LUND UNIVERSITY

Activity Report: Automatic Control 1988-1989

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1989

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

Link to publication

Total number of authors:
2

ACTIVITY REPORT

1988–1989

Department of

Automatic Control

Lund Institute of Technology

Contents

1. Introduction

This report covers the activities of the department during the period 1 July 1988 – 30 June 1989, which is the academic year 1988/89.

During the year we have spent considerable effort to develop the undergraduate curriculum by introducing mathematical software into all courses. New courses in adaptive control and process identification have been consolidated. Much effort has also been put into the design of attractive and competitive course projects in the graduate courses of control system implementation, process identification, and adaptive control. In summary 605 students have attended and passed the courses of the department (see Section 2).

Research has continued in established areas such as adaptive control, computer aided control engineering, robotics, and information technology, (see Section 3). The computational environment is described in Section 4.

The program package Simnon, that has been developed at the Department, is now available for mainframes, IBM-PC compatibles, and Sun workstations. Simnon has been licensed to SSPA, Gothenburg. SSPA is taking over the sale and further development of Simnon.

Professor Björn Wittenmark started a new position as professor at the department in March 1989. Dr Tore Hägglund reentered the department as an associate professor in April 1989 (see Appendix A).

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), Sydkraft, Vattenfall, 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)	226
Reglerteknik AK (M)	
(Automatic control, linear systems)	112
Processreglering (K)	
(Automatic Process control)	79
Digital reglering (F, E, D)	
(Computer controlled systems)	118
Datorimplementering av reglersystem (F, E, D)	
(Computer implementation of control systems)	31
Processidentifiering (F, E, D)	
(Process identification)	21
Adaptiv reglering (F, E, D)	
(Adaptive control)	18

The figures give the number of students that have passed the courses during 1988/89, totally 605 students.

Master Theses

The students exhibited an increasing interest in master thesis work in the control area. Twentytwo master theses were completed by 25 students during the year.

The theses concerned the following application areas: biomedical engineering (1), biotechnology (1), computer aided design and computer graphics (5), image processing (1), man-machine interaction (3), power systems (2), production systems (1), robotics (3),

A list of the MSc-theses is given in Appendix D.

Graduate Courses

One PhD thesis (Jan Peter Axelsson) and two Lic Tech theses (Magnus Akke, Ola Dahl) were completed during the period. One new PhD student (Klas Nilsson) was admitted to the department.

The following PhD courses have been given:

Robustness and adaptation in nonlinear control, 4p (J. J. Slotine)	August 1988
Algebraic system theory, 5p (P. Hagander)	fall 1988
Computer controlled systems, 4 p (B. Wittenmark)	spring 1989

Extension Courses

The extension program in automatic control offers courses for extended education of engineers in industry.

A new extension course on knowledge-based process control was developed by Karl-Erik Årzén and held for the first time during the spring 1989. The course covers a broad range of topics in the intersection of the areas artificial intelligence, expert systems, and process control such as overview of AI, knowledge representation, expert system development,

blackboard system, real-time aspects of knowledge-based systems, inductive systems, neural networks, model-based expert systems, monitoring and diagnosis, expert control, fuzzy control, planning, etc. During the course demonstrations of relevant state-of-the-art software such as G2, Muse, and Nexpert Object are given. The course also invites external lecturers. The following course have been given during the period:

Knowledge-based process control   29 May – 1 June 1989

A course demands 3–4 days of attendance and takes 16–20 participants. Each day of a course usually consists of two or three lectures and a laboratory session of about four hours.

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
> Stepsize control in ODE-solvers

The areas are highlighted below.

Adaptive Control

Researchers: Karl Johan Åström, Björn Wittenmark, Rolf Johansson, Tore Hägglund, Michael Lundh, Bo Bernhardsson

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

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

New emerging research problems have also arisen. In this context we would in particular like to mention the need for robust design methods and the relations between adaptive control and AI.

Although adaptive control is now starting to be used industrially, see Åström and Wittenmark (1989), there are many fundamental problems that need further investigation.

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 in Åström and Hägglund (1988) and Hägglund and Åström (1989). 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 continued during the year. Adaptive control of a robot manipulator motion designed by methods of Lyapunov theory was developed by Johansson. The methods exploit 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

During the two last years (July 1987 – June 1989) of the STU financed research project "Computer Aided Control Engineering, CACE" the efforts were focused on tools for model development and simulation.

The main result is a proposal for a kernel for model representation. The kernel may serve as a central model data base in an integrated environment for model development and simulation. The CSSL definition

from 1967 has had a profound impact on simulation and has served very well for over 20 years. It is perhaps now time to capitalize on the enormous development of information technology and reconsider the foundations of model representation. The proposal is a modest effort in this direction. If we could agree upon a common set of ideas we may lay the foundation to a new standard. The proposed kernel supports a modularized and object oriented representation of models to allow flexible and safe reuse of model components. The model developer may supply extra information which is used for automatic consistency analysis to check for unintended abuse of models. The kernel can allow any logical and mathematical framework such as differential-algebraic equations, difference equations, etc. to describe behavior, but a basic idea is that behavior descriptions should be declarative and equation based. The kernel allows integration of different customized user interfaces. A prototype of the kernel is implemented in Common Lisp and KEE. A new STU-supported project to implement the kernel in C++ has been started. The project has also included an application study focusing on modeling of chemical processes.

Expert Control

Researcher: Karl-Erik Årzén, Jan Eric Larsson, Per Persson

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 controller tuning and adaptation in a supervisory expert system. An important part of the project is architectures for real-time on-line expert systems. During the year the Department has participated in the IT4 project "Knowledge-based Real-time Control Systems" together with Asea Brown Boveri and SattControl. The aim of this project is the integration of knowledge-systems and conventional distributed control systems. The concept is based on a object-oriented multi-level, multi-view model of the process. The UHT sterilization process Steritherm from Alfa

Laval is used as a demonstrator. The responsible researcher is Karl-Erik Årzén.

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 around new chips for resolver to digital conversion. 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 based on TMS 32010. The software used is based on the language Modula-2 and on a real time programming environment developed at the department. The hardware is IBM-AT computers. A VME-based system connected to a SUN work station is under development.

Using this environment a number of projects and prototype systems have been tested in research, education and master theses work. The 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, implementation of robot control programs, and automatic generation of code for control algorithms.

Power Systems

Researcher: Magnus Akke, Bo Eliasson, Björn Wittenmark

The work in power systems has been continued along two lines. Professor Neville Rees, University of New South Wales, Australia has for part of the year been at the department as guest professor, sponsored by Sydkraft and Vattenfall. In close contact with Sydkraft work was done in modelling of units in thermal plants. The intention is to develop a model library that can be used in different studies. Simple drum-boiler models are presented in Åström and Bell (1989).

The second 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 find where to place the damping equipment. In a licentiate thesis (Akke, 1989) the problem is approached using multivariable control theory. The control problem is decomposed into three topics: modelling, finding feedback structure, and tuning of the controller. The design method used is based on linear quadratic regulator design. A new method to find a sparse feedback structure is presented in the thesis. The discussed controller is not restricted to only local measurements. The importance of information exchange in the system is discussed. The design is tested on a 16 machine model 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.

Control of Biotechnology Processes

Researchers: Per Hagander and Jan Peter Axelsson in cooperation with O. Holst, 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

15

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. Some optimal control problems are also formulated and investigated using nonlinear control theory. During the year Jan Peter Axelsson completed his PhD-thesis.

A new direction of the work is started up. The bacteria *Pseudomonas Cepacia* is grown on the toxic substrate salicylate to produce the enzyme salicylate hydroxylase. The enzyme is 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.

Modeling and Control of Medical Systems

Researchers: Rolf Johansson in cooperation with Dr. Måns Magnusson (Department 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.

Stepsize Selection 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. The controller tries to make the system produce a sufficiently accurate solution with a minimum amount of calculations.

In the case of numerical integration of ordinary differential equations the controller measures an estimate of the integration error and uses it to decide upon the stepsize to use in the next integration step. Viewing the system as a dynamic control system provides insight not supplied by the standard static asymptotic analysis in the current numerical analysis literature.

The control system viewpoint of stepsize selection has been exploited in a project partly sponsored by STU. A new improved controller was designed for explicit Runge-Kutta methods. The new controller has been implemented in one of the integration routines in the simulation package Simnon with very good results.

4. Computer Facilities

The total computer capabilities of the department are as follows:

- A **Sun Workstation** network containing a file server, Sun 3/180 with 800 MB disk and 7 workstations Sun 3/50 with 4 MB memory and a 3/110 with 16 MB memory and color graphics.

- **VAX-11/780** with 10 MB memory and 750 MB disk. The most important programs are Pro-Matlab, Macsyma, CtrlC, TEX, Lisp and our own packages Simnon and Idpac.

- 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. Interfaces are provided to PC-Matlab and to our own new PC-Simnon, so that parameters obtained in a design can be transferred both to Simnon for simulation using a nonlinear model, and 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.

- Four **Macintoshes**, used for text processing and for creating figures and drawings for the technical reports. A special program on the Vax

enables the inclusion of drawings produced on the Macintosh directly into TEX documents produced on the Vax.

- Two **Macintosh II** intended for development of control engineering software in a Macintosh environment.
- An **Iris Workstation** with 6.5 MB memory, 150 MB disk and powerful color graphics with 1024×780 pixels and 24 bitplanes. This computer is used mainly in the CACE project described elsewhere in this report.
- A **Symbolics 3650 Lisp Machine**

The Vax, the Suns, the Iris, and the Symbolics ar connected in a computer network (TCP/IP and ethernet). The Macintoshes are connected in an Apple Local Talk network, and these two networks are connected via a Kinetics FastPath bridge.

A. List of Personnel

The following list shows the status of June 1989
if nothing else is mentioned.

Professorer   (Professors)
Karl Johan Åström
Björn Wittenmark

Högskolelektorer   (Associate professors)
Per Hagander
Tore Hägglund (from 24 Oct 1988)
Rolf Johansson
Lars Nielsen

Forskarassistent   (Research associate)
Bo Bernhardsson

Forskningsingenjörer   (Research engineers)
Leif Andersson
Anders Blomdell
Rolf Braun
Tomas Schönthal

Forskningsassistenter   (Research assistants)
Magnus Akke (on leave from March 1989)
Mats Andersson
Dag Brück
Ola Dahl
Jan Eric Larsson
Sven Erik Mattsson

Bernt Nilsson
Klas Nilsson
Per-Olof Olsson
Karl-Erik Årzén

Doktorandtjänster   (Teaching assistants)

Jan Peter Axelsson
Kjell Gustafsson
Ulf Holmberg
Mats Lilja
Michael Lundh
Per Persson
Lars Rundqwist

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
(29 Aug – 19 Sept 1988)

Professor Jean Jacques Slotine
Nonlinear Systems Laboratory, MIT
Cambridge, Massachusetts, USA
(22 Aug – 2 Sept 1988)

Professor André Tits
Dept of Electrical Engineering and Systems
Systems Research Center, University of Maryland

College Park, Maryland, USA
(5–30 Sept 1988)

Professor Neville W. Rees
School of Electrical Engineering and Computer Science
University of New South Wales
Kensington, New South Wales, Australia
(9 Sept – 9 Dec 1988)

Professor C. C. Hang
National University of Singapore, Singapore
(11–15 Oct 1988)

Mr Pablo Iglesias
University of Cambridge, Dept of Engineering
Cambridge, Massachusetts
(11 Jan – 21 April 1989)

Mr Stéphane Sallé
Laboratoire d'Automatique de Grenoble
ENSIEG, Grenoble, France
(From 13 February 1989)

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

Professor Robert Kosut
Integrated Systems Inc, Santa Clara, California
(28 April – 5 June 1989)

Special Visits

Twenty-two students from the Institute of Technology in Delft, Holland, visited the department on 19 May 1989.

B. Awards

Magnus Akke received the Sydkraft energy research award for his licentiate thesis in June 1989.

Karl Johan Åström received the *1989 Donald G. Fink Prize Paper Award* for his technical paper "Adaptive Feedback Control", published February 1987 in the *Proceedings of the IEEE*. The award will be presented at the IEEE Conference on Decision and Control in Tampa, Florida, December 1989.

Ola Dahl received the SAAB-Scania award for graduate students at the SAAB-Scania shareholders' meeting on April 28, 1989.

Rolf Johansson received the award "Innovation Cup 1988" sponsored by Skandia and Dagens Industri. His contribution was "Adaptive control of robot manipulator motion".

C. Books, Papers and Conference Contributions

Books

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

Papers

Åström, K. J. (1989): "Application of the robust and adaptive pole placement design technique," *Int. J. Adaptive Control and Signal Processing*, **3**, 167–189.

Åström, K. J. (1989): "Toward intelligent control," *IEEE Control Systems Magazine*, **9**, April, 60–64.

Axelsson, J. P. (1988): "Experimental techniques and data treatment for studying the dynamics of ethanol production/consumption in baker's yeast," *Anal. Chim. Acta*, **213**, 151–163.

Bernhardsson, B. (1989): "Dual control of a first-order system with two possible gains," *Int. Jour. of Adaptive Control and Signal Processing*, **3**, 15–22.

Dahl, O., and L. Nielsen (1989): "Ash-line control," *Machine Vision and Applications*, **1**, 163–168.

Hägglund, T. (1989): "Autotuning, parameterstyrning och framkoppling för bättre processreglering," *Svensk papperstidning*, **3-1989**, 34–38.

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

24

Johansson, R., M. Magnusson, and M. Åkesson (1988): "Identification of human postural dynamics," *IEEE Trans. Biomedical Engineering*, 3, 858–869.

Mattsson, S. E. (1989): "On modelling and differential/algebraic systems," *Simulation*, 52, No. 1, 24–32.

Nielsen, L., M. A. Mahowald, and C. Mead (1989): "SeeHear," in C. Mead: *Analog VLSI and Neural Systems*, Addison-Wesley.

Conference Contributions

Akke, M., and B. Wittenmark (1989): "New analysis and tuning of stabilizers in multimachine power systems," *Preprints IFAC Symposium on Power Systems and Power Plant Control*, Seoul, Korea.

Andersson, M. (1989): "An object-oriented modeling environment," in G. Iazeolla, A. Lehman, H. J. van den Herik (Eds.): *Simulation methodologies, languages and architectures and AI and graphics for simulation*, 1989 European Simulation Multiconference, Rome, June 7–9, 1989, The Society for Computer Simulation International, pp. 77–82.

Årzén, K.-E. (1988): "An architecture for expert system based feedback control," *Preprints IFAC Workshop on Artificial Intelligence in Real-time Control*, Swansea, Wales, UK, pp. 15–20.

Årzén, K.-E. (1989): "Experiences of using G2 for modelling and simulation," *G2 Users Meeting*, Palo Alto, California.

Årzén, K.-E. (1989): "Knowledge-based real-time control systems," *Proceedings of the SAIS'89 Workshop*, Department of Automatic Control, Lund, Sweden.

Årzén, K.-E. (1989): "Knowledge-based control systems: Aspects on the unification of conventional control systems and knowledge-based systems," *Proceedings of the 1989 American Control Conference (ACC '89)*, Pittsburgh, Pennsylvania.

Åström, K. J. (1988): "Assessment of achievable performance of simple feedback loops," *27th IEEE Conference on Decision and Control*, Austin, Texas.

Åström, K. J. (1988): "Automatic tuning and adaptive control - Past accomplishments and future directions," *Shell Process Control Workshop*, Houston, Texas.

Åström, K. J. (1989): "Adaptive and self-tuning controllers," *ISA Advanced Control Conference*, Birmingham, UK.

Åström, K. J. (1989): "Adaptive control – A perspective," *IFAC Symposium on Adaptive Control and Signal Processing, ACASP'89*, Glasgow, UK.

Åström, K. J. (1989): "Intelligent process control," Plenary paper, *Annual Research Review Conference*, Systems Research Center on Automation and Information Engineering, University of Maryland, College Park, Maryland.

Åström, K. J. (1989): "Application of robust and adaptive pole placement," *Proceedings of the 1989 American Control Conference (ACC '89)*, Pittsburgh, Pennsylvania, pp. 430–435.

Åström, K. J., R. Bell (1988): "Simple drum-boiler models," *IFAC Int. Symposium on Power Systems, Modelling and Control Applications*, Brussels, Belgium.

Åström, K. J., and T. Hägglund (1988): "A new auto-tuning design," *Preprints IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88*, Lyngby, Denmark.

Åström, K. J., and L. Rundqwist (1989): "Integrator windup and how to avoid it," *Proceedings of the American Control Conference (ACC '89)*, Pittsburgh, Pennsylvania, pp. 1693–1698.

Axelsson, J. P. (1988): "Characterizing the substrate control problem of ethanol monitored fed-batch yeast production," in D. Seborg (Ed.): *Adaptive Control of Chemical Processes – ADCHEM'88/IFAC Symposium, Preprints*, IFAC, Pergamon Press.

Axelsson, J. P. (1988): "On the role of adaptive controllers in fed-batch yeast production," in D. Seborg (Ed.): *Adaptive Control of Chemical Processes – ADCHEM'88/IFAC Symposium, Preprints*, IFAC, Pergamon Press.

Axelsson, J. P., O. Holst and C. F. Mandenius (1989): "Dynamical experiments with bakers' yeast in the short time scale," in Björn Klinge and Christer Owman (Eds.): *Bio Science 89*, Lund University Press, Lund, Sweden.

Bernhardsson, B. (1989): "ARNE," *Preprints SAIS Conference*, Lund, Sweden.

Brück, D. M. (1988): "Modelling of control systems with C++ and PHIGS," *Proceedings of the USENIX C++ Technical Conference*, Denver, Colorado, USA, pp. 183–192, Also available as report TFRT-7400.

Canudas de Wit, C., K. J. Åström, and N. Fixot (1989): "Speed estimation in robot manipulators," *MTNS'89*, Amsterdam, The Netherlands.

Dahl, O., and L. Nielsen (1989): "Torque limited path following by on-line trajectory time scaling," *IEEE Int. Conference on Robotics and Automation*, Scottsdale, Arizona.

Elmqvist, H. and S. E. Mattsson (1989): "A simulator for dynamical systems using graphics and equations for modelling," *IEEE Control Systems Magazine*, **9**, No. 1, 53–58.

Ericsson, T., and L. Nielsen (1989): "Window based interactive image processing," *Symposium SSAB (Svenska Sällskapet för Automatiserad Bildanalys)*, (Swedish APR (Association for Pattern Recognition)), Gothenburg, Sweden.

Gutman, P. O., L. Neumann, and K. J. Åström (1989): "Incorporation of unstructured uncertainty into the Horowitz design method," *IEEE Int. Conference on Control and Applications, ICCON*, Jerusalem, Israel.

Hagander, P. (1988): "Control of baker's yeast production – Robustness and the role of adaptivity," *1st Japanese-Swedish Seminar on Bioprocess Engineering*, Tokyo, Japan.

Hägglund, T. (1988): "Adaptive PID control," *Advances in Process Control II*, Leeds, UK.

Hägglund, T., and K. J. Åström, "An industrial adaptive PID controller," *IFAC Symposium on Adaptive Control and Signal Processing, ACASP '89*, Glasgow, UK.

Hang, C. C., and K. J. Åström (1988): "Practical aspects of PID auto-tuners based on relay feedback," *Preprints IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88*, Lyngby, Denmark.

Hang, C. C., and K. J. Åström (1988): "Refinements of the Ziegler-Nichols tuning formula for PID auto-tuners," *IMEKO XI, Int. Measurement Confederation 11th Triennal World Congress*, ISA/88, Houston, Texas.

Hansson, A., G. Sparr, and L. Nielsen, "Nonlinear interpolation from video images to high quality printers," *Symposium SSAB (Svenska Sällskapet för Automatiserad Bildanalys)*, (Swedish APR (Association for Pattern Recognition)), Gothenburg, Sweden.

Holmberg, U., G. Olsson and B. Andersson (1988): "Simultaneous DO control and respiration estimation," *Preprints Water Science Technology*, Int. Association on Water Pollution Research and Control (IAWPRC), Brighton, UK, pp. 1185–1195.

Johansson, R. (1989): "Lyapunov design for adaptive control of robots," *Preprints IFAC Nonlinear Control Systems Design Symposium*, Capri, Italy.

Johansson, R., and M. Magnusson (1989): "Identification of human postural dynamics," *IEEE Int. Conference on Control and Applications, ICCON '89*, Jerusalem, Israel.

Johansson, R., and M. Magnusson (1989): "Determination of characteristic parameters of human posture dynamics," in C. F. Claussen et al. (Eds.): *Proceedings of the XVIth Congress of the International Neurootological & Equilobriometric Society*, Knossos, Greece.

Johansson, R., and E. Zettergren (1989): "A smooth D/A-converter for robotic applications," *IEEE Int. Conference on Control and Applications, ICCON '89*, Jerusalem, Israel.

Johansson, R., M. Magnusson, and J. Wiklund (1989): "Galvanic vestibular stimulation for performance analysis of human lateral posture stability," in C. F. Claussen et al. (Eds.): *Proceedings of the XVIth Congress of the International Neurootological & Equilibriometric Society*, Knossos, Greece.

Larsson, J. E. (Ed.) (1989): *Proceedings of the SAIS '89 Workshop*, AILU – The AI Group in Lund, Lund University and Lund Institute of Technology, Lund, Sweden.

Larsson, J. E. (1989): "Knowledge-based frequency response analysis," in Larsson, J. E. (Ed.): *Proceedings of the SAIS '89 Workshop*, AILU – The AI Group in Lund, Lund University and Lund Institute of Technology, Lund, Sweden.

Larsson, J. E., and P. Persson (1988): "An intelligent help system for Idpac," *Proceedings of the 8th European Conference on Artificial Intelligence, ECAI '88*, Technischen Universität München, Munich, FRG, pp. 119–123.

Larsson, J. E., and P. Persson (1988): "The knowledge database used in an expert interface for Idpac," *Preprints IFAC Workshop on Artificial Intelligence in Real-Time Control*, Swansea, Wales, UK, pp. 107–112.

Mattsson, S. E. (1988): "On model structuring concepts," *Preprints 4th IFAC Symposium on Computer-Aided Design in Control Systems (CADCS)*, P. R. China, pp. 269–274.

Mattsson, S. E. (1989): "Modeling of interactions between submodels," in G. Iazeolla, A. Lehman, H. J. van den Herik (Eds.): *Simulation methodologies, languages and architectures and AI and graphics for simulation*, 1989 European Simulation Multiconference, Rome, June 7–9, 1989, The Society for Computer Simulation International, pp. 63–68.

Mattsson, S. E. (1989 June 23–24): "Concepts supporting reuse of models," *Proceedings of Building Simulation '89*, The International Building Performance Simulation Association, Vancouver, British Columbia, Canada, pp. 175–180.

Nielsen, L. (1989): "Neural nets, early vision, and motion control," *First Nordic Symposium on Neural Computing*, Espoo, Finland.

Nielsen, L., and G. Sparr (1989): "Projective area-invariants as an extension of the cross-ratio," *6th Scandinavian Conference on Image Analysis*, Oulu, Finland.

Nielsen, L. (1989): "STU-projektet Visuell styrning," *Symposium SSAB (Svenska Sällskapet för Automatiserad Bildanalys)*, (Swedish APR (Association for Pattern Recognition)), Gothenburg, Sweden.

Nilsson, B., S. E. Mattsson and M. Andersson (1989): "Tools for model development and simulation," in Larsson, J. E. (Ed.): *Proceedings of the SAIS '89 Workshop*, AILU – The AI Group in Lund, Lund University and Lund Institute of Technology, Lund, Sweden.

Rundqwist, L. (1988): "Experiences of self-tuning control of an activated sludge process," *Preprints IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88*, Lyngby, Denmark.

Sparr, G., A. Hansson and L. Nielsen (1989): "Nonlinear interpolation for image expansion based on potential theory," *6th Scandinavian Conference on Image Analysis*, Oulu, Finland.

Wiklund, J., M. Magnusson, and R. Johansson (1989): "Galvanicly induced anterior-posterior bodysway in normal humans," in C. F. Claussen et al. (Eds.): *Proceedings of the XVIth Congress of the International Neurootological & Equilobriometric Society*, Knossos, Greece.

Wittenmark, B. (1988): "Implementation and application of adaptive control," Plenary paper, *Preprints IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88*, Lyngby, Denmark.

Wittenmark, B. (1988): "Adaptive stability augmentation," *Preprints 8th IFAC Symp. on Identification and System Parameter Estimation*, Beijing, P. R. China.

Wittenmark, B. (1988): "An adaptive pole placement controller based on pole zero parameterization," *Preprints 8th IFAC Symp. on Identification and System Parameter Estimation*, Beijing, P. R. China.

Wittenmark, B. (1989): "Integrators, nonlinearities and antireset windup for different control structures," *Preprints American Control Conference, ACC '89*, Pittsburgh, Pennsylvania.

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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> Uppsala Universitetsbibliotek
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There is a copying and handling charge of between 30 and 150 SEK for each document. Invoice will be sent together with the ordered report(s).

Please be certain to include both the report number and the title.

Dissertation

Axelsson, J. P., "Modelling and control of fermentation processes," TFRT-1030, March 1989.

Lic Tech Theses

Akke, M., "Power system stabilizers in multimachine systems," TFRT-3201, February 1989.

Dahl, O., "Torque limited path following by on-line trajectory time scaling," TFRT-3204, May 1989.

Final Reports

Åström, K. J., "Adaptive control theory," TFRT-3200, December 1988.

Gustafsson, K., "Stepsize control in numerical integration of ODE's," TFRT-3202, March 1989.

Activity Report

Dagnegård, E. and L. Nielsen, "Activity report 1987–88," TFRT-4016, December 1988.

Master Theses

Bergman, T., and A. Olsson, "Människa-maskin anpassning av ubåts manöverorgan," (Man-machine interface of the steering gear in a submarine), TFRT-5383, September 1988.

Davidsson, P. A., "Digital turbinregulator för små vattenkraftaggregat," (Digital turbine controller for small water power units), TFRT-5402, June 1989.

Diaz, C. A., "Implementation of adaptive tracking control for an industrial robot," TFRT-5395, January 1989.

Göransson, G., "Studie av regulatorer för elektrohydauliska lägesservon," (A study of regulators for electrohydraulic position servos), TFRT-5388, October 1988.

Hansson, A., "Nonlinear interpolation from video images to high quality printers," TFRT-5397, February 1989.

Jeppsson, U., "An evaluation of a PHIGS implementation for full graphics control systems," TFRT-5389, November 1988.

Johansson, M., "Interaktiv plottning av mätdata i flera dimensioner," (Interactive plotting of measurement data in several dimension), TFRT-5390, November 1988.

Jönsson, L., "En experimentell robotsimulator," (An experimental robot simulator), TFRT-5386, December 1988.

Larsson, T., and O. Pålsson, "Process identification applied on the dynamics of a submarine vessel," TFRT-5390, November 1988.

Magnusson, J., "Styrutrustning till elgenerator för turbojetmotor," (Control unit to an electric generator for a turbojet engine), TFRT-5398, February 1989.

Myrnäs, R., "Grafiskt presentationsprogram för processimulator," (Graphical interface program for a process simulator), TFRT-5403, June 1989.

Nilsson, A., "Object-oriented graphics for the future instrument panel," TFRT-5382, September 1988.

Norrman, L., and O. Nilsson, "Design av en estimator för en DC-motor," (Design of an estimator for a DC drive), TFRT-5401, May 1989.

Öhlin, H., "Deriverande filter för luftmålsinmätning," (Differentiating filter for maneuvering target tracking), TFRT-5387, May 1988.

Olsson, K., "Compensation of disturbances caused by coupled mass inertia," TFRT-5396, February 1989.

Sjövall, N., "Reglering av salicylathydroxylasproducerande bakterie," (Control of a salicylate hydroxylase producing bacteria), TFRT-5399, March 1989.

Söderström, O., "Kurvprofilgenerator för förpackningsmaskin," (Curve profile generator for a packing machine), TFRT-5385, October 1988.

Theorén, K., "Autopilot för Roll-Nix," (An adaptive autopilot for Roll-Nix), TFRT-5393, November 1988.

Vallinder, P. A., "Some methods for tearing of differential/algebraic systems," TFRT-5384, September 1988.

Wichtel, E., "Styrning av frekvensanalysator," (Control of frequency analyser), TFRT-5400, April 1989.

Wickström, O., "Expert systems for planning of hydro power production," TFRT-5394, December 1988.

Wiklund, J., "A study of the body sway induced in humans by galvanic stimulation of the vestibular nerve: The phenomenon. A model. Parametric identification," TFRT-5392, November 1988.

Internal Reports

Andersson, L., "Command decoding in Modula-2," TFRT-7413, January 1989.

Andersson, L., "A Modula-2 real-time scheduler – Use and implementation," TFRT-7414, January 1989.

Andersson, L., "Compact T$_E$X," TFRT-7422, June 1989.

Andersson, M., "Omola – An object-oriented modelling language," TFRT-7417, April 1989.

Axelsson, J. P., "Flow-rate control of a continuous stirred tank reactor – Start-up and large disturbances," TFRT-7420, May 1989.

Årzén, K. E., "An architecture for expert system based feedback control," TFRT-7399, September 1988.

Reports

Årzén, K. E., "Remarks and suggestions concerning G2 version 1.1," TFRT-7409, December 1988.

Åström, K. J., and T. Hägglund, "A new auto-tuning design," TFRT-7398, August 1988.

Åström, K. J., and R. D. Bell, "Simple drum-boiler models," TFRT-7402, October 1988.

Åström, K. J., C. C. Hang, and P. Persson, "Heuristics for assessment of PID control with Ziegler-Nichols tuning," TFRT-7404, November 1988.

Åström, K. J., "Assessment of achievable performance of simple feedback loops," TFRT-7411, January 1989.

Brück, D., "A foreground/background real-time scheduler for the IBM AT," TFRT-7393, July 1988.

Brück, D., "Modelling of control systems with C++ and PHIGS," TFRT-7400, August 1988.

Brück, D., "Experiences of object-oriented development in C++ and InterViews," TFRT-7418, March 1989.

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

Dahl, O., "Generation of structured Modula-2 code from a Simnon system description," TFRT-7416, February 1989.

Dahl, O., and L. Nielsen, "Torque limited path following by on-line trajectory time scaling," TFRT-7415, February 1989.

Gustafsson, K., and B. Bernhardsson, "Implementation of a control strategy for an inverted pendulum," TFRT-7405, November 1988.

Iglesias, P. A., "On the use of robust controllers in adaptive control," TFRT-7419, April 1989.

Johansson, R., "A new principle for ultrasonic monitoring of blood flow," TFRT-7394, July 1988.

Johansson, R., "Stability problems of adaptive robot control ad modum Slotine and Li," TFRT-7397, August 1988.

Johansson, R., "Adaptive control of robot manipulator motion," TFRT-7401, August 1988.

Johansson, R., "Quadratic optimization of motion coordination and control," TFRT-7425, June 1989.

Larsson, J. E., "MESS – A minimal expert system shell," TFRT-7380, August 1988.

Mattsson, S. E., "The CACE project – steering committee meeting 1988-06-01," TFRT-7395, August 1988.

Mattsson, S. E., "The CACE project – Steering committee meeting 1988-11-23," TFRT-7412, January 1989.

Murphy, S., "On the Cartesian control of orientation and force for robotic manipulators," TFRT-7396, August 1988.

Nilsson, K., and M. Andersson, "Parametrisk identifiering av robotdynamik," (Parametric identification of robot dynamics), TFRT-7410, December 1988.

O'Young, S. D., J. Hope, K. J. Åström, and I. Postlethwaite, "A comparative study and performance assessment of H^∞," TFRT-7403, October 1988.

Ruijter, H., and L. Nielsen, "A survey of robotics in rehabilitation applications," TFRT-7406, December 1988.

Ruijter, H., "Teknisk dokumentation av arbetet med UMI-RTX robot," (Technical documentation of the work with the UMI-RTX robot), TFRT-7404, December 1988.

Rundqwist, L., "Experiences of self-tuning control of an activated sludge process," TFRT-7408, December 1988.

E. Seminars at the Department

Seminars given at the department during the academic year 1988–1989, are summarized here. They are given both by the staff at the department and by invited lecturers.

1988

Aug 18   Per Persson, Jan Eric Larsson: "Impressions from the European Conference on Artificial Intelligence, ECAI, in Munich."

Aug 23   Jean Jacques Slotine (MIT, Cambridge, Massachusetts): "RANCR: Introduction." The first seminar in a series on Robustness and Adaptation in Nonlinear Control.

Aug 24   Ulf Johansson: "A scheduler to MIC-OS." MSc-thesis presentation.

Aug 25   J. J. Slotine (MIT): "RANCR: Single-input design I – Sliding surfaces."

Aug 26   J. J. Slotine (MIT): "RANCR: Single-input design II – The modelling/performance trade-offs."

Aug 29   J. J. Slotine (MIT): "RANCR: Multi-input design I – Putting physics in control."

Aug 29   P. Haves (Oxford, UK): "Simulation of environmental control systems in buildings."

Aug 30   J. J. Slotine (MIT): "RANCR: Multi-input design II – Passive feedback systems."

Aug 31   J. J. Slotine (MIT): "RANCR: Composite adaptive control."

Sept 1   Rolf Johansson: "Adaptive control of robot manipulator motion."

Sept 6   Carlos Canudas de Wit (ENSIEG, France): "Presentation of robotics activities at the Grenoble control department. Adaptive control for robots with friction."

Sept 9   Carlos Canudas de Wit (ENSIEG, France): "Robust linear design: Robots with joint flexibilities."

Sept 13   André Tits (Univ of Maryland): "Aspects of optimization-based CADCS."

Sept 16   Carlos Canudas de Wit (ENSIEG, France): "Sliding observers for robot manipulators."

Sept 20   André Tits (Univ of Maryland): "Generalized stability of parametric families of matrices."

Sept 23   André Tits (Univ of Maryland): "Robust stability and performance in the presence of parametric uncertainty and unmodelled dynamics."

Sept 28   Tomas Bergman, Anders Olson: "Man-machine adaption of the steering gear in a submarine." MSc-thesis presentation.

Sept 28   Göran Göransson: "A studie of regulators for electrohydraulic position servos." MSc-thesis presentation.

Sept 30   Karl Johan Åström: "Robust and adaptive control – The ACC test case."

Oct 3   Olof Pålsson, Tomas Larsson: "Process identification applied on the dynamics of a submarine vessel." MSc-thesis presentation.

Oct 4   Neville Rees (Univ of New South Wales): "Multivariable control of power plant."

Oct 13   Anders Nilsson: "Object-oriented graphics for the future instrument panel." MSc-thesis presentation.

Oct 13   Göran Andersson (KTH, Stockholm): "The Electric Power Research Centre at KTH."

Oct 13   C. C. Hang (Singapore): "Refinements of the Ziegler-Nichols tuning formula."

Oct 14   Magnus Akke: "On AVR-gain and PSS-parameters."

Oct 18   Jan Peter Axelsson: "Control of continuous ethanol production – Linear and time-optimal designs."

Oct 19   Per Anders Vallinder: "Some methods for tearing of differential/algebraic systems." MSc-thesis presentation.

Oct 21   Mats Lilja: "Controller design in frequency domain."

Oct 26   Karl-Erik Årzén, Per Persson, Jan Eric Larsson: "Travel report from the AI conference in Swansea."

Oct 26   Lars Nielsen: "Travel report from the robot conference in Karlsruhe."

Oct 28   Brian Armstrong (Stanford University): "Two topics in robot control: friction modelling and compensation; ensuring excitation during parameter identification."

Oct 28   Bo Bernhardsson: "On the convergence rate of the ellipsoid method for quadratic functions and its applications to optimal control and identification."

Oct 31   Olof Wickström: "Expert systems for planning of hydro power production." MSc-thesis presentation.

Nov 2   Bo Bernhardsson: "Travel report from France."

Nov 3   David Stewart (Univ of Queensland, Australia): "On the numerical solutions of discontinuous ODEs."

Nov 4   Lars Jönsson: "An experimental robot simulator."MSc-thesis presentation.

Nov 9   Dag Brück: "An overview of C++ and a report from the USENIX C++ Technical Conference in Colorado."

Nov 11   Tomas Schönthal: "Realtids-Simnon." An introduction to an internal discussion.

Nov 16   Michael Johansson: "Interactive plotting of measurement data in several dimensions." MSc-thesis presentation.

Nov 17   Ulf Jeppsson: "An evaluation of a PHIGS implementation for full graphics control systems." MSc-thesis presentation.

Nov 18   Thomas D. Garvey (Stanford Research International): "The SRI image understanding program."

Nov 18   Thomas D. Garvey (Stanford Research International): "Practical aspects of evidential reasoning."

Nov 24   Ed Sowell (California State University): "Simulation Analysis Kernal (SPANK) – and object oriented environment."

Nov 24   Per Sahlin (ITM): "Desired features in model and simulation environments for the building industry."

Nov 25   Ola Dahl: "Controller implementation: User information and demonstration."

Nov 30   Tomas Schönthal: "Real-time Simnon." Follow-up.

Dec 2   Neville Rees (Univ of New South Wales): "On the mechanization of thought processes."

Dec 14   Johan Magnusson: "Control unit to an electric generator for turbojet engine."MSc-thesis presentation.

Dec 15   Joakim Wiklund: "A study of the body sway induced in humans." MSc-thesis presentation.

Dec 16   Bengt Mårtensson (Universität Bremen): "New sufficient conditions for adaptive control."

1989

Jan 13   Karl Johan Åström: "Neural networks."

Jan 13   Bo Bernhardsson: "A dynamical system that diagonalizes matrices, with demonstration on an analog simulator."

Jan 20   Pablo Iglesias (Univ of Cambridge, Massachusetts): "Robust stabilization of normalized coprime factors."

Jan 24   Claudio Diaz: "Implementation of adaptive tracking control for an industrial robot." MSc-thesis presentation.

Jan 27   Ola Dahl: "Path following."

Jan 31   Michael Lundh: "Robust design."

Feb 3   Dag Brück: "Scones – An interactive tool for creating Simnon's connecting systems." A demonstration was also given.

Feb 10   Jerker Persson: "Hydroelectric power plants contribution to the damping of low frequency power oscillationsin large power systems." MSc-thesis presentation.

Feb 13   Kenneth Olsson: "Compensation of disturbances caused by coupled mass inertia." MSc-thesis presentation.

Feb 17   David Hill (Univ of Newcastle, Australia): "Adaptive control of nonlinear and decentralized systems."

Feb 27   Magnus Akke: "Power system stabilizers in multimachine systems." Lic Tech dissertation seminar.

March 2   Torbjörn Olsson, Klas Lysen (Kamyr AB, Karlstad): "Control of a continuous digester."

March 3   Karl Johan Åström: "Inertial navigation."

March 10   Stéphane Sallé (ENSIEG, France): "Supervision of an extended Kalman filter."

March 29   Bernard Friedland (Kearfott Guidance and Navigation Corp, New Jersey): "Another beam deflector control system design."

March 31   Tomas Schönthal: "German CACE software."

April 4   G. Koch (ETH): "Qualitative (causal) control of coupled watertanks."

April 7   Sten Bergman (ABB, Västerås): "VLSI system construction."

April 14   Torsten Bohlin (KTH, Stockholm): "On the foundations of system identification."

April 18   Per Hagander: "On the notion of strong stabilizability."

April 21   Pablo Iglesias (Univ of Cambridge): "Robust regulators in adaptive control."

April 24   Eric Wichtel: "Control of frequency analyser." MSc-thesis presentation.

April 28   Lars Rundqwist: "Anti-windup for PID-controllers."

April 28   Ulf Holmberg: "Identification of DO-dynamics."

May 5   Lars Norrman, Ola Nilsson: "Design of an estimator of a DC drive." MSc-thesis presentation.

May 9   Wiebe Draijer (Philips): "Adaptive control of the Philips compact disc servo."

May 17   Sten Bay Jørgensen (DTH, Lyngby, Denmark): "Multivariable identification and control of chemical processes."

May 18   Jan Peter Axelsson: "Modelling and control of fermentation processes." Doctoral dissertation defence.

May 18   Sten Bay Jørgensen (DTH): "Research issues in chemical process control."

May 23   Anders Hansson: "Nonlinear interpolation from video images to high quality printers." MSc-thesis presentation.

May 26   Ola Dahl: "Torque limited path following by on-line trajectory time scaling." Lic Tech dissertation seminar.

May 26   Torkel Glad (Linköping Institute of Technology): "Differential algebra and modelling."

June 1   Robert Kosut (Integrated Systems Inc, California): "System identification for control (re)-design."

June 2   Robert Kosut (Integrated Systems Inc, California): "Adaptive control of a chaotic system."

June 2   Per Arne Davisson: "Digital turbine controller for small water power units." MSc-thesis presentation.

June 5   Ville Janti (Helsingfors): "Data analysis of EEG."

June 8   Rolf Johansson: "Multivariable adaptive control."

June 14   J. Grievink (Koninklijke/Shell-Laboratorium, Amsterdam): "Process control research at KSLA – An overview."

June 14   H. Tulleken (Koninklijke/Shell-Laboratorium, Amsterdam): "The KSLA adaptive robust control project."

June 14   H. Tulleken: "Grey-box modelling and identification."

June 16   Claes Rytoft, Henrik Pålsson (ABB, Lund): "Future man-machine interaction."

June 16   Claire Valentin (ENSIEG, France): "Combining auto-tuning and adaptation."

June 19   Ralph Myrnäs: "Graphical interface program for a process simulator." MSc-thesis presentation.

June 20   Rolf Johansson: "An analytic solution to the Hamilton-Jacobi equation with application to optimal and adaptive control."

June 26   A. Annaswamy (Boston): "Adaptive control of timevarying plants."

F. Lectures by the staff

1988

July 20   Ulf Holmberg: "Simultaneous DO control and respiration estimation," Water Science Technology, Int. Association on Water Pollution Research and Control (IAWPRC) Brighton, UK.

Aug 9   Kjell Gustafsson: "Improving stepsize control in numerical integration," The NATO Advanced Study Institute on Numerical Linear Algebra, Digital Signal Processing and Parallel Algorithms, University of Leuven, Belgium.

Aug 17   Björn Wittenmark: "Implementation and application of adaptive Control," Plenary lecture, Adchem '88, Lyngby, Denmark.

Aug 18   Jan Peter Axelsson: "Characterizing the substrate control problem of ethanol monitored fed-batch yeast production," IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88, Copenhagen, Denmark.

Aug 18   Jan Peter Axelsson: "On the role of adaptive controllers in fed-batch yeast production," IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88, Copenhagen, Denmark.

Aug 19   Tore Hägglund: "A new auto-tuning design," IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88, Copenhagen, Denmark.

Aug 19   Tore Hägglund: "Practical aspects of PID auto-tuners based on relay feedback," IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88, Copenhagen, Denmark.

Aug 19   Lars Rundqwist: "Experiences of self-tuning control of an activated sludge process," IFAC Int. Symposium on Adaptive Control of Chemical Processes, ADCHEM '88, Copenhagen, Denmark.

Aug 23   Sven Erik Mattsson: "On Model Structuring Concepts," the 4th IFAC Symposium on Computer-Aided Design in Control Systems, CADCS'88, Beijing, P. R. China.

Aug 27   Björn Wittenmark: "An adaptive pole placement controller based on pole-zero parameterization," 8th IFAC Symposium on Identification and System Parameter Estimation, Beijing, P.R. China.

Aug 28   Björn Wittenmark: "Adaptive stability augmentation," 8th IFAC Symposium on Identification and System Parameter Estimation, Beijing, P.R. China.

Sept 5   Karl Johan Åström: "Simple drum-boiler models," IFAC Int. Symposium on Power Systems, Modelling and Control Applications, Brussels, Belgium.

Sept 9   Bo Bernhardsson: "Dual control of a first order system with two possible gains," INRIA, Paris, France.

Sept 9   Tore Hägglund: "Adaptive PID control," Advances in Process Control II, Leeds, UK.

Sept 12–16 Björn Wittenmark: "Adaptive control," Summer course at Spanish Open University, Santander, Spain.

Sept 22   Sven Erik Mattsson: "Methods and languages for development of simulation models," Workshop on the use of simulators in the process industry, arranged by the STU-program DUP, Stockholm, Sweden.

Sept 24–27 Björn Wittenmark: "Adaptive control," Industrial course, Maastricht, Holland. Lectures on Real-time estimation, Self-tuning regulators, Practical aspects of adaptive control, Products and case studies.

Sept 24–27 Karl Johan Åström: "Adaptive control," Industrial course, Maastricht, Holland. Lectures on Adaptive control – Introduction, Model reference adaptive control, Simulation of adaptive systems, Adaptive control theory, Perspectives on adaptive control.

Oct 11 Bo Bernhardsson: "Convergence rate of an ellipsoid method for quadratic problems, Applications: Optimal control and identification," ENSIEG, Grenoble, France.

Oct 18 Karl Johan Åström: "Refinements of the Ziegler-Nichols tuning formula for PID auto-tuners," IMEKO XI, Int. Measurement Confederation 11th Triennal World Congress, ISA/88, Houston, Texas.

Oct 19 Jan Eric Larsson: "An introduction to expert systems," Seminar on Expert Systems in Process Control, Sydkraft, Malmö, Sweden.

Oct 19 Per Persson: "The usage of expert systems in man-machine interface," Seminar on Expert Systems in Process Control, Sydkraft, Malmö, Sweden.

Oct 19 Karl-Erik Årzén: "Real-time expert systems," Seminar on Expert Systems in Process Control, Sydkraft, Malmö, Sweden.

Oct 19 Karl Johan Åström: "Expert systems for regulator tuning," Seminar on Expert Systems in Process Control, Sydkraft, Malmö, Sweden.

Oct 20 Dag Brück: "Modelling of control systems with C++ and PHIGS," The USENIX 1988 C++ Technical Conference, Denver, Colorado, USA.

Oct 25 Per Hagander: "Control of baker's yeast production – Robustness and the role of adaptivity," 1st Japanese-Swedish Seminar on Bioprocess Engineering, Tokyo, Japan.

Oct 26   Jan Eric Larsson: "The knowledge database used in an expert interface for Idpac," IFAC Workshop on Artificial Intelligence in Real-Time Control, Swansea, Wales, UK.

Nov 1   Rolf Johansson: "Människan i balans? Ett dynamiskt system" (Human posture – A dynamic system), Medicintekniska föreningen (Biomedical Engineering Society), Lund University Hospital, Lund, Sweden.

Nov 2   Sven Erik Mattsson: "Future modelling and simulation environment," a one day seminar on Simulation and Advanced Control of Power Plants at Sydkraft, Malmö, Sweden.

Nov 2   Karl Johan Åström: "Drum water modeling," a one day seminar on Simulation and Advanced Control of Power Plants at Sydkraft, Malmö, Sweden.

Nov 11   Dag Brück: "A report from the C++ Technical Conference 1988," Ericsson Radar Electronics, Mölndal, Sweden.

Nov 16   Björn Wittenmark: "Implementation and application of adaptive control," Adaptive Regulering in Praksis, Lyngby, Denmark.

Nov 17   Karl Johan Åström: "Automatic tuning, adaptation and expert control," One Day International Symposium on Advanced Process Supervision and Real-time knowledge Based Control, Newcastle-upon-Tyne, UK.

Nov 18   Karl Johan Åström: "Automatic tuning of simple regulators," Department of Engineering, University of Warwick, Control and Instrument Systems Centre, Warwick, UK.

Nov 23   Karl-Erik Årzén: "Novel trends in expert control," Expertsystemer til Industrien, Dansk Automationsselskab, Lyngby, Denmark.

Dec 8   Karl Johan Åström: "Assessment of achievable performance of simple feedback loops," The 27th IEEE Conference on Decision and Control, Austin, Texas.

Dec 13　　Karl Johan Åström: "Automatic tuning and adaptive control past accomplishments and future directions," Shell Process Control Workshop, Houston, Texas.

Dec 14　　Sven Erik Mattsson: "Future modelling and simulation environment," Workshop on Future Research Needs in CACSD, Cambridge, arranged by the Science and Engineering Research Council (SERC) in UK.

1989

Jan 10　　Karl-Erik Årzén: "Expert control: the basic ideas," Kunnskapsbaserte system: Teori og anvendelser innen automatisering og instrumentering, NTH, Trondheim, Norway.

Jan 11　　Lars Nielsen: "Robotics," STU-meeting, Lund, Sweden.

Jan 17　　Karl Johan Åström: "Process control in the future," SattControl, Copenhagen, Denmark.

Jan 25　　Karl-Erik Årzén: "Expert control," SPCI Ekmandagarna, Stockholm, Sweden.

Jan 25　　Karl Johan Åström: "Neural networks," SPCI Ekmandagarna, Stockholm, Sweden.

Jan 25　　Tore Hägglund: "Adaptive technique in PID controllers," SPCI Ekmandagarna, Stockholm, Sweden.

Feb 2　　Bo Bernhardsson: "ARNE–AnalysRäkning Numera Elektroniskt," Luleå University, Sweden.

Feb 2　　Bo Bernhardsson: "Dual control," Luleå University, Sweden.

Feb 3　　Bo Bernhardsson: "Dynamic systems that diagonalize matrices and sort lists," Luleå University, Sweden.

Feb 3　　Lars Nielsen, Ola Dahl, Klas Nilsson: "Robotics, path following and identification," ABB Robotics, Västerås, Sweden.

Feb 5   Karl Johan Åström: "Swedish engineering education in an international perspective," Education conference, Sveriges Förenade Studentkårer, Stockholm, Sweden.

Feb 7   Lars Nielsen: "Implementation of neural networks," Linköping Institute of Technology, Linköping, Sweden.

March 14 Dag Brück: "Subject C++," Workshop for Nordic Pulp and Paper Instititutes, STFI, Stockholm, Sweden.

March 14 Dag Brück: "Experiences of UNIX and VMS," Workshop for Nordic Pulp and Paper Instititutes, STFI, Stockholm, Sweden.

March 15 Lars Nielsen: "The STU-project Vision control," Symposium SSAB (Svenska Sällskapet för Automatiserad Bildanalys, Swedish APR (Association for Pattern Recognition)), Gothenburg, Sweden.

March 24 Jan Eric Larsson: "On expert systems," Högre seminariet i teoretisk filosofi och AI-gruppen i Lund, Lund, Sweden.

April 3   Karl-Erik Årzén: "Real-time expert systems," ABB, Västerås, Sweden.

April 3   Karl Johan Åström: "Knowledge-based techniques in control systems," ABB, Västerås, Sweden.

April 5   Karl Johan Åström: "Adaptive and self-tuning controllers," ISA Advanced Control Conference, Birmingham, UK.

April 5   Rolf Johansson: "A smooth D/A-converter for robotic applications," IEEE Int. Conference on Control and Applications, ICCON '89, Jerusalem, Israel.

April 6   Rolf Johansson: "Identification of human postural dynamics," IEEE Int. Conference on Control and Applications, ICCON '89, Jerusalem, Israel.

April 13 Rolf Johansson: "Grafcet," Dept of Computer Engineering, Lund Institute of Technology, Lund, Sweden.

April 14   Jan Peter Axelsson: "Control of Fed-batch Yeast Production," Laboratoire d'Automatique, Dynamique et Analys des Systems. Louvain-La-Neuve, Belgium.

April 15   Bo Bernhardsson: "ARNE," Svenska Matematikersamfundets Utbildningsdagar, Borlänge, Sweden.

April 18   Lars Nielsen: "Neural nets, early vision, and motion control," First Nordic Symposium on Neural Computing, Espoo, Finland.

April 19   Karl Johan Åström: "Adaptive control – A perspective," IFAC Symposium on Adaptive Control and Signal Processing, ACASP '89, Glasgow, Scotland, UK.

April 20   Rolf Johansson: "Galvanic vestibular stimulation for performance analysis of human lateral posture stability," XVIth Congress of the International Neurootological & Equilobriometric Society, Knossos, Greece.

April 20   Tore Hägglund: "An industrial adaptive PID controller," IFAC Symposium on Adaptive Control and Signal Processing, ACASP '89, Glasgow, Scotland, UK.

April 21   Karl Johan Åström: "Process control in the future," Reglertekniskt seminarium, SattControl, Stockholm, Sweden.

Apr 21   Tore Hägglund: "Adaptive control," Reglertekniskt seminarium, SattControl, Stockholm, Sweden.

April 21   Rolf Johansson: "Determination of characteristic parameters of human posture dynamics," XVIth Congress of the International Neurootological & Equilobriometric Society, Knossos, Greece.

April 24   Rolf Johansson: "Grafcet," Dept of Industrial Automation, Lund Institute of Technology, Lund, Sweden.

May 1   Karl Johan Åström: "Intelligent process control," Plenary speach, Annual Research Review Conference of the Systems

Research Center, Automation and Information Engineering, University of Maryland, College Park, MD.

May 2   Lars Nielsen: "Time-optimal robot path following using on-line time-scaling," Massachusetts Institute of Technology, Boston.

May 5   Karl Johan Åström: "Intelligent process control," Dow Distinguished Lecture, Pulp and Paper Centre, The University of British Columbia, Vancouver, Canada.

May 7   Bernt Nilsson: "Tools for model development and simulation," SAIS '89, the annual workshop of the Swedish Artificial Intelligence Society, Lund, Sweden.

May 8   Lars Nielsen: "Torque limited path following by on-line trajectory time scaling," University of Maryland, College Park, MD.

May 9   Bo Bernhardsson: "ARNE," SAIS Conference, Lund, Sweden.

May 9   Rolf Johansson: "Petri nets," Dept of Industrial Automation, Lund Institute of Technology, Lund, Sweden.

May 10   Lars Nielsen: "Torque limited path following by on-line trajectory time scaling," University of California, Berkeley, California.

May 12   Bo Bernhardsson: "Dynamical systems that diagonalize matrices," KTH, Stockholm, Sweden.

May 17   Lars Nielsen: "Torque limited path following by on-line trajectory time scaling," IEEE Int. Conference on Robotics and Automation, Scottsdale, Arizona.

May 31   Sven Erik Mattsson: "The CACE project and new tools for model development and simulation," the council of SIGSIM, Sweden.

June 7   Lars Nielsen: "Special machines for neural nets," Sentrum før Industriforskning, Blindern, Norway.

June 8   Mats Andersson: "An object-oriented modelling environment," ESM '89, the 1989 European Simulation Multiconference, Rome, Italy.

June 8   Sven Erik Mattsson: "Modelling of interaction between submodels," ESM '89, the 1989 European Simulation Multiconference, Rome, Italy.

June 15   Rolf Johansson: "Lyapunov design for adaptive control of robots," IFAC Nonlinear Control Systems Design Symposium, Capri, Italy.

June 20   Karl Johan Åström: "Design and implementation issues," Tutorial Workshop on Adaptive Control Theory and Applications, American Control Conference, Pittsburgh, Pennsylvania.

June 20   Karl Johan Åström: "Applications of adaptive control," Tutorial Workshop on Adaptive Control Theory and Applications, American Control Conference, Pittsburgh, Pennsylvania.

June 21   Karl Johan Åström: "Application of robust and adaptive pole placement," American Control Conference, ACC '89, Pittsburgh, Pennsylvania.

June 22   Lars Nielsen: "Projective area-invariants as an extension of the cross-ratio," 6th Scandinavian Conference on Image Analysis, Oulu, Finland.

June 22   Karl Johan Åström: "Integrator windup and how to avoid it," American Control Conference, ACC '89, Pittsburgh, Pennsylvania.

June 22   Björn Wittenmark: "Integrators, nonlinearities and antireset windup for different control structures," American Control Conference, ACC '89, Pittsburgh, Pennsylvania.

June 23   Karl Johan Åström: "Knowledge-based control systems – Aspects on the unification of conventional control systems

and knowledge-based systems," American Control Conference, ACC '89, Pittsburgh, Pennsylvania.

June 23   Sven Erik Mattsson: "Concepts supporting reuse of models," Building Simulation '89, Vancouver, British Columbia, Canada.

G. Travels

Magnus Akke participated and presented a paper at "IFAC Symposium on Power Systems and Power Plant Control" held in Seoul, Korea, August 1989. From Mars to August 1989 he visited University of Newcastle, Australia. He also visited the following professors: B. D. O. Anderson, ANU, N. W. Rees, UNSW, and J. Nichols, SUT. Furthermore he visited professor C. C. Hang in Singapore.

Leif Andersson visited computer manufacturers and universities in California in May 1989. The visits included Sun Microsystems, Silicon Graphics, Stanford University and Berkeley University. In June he attended the Nordic $T_{E}X$ Meeting in Stockholm, arranged by the Royal Institute of Stockholm, Sweden.

Mats Andersson attended the "International Conference on System Development Environments & Factories" in Berlin in May 1989. He and Sven Erik Mattsson participated in ESM'89, the "1989 European Simulation Multiconference" in Rome, Italy, in June. He also attended the "Summer School on User Interfaces" organized by the Finnish Society for Computer Science and the University of Tampere in Tampere, Finland, in the end of June.

Karl-Erik Årzén participated in the "IFAC Workshop on AI in Real-time Control" held in Swansea, UK, September 21–23, 1988. On November 23 he was invited to the seminar "Expert Systems for the Industry" in Lyngby, Denmark. He acted as the external examiner for the licentiat degree thesis by Peter Nagy in Linköping on December 2.

On January 10–11, 1989, he gave a lecture in the Knowledge-based systems course in Trondheim, Norway. In January he also attended the conference "Ekmandagarna" in Stockholm and a seminar on knowledge-based systems in the steel industry in Borlänge. On April 22 – May 1

he visited Palo Alto. On April 24–25 he attended the G2 users group meeting. The rest of the time he visited Neuron Data, Intellicorp, Center for Integrated Systems at Stanford University, FMC Corp., and Santa Clara University.

Karl Johan Åström participated in the "IFAC Symposium on Power Systems Modelling and Control Applications" held in Brussels, Belgium, in September. In November he visited England to participate in the "International Symposium on Advanced Process Supervision and Real-time Knowledge-based Control" in Newcastle. He also visited University of Warwick. In December he participated in the "27th IEEE Conference on Decision and Control" in Austin, Texas, and in the "Shell Process Control Workshop on Process Control" in Houston, Texas.

In April 1989 Åström visited England to participate in the "ISA Advanced Control Conference", Birmingham, and in the "IFAC Symposium on Adaptive Control and Signal Processing" held in Glasgow. In May he participated in the "Annual Research Review Conference" of the Systems Research Center, Automation and Information Engineering at University of Maryland. He also visited the Pulp and Paper Research Center at the University of British Columbia, Vancouver, Canada. In June he participated in the "American Control Conference" held in Pittsburgh, Pennsylvania.

Jan Peter Axelsson participated in the "IFAC conference on Adaptive Control of Chemical Processes (ADCHEM '88)" held in Copenhagen, Denmark, August 1988. He presented two papers. In October he attended a symposium on Bioprocess Engineering in Lund, arranged by the Biotechnology Research Foundation SBF. In April 1989 he visited dr Dochain and dr Bastin in Louvain-La-Neuf, Belgium and gave a seminar at their department, Laboratoire d'Automatiqe, Dynamique et Analyse des Systems. At the end of April a poster was presented at Bio-Science 89 in Malmö, Sweden.

Bo Bernhardsson visited INRIA in Paris September 5 – October 14, 1988. During that period he also visited Professors Praly and Levine at Ecole

des Mines, Carlos Canudas, ENSIEG Grenoble, Mme Siguerdidjane at SUPELEC, Paris. He also attended a conference "Analysis of Dynamical Systems, in the honour of René Thom" and a workshop in nonlinear control October 3–5 in Paris. In Paris he also visited a very nice restaurant with his girlfriend Helen, with whom he later (Oct 30) got engaged.

In October 1988 he visited Bengt Lennartsson at the Department of Automatic Control in Gothenburg. On February 2–4, 1989, he visited the institution for mathematics at Luleå university. During that stay he also visited the department of Automatic Control. On April 7 he visited the Department of Systems Science and Optimization in Stockholm. On April 15 he gave an invited talk in Borlänge at the educational days for the Swedish Mathematical Society. On April 24–25 he visited the Department of Automatic Control in Linköping, where he also met B.D.O. Anderson. On May 12 he visited Anders Lindquist at the Department of Systems Science and Optimization. On June 19–23 he attended the "Mathematical Theory of Networks and Systems" conference in Amsterdam.

Dag Brück participated in the USENIX 1988 C++ Conference, held in Denver, Colorado, USA, October 17–20, where he presented a paper. He also participated in the Implementer's Workshop, held in Estes Park, Colorado, USA, on October 21. On October 26 he visited Barbara E. Moo and Andrew R. Koenig, both working with the development of C++ at AT&T Bell Labs. On November 11 Dag Brück visited Ericsson Radar Electronics, Mölndal, Sweden, and presented a travel report from the USENIX 1988 C++ Conference, Denver, Colorado.

On March 7, 1989, Dag Brück attended "GKS 3D and PHIGS," a one-day seminar given at KTH, Stockholm, by Roger Hubbold and Terry Hewitt from Manchester University. On March 14–15 he visited STFI in Stockholm to give two seminars on C++ and UNIX, and to discuss experiences with workstations.

Ola Dahl visited the SYROCO Conference in Karlsruhe, October 5–7, 1988.

Kjell Gustafsson attended the "NATO Advanced Study Institute on Numerical Linear Algebra, Digital Signal Processing and Parallel Algorithms" held on August 1–12 in Leuven, Belgium, where he presented a paper. On April 24–25, 1989 he visited the Department of Automatic Control in Linköping.

Per Hagander participated in the "IFAC conference on Adaptive Control of Chemical Processes (ADCHEM '88)" held in Copenhagen, Denmark, August 1988. In October he attended a symposium on Bioprocess Engineering in Lund, arranged by the Biotechnology Research Foundation SBF. He also participated in and presented a paper at the "1st Japanese-Swedish Seminar on Bioprocess Engineering" in Tokyo, October 24–27, 1988. During the stay in Japan he also made a tour to some Japanese biotechnical industries. On October 31 he visited the National University of Singapore.

Tore Hägglund participated and presented papers at the following conferences: "IFAC Int. Symposium on Adaptive Control of Chemical Processes" held in Copenhagen, August 17–19, 1988; "Advances in Process Control II" in Leeds, September 8–9; "IFAC Symposium on Adaptive Systems in Control and Signal Processing" in Glasgow, April 18–20, 1989.

Rolf Johansson visited Luleå University to receive the diploma of "Innovation Cup 1988" sponsored by Skandia and Dagens Industri. He also participated and lectured in the following conferences: IEEE Int. Conference on Control and Applications, ICCON 89, Jerusalem, Israel, April 3-6 1989; XVIth Congress of the Int. Neurootological and Equilibriometric Society, Knossos, Greece, April 16-21 1989; and IFAC Nonlinear Control Systems Design Symposium, Capri, Italy, June 14-16 1989.

Jan Eric Larsson attended the "European Conference on Artificial Intelligence," ECAI, in Munich, August 1–5, 1988. He and Per Persson gave a demonstration of their intelligent help system for Idpac. He

also attended the "IFAC Workshop on Artificial Intelligence in Real-Time Control" in Swansea, Wales, September 21–23, 1988. In October he participated in a one-day seminar on expert systems at Southern Sweden Power Supply at Sydkraft, Malmö, Sweden. He organized SAIS '89 Workshop arranged by AI-gruppen i Lund at Idéon in Lund, Sweden, on May 7–9, 1989. He visited Morten Lind and Jan Creutzberg at DTH, Denmark, on June 22, 1989.

Sven Erik Mattsson participated in the "4th IFAC Symposium on Computer-Aided Design in Control Systems, CADCS '88"held in Beijing, P. R. China, in August. In December he was invited to the workshop on "Future Research Needs in CACSD" in Cambridge, arranged by the Science and Engineering Research Council, SERC in UK. He and Mats Andersson participated in ESM'89, the "1989 European Simulation Multiconference" held in Rome, Italy, in June. In midsummer he participated in "Building Simulation '89" in Vancouver, Canada.

Lars Nielsen visited the SYROCO conference in Karlsruhe, October 5–7, 1988. He also made a visit to the Fraunhofer Institute and specifically the robotics group headed by Dr.Ing. Kuntze. He visited ABB Robotics in Västerås on February 3. During the spring 1989 he gave a number of seminars related to his work in VLSI. These included invited lectures: February 7 at Linköping Institute of Technology, April 17–18 at the "Nordic Symposium on Neural Computing" in Espoo, Finland, and June 7 at the Centre for Industrial Research in Blindern, Norway.

Travels related to image analysis were participation in the SSAB Symposium (Swedish Association for Pattern Recognition), in Gothenburg, March 15–16, 1989, and participation in the 6th Scandinavian Conference on Image Analysis, in Oulu, Finland, June 19–22.

Nielsen was invited to a IVA-meeting on visionary technology March 9–10. He visited the control group in Linköping headed by Lennart Ljung on March 13, and participated in a STU-meeting in Linköping on March 14.

During May he participated in the "IEEE Int. Conference on Robotics and Automation" in Scottsdale, Arizona, May 14–19, and he made a number

of visits the weeks before. The major ones were with Prof Slotine at MIT, Cambridge, Prof Brockett at Harvard University, Cambridge, Prof Saridis at Rensselaer Polytechnic Institute, Troy, New York, Prof Baras at University of Maryland, College Park, Prof Sastry at University of California, Berkeley, and Prof Mead at Caltech, Pasadena.

Per Persson attended the "European Conference on Artificial Intelligence," ECAI, in Munich, August 1–5, 1988. He and Jan Eric Larsson gave a demonstration of their intelligent help system for Idpac. He also attended the "IFAC Workshop on Artificial Intelligence in Real-Time Control" in Swansea, Wales, September 21–23, 1988.

Lars Rundqwist participated in the "IFAC Symposium on Adaptive Control in Chemical Processes (ADCHEM '88)" in Lyngby, Denmark, August 17–19, 1988, where he presented a paper.

Tomas Schönthal held a presentation and a demonstration of Simnon at a workshop titled "Regelungstechnische Programpakete für den IBM-PC und kompatible Personalcomputer unter MS-DOS", organized by VDI (Association of German Engineers) Bildungswerk in Düsseldorf, West Germany, March 2–3, 1989.

Björn Wittenmark participated and gave presentations at the following conferences: IFAC Symposium "Adchem '88" in Lyngby, Denmark, August 17–19, "8th IFAC Symposium on Identification and System Parameter Estimation" in Beijing, P.R. China, August 27–31, "Adaptive Regulering in Praksis" in Lyngby, Denmark, November 16, 1988, and during spring 1989 "American Control Conference" in Pittsburgh PA, June 21–23. Further, during September 1988, he lectured at two courses on adaptive control: one course at the Spanish Open University in Santander, Spain, and one industrial course in Maastricht, Holland.