ACTIVITY REPORT 1976 - 1977

Karl Johan Åström and Gustaf Olsson

ABSTRACT

The report surveys the activity at the Department of Automatic Control, Lund Institute of Technology, during the academic year 1976 - 77. It covers education and research. About 420 students took courses from the department during the period. 15 MS-theses and 1 PhD-thesis were completed during the academic year. The major areas of research were system identification, adaptive control, computer aided design of control systems and algebraic system theory. The applied research was devoted to adaptive ship steering, control of waste water treatment plants, control of heating and ventilation systems, and biomedical control problems.
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1. INTRODUCTION

The report follows the pattern of the previous activity reports. This time we will, however, only give an overview of the research projects because they have been presented in great detail in the previous yearly reports.

A major course revision has been initiated. The idea is to get a good base to revise all curricula. The input is obtained from discussions with colleagues and interviews with people in industry.

With regards to trends the impression from last year report concerning industrial use of interactive computing has been strengthened. There are now several industrial users of the packages IDPAC and SIMNON. We are also of the impression that the industrial use of self-tuning regulators will increase considerably with the availability of cheap microprocessors.

We will thank our sponsors the Swedish Board of Technical Development (STU), the Swedish Institute of Applied Mathematics (ITM), the National Board of Building Research (BFR), and the Scandinavian Council for Applied Research (Nordforsk) for their support of our projects.
2. A CURRICULUM REVISION FOR THE CIV ING PROGRAM

Most courses in the civ ing program have remained invariant for several years. We have therefore initiated a project to gather information for course reforms. We have had internal discussions. Many industries have been visited. Questionaries have been sent out. Colleagues at other universities and engineers have been interviewed. The material obtained is being digested. It will most likely result in revisions of our basic courses and in new courses for continued education.
3. RESEARCH

The major research areas are the following:

- STOCHASTIC CONTROL THEORY
- COMPUTER AIDED DESIGN
- ALGEBRAIC SYSTEM THEORY
- APPLICATIONS.

Within stochastic control theory there has been a shift in emphasis from system identification to adaptive control. The major work in system identification has been to round off results on recursive parameter estimation. The major work in system identification is now done within the applications project on ship modeling. It is expected that the work on adaptive control will be a major undertaking also for the years to come. Important areas which have been covered this period are dual control and adaptive prediction. Self-tuning regulators were also implemented in microprocessors. To follow the line of keeping abreast with work done elsewhere, professor Oliver Jacobs, Oxford University, spent a month with our adaptive control project.

A major change of direction was made in the computer aided design project. A commercial version of IDPAC was developed in response to industrial demands. To do this the system development was moved from PDP-15 to UNIVAC 1108. This made possible use of standard FORTRAN (not entirely available on PDP-15). It also gave an opportunity to isolate those parts that by necessity are implementation dependent. All the basic interaction was grouped into one package called INTRAC which is now the basis for all our interactive software. INTRAC can also be used separately to make a set of FORTRAN routines interactive. The availability of the programs have also increased substantially because they are now run under the ordinary time-sharing system.
A first version of a model transformation package MODPAC was also implemented. A substantial work to standardize software was carried out. This led to rules for subroutines in cooperation with other Scandinavian universities and the formation of the Scandinavian Control Library.

The work in algebraic system theory was devoted to development of software for algebraic control problems, algebraic design methods and theory for systems described by the backward shift operator.

The major application fields are:

- **MODELING OF SHIP DYNAMICS** (joint project with the Swedish State Shipbuilding Experimental Tank, Gothenburg)
- **ADAPTIVE SHIP STEERING** (joint project with Kockums Automation AB, Malmö)
- **CONTROL OF HEATING AND VENTILATION SYSTEMS** (joint project with the Department of Building Science, Lund)
- **CONTROL OF WASTE WATER TREATMENT** (joint projects with Datema AB, Nynäshamn, and University of Houston, Texas)
- **MODELING OF GLUCOSE AND INSULIN** (joint projects with the University Hospitals in Malmö and Lund)
4. LABORATORY

Plans have been made for upgrading our teaching laboratories. Several candidates for laboratory processes have been explored. Four microprocessors LSI-11 were bought. Small process control systems were built around the processors.
## APPENDIX A - LIST OF PERSONNEL

<table>
<thead>
<tr>
<th>Position</th>
<th>Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor</td>
<td>Karl Johan Åström</td>
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<tr>
<td>University lecturers</td>
<td>Gustaf Olsson</td>
</tr>
<tr>
<td></td>
<td>Björn Wittenmark</td>
</tr>
<tr>
<td>Research assistant</td>
<td>Per Hagander (PhD)</td>
</tr>
<tr>
<td>Research engineers</td>
<td>Leif Andersson</td>
</tr>
<tr>
<td></td>
<td>Hilding Elmqvist (PhD candidate)</td>
</tr>
<tr>
<td></td>
<td>Tommy Essebo (programmer)</td>
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<tr>
<td></td>
<td>Ivar Gustavsson (PhD)</td>
</tr>
<tr>
<td></td>
<td>Jan Holst (PhD candidate)</td>
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<tr>
<td></td>
<td>Lars Jensen (PhD candidate)</td>
</tr>
<tr>
<td></td>
<td>Claes Källström (PhD candidate)</td>
</tr>
<tr>
<td></td>
<td>Ann-Britt Nilsson (programmer)</td>
</tr>
<tr>
<td>Teaching assistants</td>
<td>Bo Egardt (PhD candidate)</td>
</tr>
<tr>
<td></td>
<td>Matz Lenells (PhD candidate)</td>
</tr>
<tr>
<td></td>
<td>Carl Fredrik Mannerfelt (PhD candidate)</td>
</tr>
<tr>
<td></td>
<td>Sven-Erik Mattsson (PhD candidate)</td>
</tr>
<tr>
<td></td>
<td>Per Molander (PhD candidate)</td>
</tr>
</tbody>
</table>
Laboratory engineer
Laboratorieingenjör

Rolf Braun

Visiting scientists
Gästforskare

Mr André Barbé, Leuven, Belgium
(6 months)

Prof H R Sirisena, New Zealand
(3 months)

Dr Vsevolod Razevig, Moscow, USSR
(6 months)

Mr Asko Kippo, Univ of Oulu, Finland
(5 months)

Technical drawings
Tekniskt biträde

Britt-Marie Carlsson

Secretaries
Sekreterare

Eva Schildt

Eva Dagnegård

Lilian Andersson (part time)

Typist
Skrivhjälp

Gudrun Christensen
APPENDIX B - PUBLISHED PAPERS AND CONFERENCE PAPERS


Leden B: Multivariable dead-beat control. Automatica 13 (1977) 185-188.


APPENDIX C - REPORTS

DISSEMINATIONS


FINAL REPORTS


ACTIVITY REPORTS


MASTER THESSES


TFRT-5190  Gustafsson G: Jämförelse av olika dynamiska modeller för sedimenteringen i biologisk vattenrenning (Comparison of different dynamical models of secondary sedimentation in biological wastewater treatment). Jan 1977.


INTERNAL REPORTS


TFRT-7114  Aström K J: Limitations of system performance due to time delays, instability, and non-minimum phase characteristics - An example. Dec 1976.


TRAVEL REPORTS

APPENDIX D - GRADUATE COURSES AND SEMINARS

Seminars and graduate courses, given at the department during the year, are summarized here. They are given by the staff at the department, by invited lecturers, or in cooperation with other departments at the Institute.

PHD COURSES

The following PhD courses were given:

Modeling  (K J Aström)
Control System Design  (K J Aström) with guest lecturers
  H S Sirisena, Univ of Canterbury, New Zealand
  A G J MacFarlane, Univ of Cambridge, England
  D Q Mayne, Imperial College, London, England
  O Jacobs, Univ of Oxford, England
System Theory  (P Hagander)
Optimization Theory  (P Hagander)

The courses on modelbuilding and control system design were given for the first time. The contents of the courses are listed below.

Modeling:

1. Introduction
2. Principles of modeling
3. Review of physics
4. Examples
5. Model simplification
6. Composition of simple models. Interconnection
7. Examples
Control System Design:

1. Introduction
   Control theory as control system design

2. Regulator structures

3. Review of relevant theory

4. Pole placement design

5. Frequency response

The following individual PhD tutorials were also given to individual studies:

- Stochastic Control (S-E Mattsson)
- Linear Quadratic Control (M Lenells)
- Nonlinear Systems (P Molander)
- Stochastic Processes (P Molander)
- Identification and Adaptive Control (P Molander)
- Identification (A Knutsson)

SEMINARS

Dr Don Rutherford, University of Manchester (UMIST), England.
"Computerized equipment for teaching automatic control", Aug 20, 1976,
"Applications of microprocessors in process control and instrumentation", Aug 23, 1976,
"Fuzzy mathematics", Aug 25, 1976,
Prof Peter Falb, Brown University, Providence, R I, USA.
"Differential Geometry and Dynamic Systems", five lectures:
"Introduction", Aug 19, 1976,
"Overview of applications to nonlinear systems", Aug 24, 1976,
"Overview of applications to linear systems", Aug 27, 1976,
"Overview of applications to linear systems", Aug 31, 1976,
"An application to nonlinear filtering", Sep 1, 1976.

Prof George N Saridis, Purdue University, Lafayette, Ind, USA.
"Hierarchically intelligent control of a bionic arm", Sep 13, 1976.

Prof K J Aström, Lund.
"Actual problems in control, with emphasis on the research at the Department", Sep 10, 1976,
"Control system design I", Sep 14, 1976,
"Control system design II", Sep 17, 1976,

Prof G Goodwin, Univ of Newcastle, Australia.

Dr John Ockendon, Oxford.

Dr P J Gawthrop, Univ of Oxford, England.

Mr André Barbé, Leuven, Belgium.

Johan Wieslander and Hilding Elmqvist, Lund.

Dr Ivar Gustavsson, Lund.

Mr Krister Lundberg, Eur Control, Säffle.

Mr Sture Lindahl, Swedish State Power Board (Vattenfall), Stockholm.

Prof K E Bollinger, Univ of Manchester (on leave from Univ of Saskatchewan), England.
"Views of tuning power plant controllers", Dec 6, 1976.

Prof Donald Wiberg, UCLA, Los Angeles, USA.
"Optimal control location for some classical PDE", Jan 12, 1977.

Prof H R Sirisena, New Zealand.
"Reduced order observers for estimating linear functions of the state", Jan 21, 1977,

Prof Lennart Ljung, University of Linköping.

Dr Ivar Gustavsson, Lund.

Dr Per Hagander, Lund.
Dr S Razewig, Moscow.  

Mr Leif Andersson, Lund.  

Mr Lars Pernebo, Lund.  
"Introduction to the graduate course in design of feedback systems, given by Prof A G J MacFarlane", March 10, 1977.


Dr B Francis, Cambridge, England.  

Prof H R Sirisena, New Zealand.  
"New results on reduced order observers", March 25, 1977.

Prof David Mayne, Imperial College, London.  
"Feasible direction algorithms for optimization problems with equality and inequality constraints", March 29, 1977,  
"A cut map algorithm for a class of computer aided design problems", April 1, 1977,  
"A feasible directions algorithm for optimal control problems with control and terminal inequality constraints", April 13, 1977,  
"An exact penalty function algorithm for optimal control and terminal equality constraints", April 15, 1977,  
"Relaxed control and the convergence of optimal control problems", April 22, 1977.
Prof K J Åström, Lund.
"Two examples of poleplacement design", March 31, 1977.

Dr Consuelo de Padilla, Venezuela.

Jan Sternby, Lund
"Dual control, an example", April 27, 1977.
"Regulators for time varying stochastic systems", May 2, 1977.

Dr S Razewig, Moscow.

Prof Granino Korn, Univ of Arizona, USA.
"Digital simulation", May 9, 1977.


Prof John Casti, Univ of Arizona, USA.

Prof A V Oppenheim, MIT, Cambridge, USA.
APPENDIX E - LECTURES BY THE STAFF

1976

July 5-9  K J Aström: Five lectures on system identification:
          Industrial experiences,
          Computer aided design packages,
          Recursive estimation,
          Prediction error methods and maximum likelihood
          identification,
          Identification of closed loop systems.
          University of Manchester, Manchester, England.

Sep 21-27 IFAC Symposium on Identification and System Parameter
          Estimation, Tbilisi, USSR:

          K J Aström (co-authors C Källström, T Essebo): A com-
          puter program for Maximum Likelihood Identification of
          linear multivariable stochastic systems.

          I Gustavsson (co-authors L Ljung, T Söderström): Iden-
          tification of processes in closed loop - identifiability
          and accuracy aspects. Invited survey paper.

          G Olsson (co-author O Hansson): Modeling and identifi-
          cation of an activated sludge process.

          J Wieslander (co-author I Gustavsson): IDPAC - an
          efficient interactive identification program.

          T Söderström (co-authors L Ljung, I Gustavsson): Ana-
          lysis of some on-line identification methods.

          B Wittenmark (co-author L Ljung): On a stabilizing
          property of adaptive regulators.
Fall 1976

P Hagander: Graduate course at the Medical Faculty, Lund University (20 lectures). "Metoder för analys och karakterisering av fysiologiska förlopp" ("Methods for the analysis and characterization of physiological phenomena").

Oct 20

G Olsson: Estimation and identification problems in wastewater treatment. IIASA workshop on recent developments in real-time forecasting/control of water resource systems, Laxenburg, Austria.

Nov 10

G Olsson: On the use of dissolved oxygen profiles in the control of activated sludge plants. University of Houston, Houston, Texas, USA.

Dec 15


1977

Feb 8

K J Aström: Stochastic control theory and some of its industrial applications. ETH, Zürich, Switzerland.

Feb 10

K J Aström: Maximum likelihood and prediction error methods for system identification. ETH, Zürich, Switzerland.

Feb 10


Feb 10

K J Aström: Identification of ship steering dynamics. ETH, Zürich, Switzerland.

Feb 14

K J Aström: Self-tuning regulators. ETH, Zürich, Switzerland.
March 8  G Olsson: Modellbyggnad och reglering av biologiska reningsverk (Modeling and control of biological wastewater treatment processes). 3 lectures. Department of Biology, University of Gothenburg, Sweden.

March 11 G Olsson: Interactive simulation and data analysis. Institute of Technology, Lyngby, Denmark.


April 25 K J Aström: The role of system identification in process modeling. VDI/VDE Tagung Prozessmodelle, Wiesbaden, Germany.

April 28 K J Aström: Adaptive control of stochastic systems. Ruhr-Universität Bochum, Germany.

May 16-20 IAWPR Int Workshop on Instrumentation and Control for Water and Wastewater Treatment and Transport Systems, London, England:

T Gillblad and G Olsson: Computer control of a medium sized activated sludge plant.

G Olsson: Convenors report on 'control system philosophies'.

June 6 G Olsson: New ideas on control methods for the activated sludge process. Dept of Civil Engineering, Univ of Houston, Houston, Texas, USA.

June 10 P Hagander: Okända begynnelsevärden (Unknown initial conditions). Seminar at a one day workshop on Kalman filtering and smoothing, Dept of Information Theory, Chalmers Inst of Technology, Gothenburg, Sweden.

June 22  H Elmqvist: SIMNON - An interactive simulation program for nonlinear systems. Paper, Simulation 77, Montreux, Switzerland.
APPENDIX F - TRAVELS

Leif Andersson participated in the IFAC symposium on Trends in Automatic Control Education in Barcelona, Spain, March 30 - April 1, 1977. During the same travel he also visited the University of Technology, Delft, Netherlands.

Hilding Elmqvist participated in the conference Simulation 77 in Montreux, Switzerland, June 22-24, 1977, and presented a paper there. Before the conference he visited the Fachgruppe für Automatik, ETH, Zürich, Switzerland, June 16-21.


G Olsson participated in the 4th IFAC symposium on Identification and Systems Parameter Estimation in Tbilisi, USSR, Sep 21-27, 1976. In October he was invited to the IIASA Workshop on Recent Developments in Real-time Forecasting/Control of Water Resource Systems, Laxenburg, Austria. The workshop lasted Oct 18-20, 1976. On Nov 8-12 he participated in a meeting between the Sparling Division of Environtech and the Department of Civil Engineering, Univ of Houston, in Houston, Texas. He has acted as program co-chairman for the IAWPR Int Workshop on Instrumentation and Control for Water and Wastewater Treatment and Transport Systems. The program committee met in London on February 8, 1977. The workshop took place in London on May 16-20. During June and July 1977 he has been a visiting professor at the University of Houston. He also participated in the 1977 JACC conference in San Francisco, June 1977.


Karl Johan Åström visited University of Manchester (UMIST) and Imperial College (IC), London, in July 1976. In September he visited the Soviet Union to participate in the 4th IFAC Symposium on Identification and System Parameter Estimation in Tbilisi. He also visited the Institute of Control Sciences in Moscow. In December 1976 he participated in the IRIA Symposium on New Directions in System Analysis, Versailles, France. In February 1977 he visited Zürich, Switzerland, to explore the possibilities of a closer cooperation between ETH and LTH. In April he visited Wiesbaden, Germany, to participate in the VDI/VDE Meeting on Process Modeling. In May Åström was external examiner on the dissertation by C Doncarli, Nantes, France, for the degree "docteur d'état". In June 1977 he participated in the 5th IFAC/IFIP Symposium on Digital Computer Applications to Process Control, The Hague, Netherlands. During the year Åström has been associate editor of Automatica, International Journal on Control, Journal of Mathematical Analysis and Applications, and Mathematical Biosciences. He also participated in a special IEEE panel to evaluate the IEEE Transactions on Automatic Control.