formed and formally started. In March 1990, Lars Nielsen participated in the Symposium SSAB (Svenska Sällskapet för Automatiserad Bildanalys), Swedish APR (Association for Pattern Recognition), Linköping, Sweden, where he was elected to the Board of the Swedish APR.

He also participated and presented contributions in the conferences: First European Conference on Computer Vision, Antibes, France, in April, and 1990 IEEE Int. Conference on Robotics and Automation, Cincinnati, Ohio in May. Further, he participated in STU-seminars and evaluations in October, February, April and May. There has also been travels where

he gave advice to STU (Swedish Board for Technological Development), on neural networks and on real time systems.

Bernt Nilsson visited USA in November 1989. He participated in the Annual AIChE meeting, San Francisco, where he presented a paper. He also visited California Institute of Technology and Manfred Morari's group "Process control and design".

Klas Nilsson visited the seminar "Digital Signal Processing, Single Chip DSP Processors" in Munich, October 1989. DSP associates arranged the seminar, where all major DSP companies presented their latest technology.

Björn Wittenmark participated and made presentations at the conferences: 2nd IFAC Symposium on Low Cost Automation in Milano, Italy and 5th Annual Conference of the European Consortium for Mathematics in Industry, Lahti, Finland. In connection with 1990 American Control Conference in San Diego he lectured at a workshop on Adaptive Control. Further he lectured at one industrial course in Adaptive Control in Davos, Switzerland. During the year he visited Imperial College, UK and the OECD Halden Project. Together with graduates from Lund Institute of Technology he visited several industries in Japan in June 1990.