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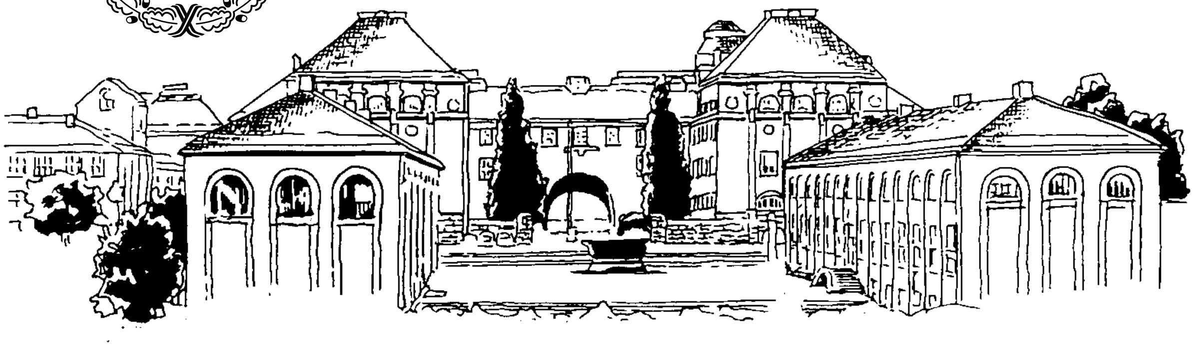

Activity Report

1999/2000

Division of Optimization and Systems Theory
Department of Mathematics
Royal Institute of Technology
SE–100 44 Stockholm, Sweden
http://www.math.kth.se/optsyst/

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The Division of Optimization and Systems Theory is part of the Department of Mathematics at the Royal Institute of Technology. This report summarizes the activities at this division during the academic year 1999/2000 (July 1999 – June 2000).

Optimization and Systems Theory is a discipline in applied mathematics primarily devoted to methods of optimization, including mathematical programming and optimal control, and systems theoretic aspects of control and signal processing. In addition, attention is given to mathematical economics and applied problems in operations research, systems engineering and control engineering.

Research performed at the Division of Optimization and Systems Theory includes various topics in *mathematical systems theory*, with particular emphasis on stochastic systems, filtering, identification and robust and nonlinear control; *mathematical programming*, with emphasis on nondifferentiable optimization, large-scale nonlinear programming, dual optimization methods, structural optimization, and a wide range of applications; *systems engineering*; and *mathematical economics*. The division also has an Optimization Laboratory devoted to collecting state-of-the-art optimization routines, making them available to research institutions and industry. The division is also one of four core groups in the Center for Autonomous Systems, a research consortium supported by a grant from the Strategic Research Foundation.

The Division of Optimization and Systems Theory offers undergraduate courses in mathematical programming, mathematical systems theory, optimal control and mathematical economics, as well as various topics in operations research and modeling. There is an extensive graduate program.

A regular *Optimization and Systems Theory Seminar* has been running weekly. In addition, more tutorial and informal seminars in mathematical programming and systems and control have been running in parallel.

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1 Personnel

1.1 List of personnel

Professor (Professor)

Anders Lindquist, TeknD

Docenter (Associate professors)

Anders Forsgren, TeknD, universitetslektor
Xiaoming Hu, PhD, forskare
Krister Svanberg, TeknD, universitetslektor Director of undergraduate studies

Universitetslektorer (Senior lecturers)

Ulf Brännlund, TeknD
Claes Trygger, TeknD

Forskare (Researchers)

Stefan Feltenmark, TeknD
Ulf Jönsson, TeknD

Postdoktorstipendiat (Postdoctoral fellow)

Alessandro Chiuso, PhD

Gästforskare (Visiting professors)

Per-Olof Gutman, associate professor
Clyde F. Martin, professor
Vladimir Yakubovich, professor

Handläggare (Executive administrator)

Leena Druck

Doktorander (Graduate students)

Claudio Altafini
Gianantonio Bortolin
Anders Dahlén, FK, TeknL
Magnus Egerstedt, civing (graduated (TeknD) April 2000)
Per Enqvist, civing
Torvald Ersson, civing
Camilla Landén, civing
Ryozo Nagamune
Mattias Nordin, civing, TeknL
Mikael Prytz, civing
Jonas Rappe, civing
Henrik Rehbinder, civing
Göran Sporre, civing
Mathias Stolpe, civing
Petter Ögren, civing

1.2 Biographies

Claudio Altafini received a degree ("laurea") in Electrical Engineering in 1996, from the University of Padova, Italy. In 1995 he worked for ABB Industrial Systems in Västerås, Sweden. In 1996 he held a position as process control engineer at Cerestar Italia SpA. He is currently a PhD student at the division, affiliated with the Center for Autonomous Systems. His current research interests are geometric control theory with applications to robotics.

Gianantonio Bortolin was born in Pordenone, Italy, in 1973. He received his degree in Electrical Engineering in 1999 from University of Padova. He did his undergraduate thesis in 1999 at Scania with KTH. Presently he is a PhD student at the Division of Optimization and Systems Theory and cooperates in a NUTEK project on "Process modelling, operator training simulation, and optimization applied to a paper board manufactoring".

Ulf Brännlund was born in 1961. He received a civilingenjör degree in Aeronautical Engineering from KTH in 1986 and an MS degree in Engineering-Economic Systems from Stanford University in 1988 and his doctorate degree from KTH in 1993. He is the chairman of the board and cofounder of the company Optimization Partner Stockholm AB (www.optimizationpartner.com). His main research interests are nondifferentiable optimization, semidefinite programming and structural optimization.

Alessandro Chiuso was born in Venice on December 21st, 1972. He received a degree ("laurea", summa cum laude) in Telecomunications Engineering in 1996, from the University of Padova, Italy and the Ph.D. degree in System Engineering in February 2000 with a thesis on "Geometric Subspace Methods for Subspace Identification" (Tutor Prof. G. Picci). From August 1998 to June 1999 he has been a visiting research scholar at Washington University in St. Louis, (MO) USA, where he has been performing research under the supervision of Prof. Stefano Soatto. From March 2000 to July 2000 he has been a Post-Doctoral researcher with the Division of Optimization and System Theory, Dept. of Mathematics, KTH, funded by the European Community through the European Research Network on System Identification (ERNSI). Since September 2000 he is "assegnista di ricerca" with the department of Electronics and Informatics, University of Padova, Italy. His current research interests include stochastic realization theory, system identification (in particular subspace methods), estimation theory and computer vision.

Anders Dahlén was born in Karlskrona, Sweden, in 1969. He did his undergraduate work in Mathematics of Science at the University of Växjö. He is presently a PhD student at the Division of Optimization and Systems Theory, and received in May 1998 the Teknisk Licenciat degree. His main professional interest is Mathematical Systems Theory, and especially Stochastic Realization theory and Identification.

Leena Druck has been at the Division of Optimization and Systems Theory since 1992. Since 1999 she is the executive administrator at the Department of Mathematics.

Magnus Egerstedt was born in Täby, Sweden, in 1971. He received the M.S. degree in Engineering Physics and the Ph.D. degree in Optimiziation and Systems Theory from the Royal Institute of Technology, in 1996 and 2000 respectively. He also received a B.A. degree in philosophy from Stockholm University in 1996. Since January 2000 he is working as a Postdoctoral Fellow at the Division of Engineering and Applied Sciences at Harvard University. His main research interest is in modeling and analysis of hybrid systems, with emphasis on motion planning and control of mobile robots.

Per Enqvist was born in Upplands Väsby, Sweden, in 1971. He received a civilingenjörs degree in Engineering Physics from KTH in 1994. He is presently a PhD student at the Division of Optimization and Systems Theory. His main research interest is Mathematical Systems Theory, and especially Stochastic Realization Theory. At the moment he is studying various interpolation problems for filters of stochastic systems, in particular the covariance extension problem and cepstrum interpolation problems are considered.

Torvald Ersson was born in Västmanland, Sweden, in 1973. He received a Master of Science degree from the School of Engineering Physics, KTH, in 1998. Presently he is a graduate student at the division and cooperates with the Centre for Autonomous Systems (CAS). His main research interests are robotics and autonomous systems.

Stefan Feltenmark was born in Boden in 1968. He recieved a civilingenjör degree in Engineering Physics from KTH in 1991, and a TeknD (PhD) degree from the Division of Optimization and Systems Theory, KTH, in 1997. Research interests include power systems optimization, stochastic programming, dual methods, decomposition methods, and large-scale optimization. In addition to being a researcher at KTH, Feltenmark is the CEO of the company Optimization Partner, which he founded in 2000 together with Ulf Brännlund.

Anders Forsgren was born in Danderyd, Sweden, in 1961. He received a civilingenjör degree in Engineering Physics from KTH in 1985, an MS degree in Operations Research from Stanford University in 1987 and a TeknD degree in Optimization and Systems Theory from KTH in 1990. Between 1991 and 1995 he held a position as research associate at the Division of Optimization and Systems Theory, where in 1995 he was appointed Docent. Since 1995 he is an associate professor at this division. Forsgren was a Visiting Fulbright Scholar at the University of California, San Diego, during three months in 1996. His main research interest is nonlinear programming, numerical optimization in particular.

Per-Olof Gutman was born in Höganäs, Sweden on May 21, 1949. He received the Civ.-Ing. degree in engineering physics in 1973, the Ph.D. degree in automatic control, and the title of docent in automatic control in 1988, all from the Lund Institute of Technology, Lund, Sweden. As a Fulbright grant recipient, he received the M.S.E. degree in 1977 from the University of California, Los Angeles.

He taught mathematics in Tanzania 1973-1975. 1983-1984 he held a post-doctoral position with the Faculty of Electrical Engineering, Technion - Israel Institute of Technology, Haifa, Israel. 1984-1990 he was a scientist with the Control Systems Section, El-Op Electro-Optics Industries, Rehovot, Israel, where he designed high precision electro-optical and electro-mechanical control systems. In 1990 he joined the Faculty of Agricultural Engineering, Technion — Israel Institute of Technology, Haifa, where he is currently an Associate Professor.

He has spent several periods as a guest researcher at the Division of Optimization an Systems Theory, Royal Institute of Technology, Stockholm, Sweden. He was a Visiting Professor at the Laboratoire d'Automatique de Grenoble, France, 1995-96. Gutman serves on the editorial board of Automatica.

Xiaoming Hu was born in Chengdu, China, in 1961. He received the B.S. degree from University of Science and Technology of China in 1983. He received the M.S. and Ph.D degrees from Arizona State University in 1986 and 1989 respectively. He served as a research assistant at the Institute of Automation, Academia Sinica, from 1983 to 1984. He was Gustafsson Postdoctoral Fellow at the Royal Institute of Technology, Stockholm, from 1989 to 1990. His main research interests are nonlinear control theory, the analysis and design of nonlinear feedback systems and the applications of nonlinear dynamics in control and state estimation.

Ulf Jönsson was born in Barsebäck, Sweden. He received the M.Sc. degree in Electrical Engineering in 1989 and the Ph.D. degree in Automatic Control in 1996, both from Lund Institute of Technology, Lund, Sweden. He spent the academic year 1989-1990 at the Department of Electrical Engineering at University of California, Santa Barbara on the education abroad scholarship. In the first half of 1997 he was a postdoctoral fellow at California Institute of Technology and thereafter he worked two years as a postdoctoral fellow at the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology. His current research interests include design and analysis of nonlinear and uncertain control systems, periodic systems theory, robust control along trajectories, and convex optimization applications in systems theory.

Camilla Landén was born in Upplands Väsby, Sweden, in 1970. She received a civilingenjör degree in Engineering Physics from KTH in 1994. She is presently a PhD student at the Division of Optimization and Systems Theory. Her main research interests are financial mathematics and stochastic differential equations.

Anders Lindquist received his PhD degree from the Royal Institute of Technology, Stockholm, Sweden, where in 1972 he was appointed a Docent of Optimization and Systems Theory. From 1972 to 1974 he held visiting positions at the University of Florida, Brown University, and State University of New York at Albany. In 1974 he became an Associate Professor, and in 1980 a (full) Professor of Mathematics at the University of Kentucky, where he remained until 1983. He is now a Professor at the Royal Institute of Technology, where in 1982 he was appointed to the Chair of Optimization and Systems Theory. Since then he has also held visiting positions at the University of Padova, Italy, University of Arizona, USSR Academy of Sciences, Moscow, East China Normal University, Shanghai, and Technion, Haifa, Israel.

Presently, Anders Lindquist is the Chairman of the Mathematics Department at the Royal Institute of Technology. He is a Member of the Royal Swedish Academy Sciences, a Foreign Mamber of the Russian Academy of Natural Sciences, a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), and an Honorary Member the Hungarian Operations Research Society. He is an Affiliate Professor at Washington University, St Louis (since 1989) and an Advisory Board Member of the Institute for Mathematics of the Life Sciences, Texas Tech University.

Lindquist has served on many editorial boards of journals, among them the *Journal of Mathematical Systems, Estimation, and Control* (Communicating Editor), *Systems and Control Letters*, *Adaptive Control and Signal Processing*, and book series, namely *Systems and Control: Foundations and Applications*, *Applied and Computational Control, Signals, and Circuits*, and *Progress in Systems and Control.* Since 1983 he has been a member, and between 1985 and 1987 the chairman, of the steering committee for the biannual international symposia on the Mathematical Theory of Networks and Systems (MTNS).

Ryozo Nagamune was born in Yamaguchi, Japan, in 1972. He received Master's degree in Engineering from Osaka University in 1997. He is presently a PhD student at the Division of Optimization and Systems Theory. His research interests are the application of the Nevanlinna-Pick interpolation theory with degree constraint to H^∞ control and the extension of the analytic interpolation theory to the multivariable cases.

Mikael Prytz was born in 1969 in Stockholm, Sweden. He has a Master of Science-degree in Engineering Physics from the Royal Institute of Technology (1993) and a Masters-degree in Engineering-Economic Systems and Operations Research from Stanford University (1998). From 1993 to 1996 he worked at Ericsson Telecom where he developed models and methods for telecommunications network design problems and participated in network design projects. In 1997 he began as an industry Ph.D. student at the department in a project that is jointly funded by Ericsson Radio Systems AB and the Swedish Research Council for Engineering Sciences. He maintains a position at Ericsson Radio Systems where he also works part time. He spent the academic year 1997-98 in the MS-program at the Department of Engineering-Econonic Systems and Operations Research, Stanford University, USA. His research interests are in optimization methods for telecommunications network design problems.

Jonas Rappe was born in 1970. He received a civilingenjör degree in Vehicle Engineering from KTH in 1997. In 1998 he worked for Sigma Design & Development in Solna, Sweden. He is currently a PhD student at the Division of Optimization and Systems Theory. His main research interests are hydro power systems optimization and stochastic programming.

Henrik Rehbinder was born in 1972 in Värmdö, Stockholm, Sweden. He recieved his Master of Science degree in Engineering Physics from KTH in 1996. He is currently a PhD-student at the division, affiliated with the WARP at the Centre for Autonomous Systems. His research interests are in sensor fusion for state estimation focused on nonlinear attitude estimation for walking machines using inertial sensors and vision. He is also interested in control and filtering with limited communication.

Göran Sporre was born in Järfälla, Sweden, in 1972. He received a civilingenjör degree in Engineering Physics from KTH in 1996. In 1997 he was employed at Telia Engineering, working with issues related to network planning for telecommunication. Since the beginning of 1998 he is a PhD student at the Division of Optimization and Systems Theory. His main research interest is interior methods for nonlinear programming.

Mathias Stolpe was born in Skerike, Sweden, in 1972. He received a Master of Science degree in Vehicle Engineering from KTH in 1997. He is presently a PhD student at the Division of Optimization and Systems Theory. His main area of research is structural optimization.

Krister Svanberg was born in Stockholm in 1950. In 1975 he got his Civilingenjör degree in Engineering Physics, and 1982 he got his TeknD degree in Optimization Theory. 1993 he was appointed Docent. Between 1976 and 1985 he worked for the Contract Research Group of Applied Mathematics, and since 1985 he is a Senior Lecturer. His main area of research is structural optimization, dealing with theory and methods for optimal design of load-carrying structures.

Claes Trygger was born in Stockholm, Sweden, in 1945. He received his civilingenjör degree in Engineering Physics in 1969 and his TeknL and TeknD degrees in Optimization and Systems Theory in 1974 and 1980, respectively; all from KTH. Since 1966 he has been employed in various positions at the Department of Mathematics at KTH, mainly in the Division of Optimization. At present he is a Senior Lecturer of Optimization and Systems Theory. Apart from teaching, his main professional interests are control theory and mathematical biology.

Vladimir Yakubovich was born in Novosibirsk, Russia, in 1926. He was a student of Mechanics and Mathematics at Moscow University from 1946 to 1949. In 1949 he received the first prize for student scientific work and was recommended by two chairs (those of I. M. Gelfand and V. V. Nemyzki) for postgraduate education but was refused at the request of Comsomol and the Communist Party (after he had protested against discrimination of Jewish students in admittance to postgraduate studies). In 1953, after having worked for some time in industry as an engineer, he received the Candidate of Science degree (PhD), and then he served as an Assistant and an Associate Professor at Leningrad Mining Institute. From 1956 to present time he has been associated with St. Petersburg University (formerly Leningrad University), where in 1959 he received the Doctor of Science Degree. He became a (full) Professor of Mathematics in 1963 and head of the Theoretical Cybernetics Chair in 1971.

He is the author of more than 250 papers and coauthor of seven books in different areas of mathematics, especially applied mathematics and control theory. He has worked in parametric resonance theory (extending and improving some Lyapunov results), in the theory of stability of nonlinear systems, and in optimization theory. He introduced a method of "recursive aim inequalities" in the theory of adaptive systems, and an abstract theory of optimal control, extending the Pontrjagin maximum principle to many new cases. The "Kalman-Yakubovich-Popov Lemma" connects two areas of control theory, frequency methods and Lyaponov methods, and it is also of importance in stochastic realization theory. His main results in recent years concern new aspects of linear-quadratic optimization problems.

Yakubovich has served on the editorial boards of Siberian Mathematical Journal (1973-1980), Systems and Control Letters (1981-1988) and Dynamics and Control (since 1990). He has served on many scientific committees and is a member of several scientific societies in Russia. In 1991 he was awarded the Norbert Wiener Prize by the Russian Academy of Natural Sciences. Since 1991 he is a corresponding member of the Russian Academy of Sciences and since 1992 a member of the Russian Academy of Natural Science.

1.3 Visiting and interacting scientists

- Professor Tomas Björk, Department of Finance, Stockholm School of Economics
- Professor Christopher I. Byrnes, Department of Systems Science and Mathematics, Washington University, St. Louis, Missouri, USA
- Fernando D'Amato, School of Aeronautics and Astronautics, Purdue University, West Lafayette, IN, USA
- Professor W. P. Dayawansa, Department of Mathematics, Texas Tech University, Lubbock, Texas, USA
- Professor Ruggero Frezza, Dipartimento di Elettronica, Universita di Padova, Padova, Italy
- Professor Tryphon T. Georgiou, Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, Minnesota, USA
- Professor Bijoy K. Ghosh, Department of Systems Science and Mathematics, Washington University, St. Louis, Missouri, USA
- Dr. Karl H. Johansson, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, USA
- Professor Philip E. Gill, Department of Mathematics, University of California, San Diego, La Jolla, California, USA
- Dr. S. V. Gusev, Department of Mathematics, St. Petersburg University, St. Petersburg, Russia
- Professor Jan Holst, Department of Mathematical Statistics, Lund University, Lund, Sweden
- Dr. Ilya Ioslovich, Faculty of Agricultural Engineering, Technion, Haifa, Israel
- Chung-Yao Kao, Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.
- Dr. John Lygeros, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, USA
- Dr. Jorge Marí, Adtranz, Västerås, Sweden
- Professor Alexandre Megretski, Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.
- Professor György Michaletzky, Department of Probability Theory and Statistics, Eötvös Lorand University, Budapest, Hungary
- Professor Giorgio Picci, Department of Electronics and Informatics, University of Padova, Padova, Italy
- Professor Alfredo Piria, Department of Mathematics, Facultad Ingeneria, Montevideo, Uruguay
- Professor Anders Rantzer, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden.
- Professor Mario Rotea, School of Aeronautics and Astronautics, Purdue University, West Lafayette, IN, USA
- Professor Shankar Sastry, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, USA

1.4 Networks

- European Research Consortium for Informatics and Mathematics (ERCIM): Working Group on Control and System Theory
- European Research Network for Systems Identification (ERNSI)
- INTAS Network on Robust Control
- NorFa Network on Structural Optimization.
- Strategic Research Consortium of Autonomous Systems, KTH

2 Research

2.1 List of projects

- Control theoretic smoothing splines
- Financial economics
- Geometric theory of linear stochastic systems
- Hybrid control of autonomous system
- Integral quadratic constraints
- KTH optimization laboratory
- Large-scale nonlinear programming
- Models and methods for structural optimization
- Optimal damping of forced oscillations in discrete-time systems
- Optimization in telecommunications network design
- Optimization of power systems under uncertainty
- Periodic systems
- Process modeling, operator training simulation and optimization applied to paper board manufacturing
- Rational Nevanlinna-Pick interpolation with degree constraints
- Robust control of electrical drives
- Semidefinite programming and structural optimization
- Some problems in navigation and motion control of nonlinear systems
- Stochastic realization theory and identification
- The rational covariance extension problem, Cepstral geometry and global analysis of shaping filters

2.2 Description of projects

Control theoretic smoothing splines

Researchers: Magnus Egerstedt and Clyde F. Martin (Texas Tech University).

Sponsors: The Swedish Foundation for Strategic Researches (SSF), NSF, and NASA.

When planning trajectories for linear control systems, a demand that arises naturally in, for instance, air traffic control, noise contaminated data interpolation, and planning for switched control systems, is that the curve interpolate through given points or intervals at given times. We address this problem by showing how linear optimal control techniques, together with mathematical programming, can be used to solve the problem in a numerically feasible way. We thus provide a theoretical framework for producing a rich set of curves called generalized smoothing splines.

Financial economics

Researchers: Camilla Landén, in cooperation with Tomas Björk (Stockholm School of Economics).

The goal of this project is to study the mathematical theory of financial derivatives.

During the year we have investigated the term structure of forwards and futures. We have derived the following: drift conditions for forwards and futures similar to the Heath-Jarrow-Morton drift condition for forward rates, sufficient conditions for the term structures of forwards and futures to be affine, and a pricing formula for options on futures. We have also studied the problem of inverting the futures term structure.

Geometric theory of linear stochastic systems

Researchers: Anders Lindquist, in cooperation with Giorgio Picci (University of Padova) and Gy. Michaletzky (Eötvös Lorand University, Budapest).

Sponsors: The Swedish Research Council for Engineering Sciences (TFR) and the Göran Gustafsson Foundation.

The objective of this project is to develop a comprehensive geometric theory for state-space modeling of stochastic processes within the coordinate-free framework of Markovian splitting subspaces and with emphasis on systems theoretical concepts, and to apply these results to problems in identification and model reduction. A theory for linear stochastic systems has been developed which describes structural systems-theoretic properties in the geometric language of Hilbert space theory. A monograph, jointly authored by Lindquist and Picci, is under preparation. Recent results include:

- We have developed a synthesis of stochastic realization theory and geometric control theory in the style of Wonham and Basile and Marro.
- We have generalized the well-known characterization of the solutions of the algebraic Riccati equation in terms of Lagrangian subspaces invariant under the corresponding Hamiltonian to the larger solution set of the algebraic Riccati inequality. The discrete-time Riccati equation has been studied in detail.
- Connections have been established between stochastic realization theory and identification algorithms based on canonical correlation analysis. Some geometric alternatives to subspace identification methods are considered.

- A causal realization theory for stochastic models of random phenomena that are spatially distributed have been developed (J. Sand).
- A procedure for reconstructing the lost state when a "black out" of state information has occurred during a finite interval of time but noisy output observation still are.

Hybrid control of autonomous system

Researchers: Anders Lindquist, Xiaoming Hu, Magnus Egerstedt, Henrik Rehbinder, Claudio Altafini, Torvald Ersson and Petter Ögren.

Sponsor: The Swedish Foundation for Strategic Researches (SSF).

This project is part of the ongoing research effort of the Center for Autonomous Systems. In this project we use a hybrid system approach to study some issues concerning the integration of control and sensor systems for a mobile manipulator. In particular, the following issues are studied.

1. Modeling of basic behaviors as dynamic systems. In order to take advantage of HDS methods, one should model individual behaviors of a robot (action responses to sensory inputs) as dynamical systems, or as a set of differential or/and difference equations. Then one can study problems such as path planning and obstacle avoidance for systems with possibly nonholonomic constraints.
2. Modeling of tasks as hybrid dynamic systems. In a Behavior Based robot architecture, many behaviors are affecting the system simultaneously. Therefore questions concerning safety, task-achievement and liveliness (non-blocking behaviors) are hard to answer due to the complexity of the system. However, if these behaviors could be modeled as nodes in a hybrid automata, features about the system could be proved.
3. Sensor fusion. The multiple sensor problem, known as sensor fusion, has been studied extensively, but a fully satisfying solution has not yet been provided and many research issues are still open. We study the basic problems of designing and tailor-making filter algorithms for our applications as well as more general filtering problems for sensors in distributed control systems.
4. Feedback Control of Hybrid Systems. A few different problems on the control of hybrid system will be studied. By the use of abstraction, it is possible to simplify complex decision-making problems into hierarchical control systems. It is then necessary to have consistent methods for aggregating system properties from one level to another. This crucial problem in the design of complex control systems have only recently been addressed. We will study this problem together with the related problem of composition of hybrid systems.

Integral quadratic constraints

Researchers: U. Jönsson, in cooperation with A. Megretski (M.I.T), A. Rantzer (Lund Institute of Technology, C. Kao (M.I.T), M. Rotea (Purdue University), and F. D'Amato (Purdue University).

Sponsor: The Swedish Research Council for Engineering Sciences (TFR).

We are involved in an effort to develop the framework of Integral Quadratic Constraints (IQCs). The notion integral quadratic constraint was introduced by Yakubovich in the 1960s and it has been shown to be a useful concept in systems analysis. Indeed, it can be used to unify much of the existing stability theory and it results in stability criteria that can be verified using convex optimization.

There has been a rapid development in this research area during the last few years. One important direction is the development efficient and user friendly software for IQC analysis. One of the first efforts was published in [A14]. This work has been continued in collaboration with with Megretskis group at LIDS-MIT, where the software package IQCbeta was developed [R12]. We have also worked on theoretical issues of IQC optimization. One contribution was to consider the quality of approximations to infinite dimensional IQC optimization using duality theory [A15]. Another was the development of a new algorithm for fast IQC optimization in [C28].

Another direction of research is the development of new IQC descriptions of system components and noise signals. We published two papers that discuss modeling of noise and disturbance signals using IQCs [C22], [C26]. We have also published several papers on analysis of uncertain systems with nonlinearities during this year. In [A16], we used an encapsulation technique to obtain general analysis results for a class of uncertain neutrally stable systems in feedback interconnection with slope restricted nonlinearities. Analysis of systems with multiple repeated slope restricted nonlinearities was discussed in [C25] using an IQC developed in [A9].

KTH optimization laboratory

Researchers: Ulf Brännlund, Stefan Feltenmark, Anders Forsgren, Mikael Prytz, Jonas Rappe, Göran Sporre, Mathias Stolpe, Krister Svanberg.

This project aims at creating a productive research environment for development of optimization methods and at spreading modern optimization practice in Swedish industry. This is done by collecting state-of-the-art portable optimization routines as well as optimization problems and keeping them available in a network of work stations. This obviously will facilitate research, but through our projects and through making the routines available for testing, we also fulfill the other goal.

A partial list of routines include:

MINOS, SNOPT, QPOPT, LSSOL, NPOPT	(Gill et al, Stanford and UCSD)
CPLEX	(Cplex Corporation)
MMA	(Svanberg, KTH)
GRG2	(Lasdon, U Texas)
RELAX	(Bertsekas, MIT)
NETFLO, NETSIDE	(Kennington, S Methodist U)
NLPQL	(Schittkowski, U Bayreuth)
NOA3	(Kiwiel, Polish Academy of Sciences)
RSDNET, RSDTA	(Hearn, U Florida)
GAMS	(GAMS)
ELSUNC, ENLSIP	(Umeå University)

The routines reside in a Unix workstation environment, in which we have written an interfaces to Matlab for several routines, thereby making them easy to use. These interfaced routines have been used extensively, both in our own research and for educational purposes.

Large-scale nonlinear programming

Researchers: Anders Forsgren and Göran Sporre, in cooperation with Philip E. Gill (UCSD).

Sponsor: The Swedish Natural Science Research Council (NFR).

The goal of this project is the development of computationally efficient methods for solving large sparse nonlinear optimization problems. We focus on methods that utilize second-derivatives, since we expect such methods to prove more robust and efficient than methods that only use first-derivative information.

Recent algorithmic work has been directed towards penalty-barrier methods for general nonlinear programming methods. A method, solving a primal-dual system of equations at each iteration, utilizing an augmented penalty-barrier merit function, has been developed. The current focus of Sporre's research is on primal-dual interior methods, convergence properties in particular. A report relating this research to interior methods for quadratic programming has been written [R8]. A paper on optimality conditions for semidefinite programming has been published [A12].

Models and methods for structural optimization

Researchers: Krister Svanberg and Mathias Stolpe.

Sponsor: The Swedish Research Council for Engineering Sciences (TFR).

Structural optimization deals with optimal design of load-carrying structures. The purpose of this project is to develop mathematical models and efficient numerical methods for different types of structural optimization problems. Here follows a brief summary of our research during the year. First, we have studied the trajectories of optimal solutions to penalized or relaxed topology optimization problems as the penalization- or relaxation parameter is varied. As a result, we identified certain intrinsic difficulties with penalization- and relaxation methods in topology optimization, see [A30], [A31], [C40]. Second, we have developed a new artificial material interpolation model, defining stiffness as a certain rational function of density. The model appear to be a useful tool for obtaining zero-one solutions in topology optimization, see [R14]. Third, we have proved global convergence of a new version of our structural optimization method MMA, [R15], and later extended this convergence proof to a larger class of optimization methods based on conservative convex approximations, [R16].

Optimal damping of forced oscillations in discrete-time systems

Researchers: Anders Lindquist and Vladimir A. Yakubovich.

Sponsors: The Swedish Research Council for Engineering Sciences (TFR), the Royal Swedish Academy of Sciences, NUTEK and INTAS.

In this project we consider a linear discrete-time control system affected by additive harmonic disturbances with known frequencies but unknown amplitudes and phases. The problem is to damp this forced oscillation in an optimal fashion by output feedback and to track a given signal. To this end we design a robust optimal regulator which is universal in the sense that it does not depend on the unknown amplitudes and phases and is optimal for all choices of these values. In [A19] we show that, under certain natural technical conditions, an optimal universal regulator (OUR) exists in some suitable class of linear or nonlinear stabilizing and realizable regulators, provided the dimension of the output is no smaller than the dimension of the quasi-harmonic disturbance. When this dimensionality condition is not satisfied, the existence of an OUR is not a generic property. We have also shown that any OUR for this (deterministic) problem is an optimal regulator for a class of stochastic control problems of similar structure. Nonrationals solutions are also being studied.

We stress that our solutions are optimal in the sense stated above only, arbitrary universal optimal regulator. Therefore it is an important for an property of our procedure that it allows for a considerable degree of design freedom, and optimality should be regarded as one of several design specifications.

Optimization in telecommunications network design

Researchers: Mikael Prytz and Anders Forsgren (advisor).

Sponsor: Ericsson Radio Systems AB, The Swedish Research Council for Engineering Sciences (TFR), The Swedish Natural Science Research Council (NFR).

This project considers models and optimization methods for telecommunications network design problems. The focus is on practical solution methods for real problems that are relevant for network designers in the tele- and datacommunications industry.

Recent work has been directed on a capacity dimensioning problem in communications networks with multicast traffic, which is point-to-multipoint or multipoint to multipoint. Some examples of multicast traffic are real-time distribution of live video, audio, and data (e.g. TV-channels and stock tickers), teleconferencing, routing protocol route updates, multiplayer games, etc. The problem has been modelled as a mixed integer program, which, unfortunately, becomes very large and difficult to solve exactly for problem sizes that occur in practice. A relaxation approach based on "splitting" variables has been found to yield very good lower and upper bounds on the problem. Results have been presented [P52] and a report is currently being finalized.

Optimization of power systems under uncertainty

Researchers: Stefan Feltenmark and Jonas Rappe, in cooperation with Roger Halldin and Jan Holst (Lund University).

Sponsor: ITM, Vattenfall, Sydkraft, Elforsk.

Within this project, we study optimization of hydro-thermal power systems in situations with imperfect information about problem data. Such data is future dam inflows, power prices, and power demand. We address these problems by *stochastic programming*, combined with advanced sampling techniques.

An optimization model has been put up and is described in [R7]. The project activities in 1999 are summarized in [O2].

Periodic systems

Researchers: Ulf Jönsson, in cooperation with Alexandre Megretski (M.I.T) Chung-Yao Kao (M.I.T).

Sponsor: The Swedish Research Council for Engineering Sciences (TFR).

Applications for periodic system theory abound in science and engineering. Periodic phenomena can appear due to limit-cycle oscillation, forced vibration, or parametric excitation of the system. In this project we consider the questions of robustness and stability for periodic systems. As an example, we are interested in deciding whether periodic solutions remain and if they stay stable when the dynamics of the system changes. In other words, we develop tools for studying robustness against period changing bifurcations.

The results so far are along two different directions. In [C24],[C31], and [R10] we discuss robustness of periodic solutions of non-autonomous systems with respect to structured uncertainty. We use a worst case sensitivity derivatives of the trajectory with respect to the structured uncertainty in order to derive conditions for existence of an exponentially stable periodic solution in a given neighborhood of the nominal solution. In order to solve this problem we need tools for robustness analysis of linear time periodic systems, which is the second direction of research. For this we have shown how integral quadratic constraints and a special convex optimization algorithm can be used for general stability and performance analysis of periodic systems [A17],[C23].

Process modeling, operator training simulation and optimization applied to paper board manufacturing

Researchers: Per-Olof Gutman, Anders Lindquist, Xiaoming Hu, Gianantonio Bortolin in cooperation with with Bengt Nilsson (AssiDomän Carton Board AB, Frövi), Johan Tryding (AssiDomän Corporate R&D, Skärblacka), Hilding Elmqvist (Dynasim AB, Lund), and Pontus Ryd (Solvina AB, Göteborg).

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK) through its KTS (Complex Technical Systems) program, and AssiDomän Carton Board AB, AssiDomän Corporate R&D, Dynasim AB, and Solvina AB.

The project started in April 1999. The aim of the project is to integrate existing models of the paper board manufacturing process at AssiDomän Carton Board AB, together with on-line identification routines, into a comprehensive Modelica model with the purpose of interactive operator simulation and operator assisted optimization of important quality variables.

Dynamic models will be developed for those subprocesses for which suitable models do not exist. A library of reusable model components will be developed in the new modeling language Modelica.

The following has been achieved during 1999/2000: A Modelica model for the wet end of the AssiDomän Carton Board AB carton board machine KM5 in Frövi has been written, as well as a preliminary model for the drying section. Modelica language elements for the purpose of the project have been developed. Gianantonio Bortolin has been recruited as a graduate student and will write an licentiate thesis on one of the modelling topics.

The project can be seen as a continuation of the project "Robust quality control for paper manufacturing" that was completed last year.

Rational Nevanlinna-Pick interpolation with degree constraints

Researchers: Anders Lindquist and Ryozo Nagamune in cooperation with C. I. Byrnes (Washington University, St Louis) and T. T. Georgiou (University of Minesota).

Sponsors: The Swedish Research Council for Engineering Sciences (TFR) and the Göran Gustafsson Foundation.

Several important problems in circuit theory, robust stabilization and control, signal processing, and stochastic systems theory lead to a Nevanlinna-Pick interpolation problem, in which the interpolant must be a rational function of at most a prescribed degree. We have obtained a complete parameterization of all such solutions in terms of the zero structure of a certain function appearing naturally in several applications, and this parameterization can be used as a design instrument. We have developed an algorithm to determine any such solution by solving a convex optimization problem, which is the dual of the problem to maximize a certain generalized entropy critierion [A4]. Software based on state space concepts is being developed, and the computational methods are applied to several problems in systems and control.

Solutions of bounded complexity for generalized interpolation in H^∞ are also being studied together with the connections to the commutant lifting theorem of Sarason.

In [A5] and [A6] we present a new approach to spectral estimation, which is based on the use of filter banks as a means of obtaining spectral interpolation data. Such data replaces standard covariance estimates. A computational procedure for obtaining suitable pole-zero (ARMA) models from such data is presented. The choice of the zeros (MA-part) of the model is completely arbitrary. By suitably choices of filter-bank poles and spectral zeros the estimator can be tuned to exhibit high resolution in targeted regions of the spectrum.

In [A7] we study certain manifolds and submanifolds of positive real transfer functions, describing a fundamental geometric duality between filtering and Nevanlinna-Pick interpolation. More precisely, we prove a duality theorem, which we motivate in terms of both the interpolation problem, and a fast algorithm for Kalman filtering, viewed as a nonlinear dynamical system on the space of positive real transfer functions.

In [C33] and [A27], the well-known sensitivity reduction problem is solved by means of interpolation theory of [A4]. To shape the frequency response of the sensitivity function S, instead of using the weighting functions, we tune the spectral zeros of a function related to S. If necessary, extra interpolation constraints can be introduced. A bound on the controller degree is derived and the guidelines on how to tune the design parameters are provided.

Robust control of electrical drives

Researchers: Per-Olof Gutman, Mattias Nordin, Xiaoming Hu and Anders Lindquist.

Industrial contact: ABB Industrial Systems AB.

The aim of this project is to combine robust linear control with nonlinear control elements, implemented in a microprocessor, that alleviate the effects of the process nonlinearities. In particular electrical drives with friction, backlash and uncertain loads and disturbances are being studied. The emphasis is on applicable solutions, i.e. that the algorithms an methods should work in real life.

The project was concluded this year by Mattias Nordin submitting his Ph.D.-thesis entitled *Non-linear Backlash Compensation for Speed Controlled Elastic Systems* [T2]. The novel methods presented in the thesis are successfully being implemented in ABB electrical drive systems.

Semidefinite programming and structural optimization

Researchers: Ulf Brännlund, Mathias Stolpe, Krister Svanberg.

Sponsor: The Swedish Research Council for Engineering Sciences (TFR).

Semidefinite programming is a matrix generalization of linear programming which recently has been proven to be valuable in solving many applications of convex optimization.

Structural optimization deals with computer-aided optimal design of load carrying structures. A typical objective is to minimize the structural weight subject to various constraints on structural stiffness and strength.

The subject of this project is to develop mathematical models and numerical methods for optimizing the topology of different types of load-carrying structures. Such problems are in general much harder than for example problems dealing only with element sizes. The emphasis in this project is development of methods for semidefinite programming with the special structure found in truss topology design problems.

Some problems in navigation and motion control of nonlinear systems

Researchers: Xiaoming Hu, in cooperation with Ruggero Frezza (Univ. of Padova) and Clyde F. Martin (Texas Tech. Univ.).

Sponsor: The Swedish Research Council for Engineering Sciences (TFR).

In recent years autonomous systems have attracted a great deal of attention worldwide. Despite some successful examples and recent progress, the theory still lags. The establishment of the research center and graduate school on autonomous systems at KTH, and the ECSEL project at Linköping University about four years ago, both funded by the Swedish foundation for strategic research, have contributed to the better understanding of autonomous systems. This project is related but complementary to the autonomous system project at KTH. Although we are motivated by autonomous systems, the subjects we study are also important, in their own right, to path planning, sensor fusion, nonlinear control and nonlinear observer and filter design.

An integral part in the design and operation of autonomous systems is path planning and following. Both are difficult problems in a realistic environment and for a realistic mobile system. Equally if not even more difficult , is the problem of observing the structure of a dynamic environment using state variables. In brief, in this project we will study how to use sensor data for sensing, modeling and control. Several relevant theoretical issues will be studied. They include: using splines and other methods for environment reconstruction and path planning, fusing data from different types of sensors for more robust environment reconstruction and state observation, robust path following control and global feedback stabilization. Our methods will be strongly motivated from approaches in systems and control theory.

Stochastic realization theory and identification

Researchers: Anders Lindquist, Anders Dahlén and Jorge Marí, in cooperation with Giorgio Picci (University of Padova).

Sponsors: The Swedish Research Council for Engineering Sciences (TFR) and the Göran Gustafsson Foundation.

In this project we analyze a class of identification algorithms based on canonical correlation analysis in the light of recent results on stochastic systems theory. In principle these so called "subspace methods" can be described as covariance estimation followed by stochastic realization. The method offers the major advantage of converting the nonlinear parameter estimation phase in traditional ARMA models identification into the solution of a Riccati equation but introduces at the same time some nontrivial mathematical problems related to positivity. The reason for this is that an essential part of the problem is equivalent to the well-known rational covariance extension problem. Therefore the usual deterministic arguments based on factorization of a Hankel matrix are not valid, something that is habitually overlooked in the literature.

We have demonstrated that there is no guarantee that several popular subspace identification procedures will not fail to produce a positive extension, unless some rather stringent assumptions are made which, in general, are not explicitly stated. These assumptions are equivalent to the condition that the positive and algebraic degrees of a certain estimated covariance sequence coincide. We have previously described how to generate data with the property that this condition is not satisfied. Using this data we have shown through simulations that several subspace identification algorithms exhibit massive failure.

Therefore we have studied alternative identification strategies. In [A22] we consider a three-step procedure for identification of time series, based on covariance extension and model reduction, and we present a complete analysis of its statistical convergence properties. A partial covariance sequence is estimated from statistical data. Then a high-order maximum-entropy model is determined, which is finally approximated by a lower-order model by stochastically balanced model truncation. Such procedures have been studied before, in various combinations, but an overall convergence analysis comprising all three steps has been lacking. Supposing the data is generated from a true finite-dimensional system which is minimum phase, it is shown that the transfer function of the estimated system tends in $\mathcal{H}^\infty$ to the true transfer function as the data length tends to infinity, if the covariance extension and the model reduction is done properly. The proposed identification procedure, and some variations of it, are evaluated by simulations. In particular, these simulations show that our procedure compares favorably to the subspace methods.

In [R4] we consider the multivariate case and compare it with the CCA subspace method. It is shown that the two methods are asymptotically equivalent in the sense that the difference of the two estimates multiplied with the square root of the sample size converges to zero. This means that the two procedures have the same asymptotic normal distribution.

The rational covariance extension problem, Cepstral geometry and global analysis of shaping filters

Researchers: Anders Lindquist and Per Enqvist, in cooperation with C. I. Byrnes (Washington University, St Louis).

Sponsors: The Swedish Research Council for Engineering Sciences (TFR) and the Gran Gustafsson Foundation.

One of the most widely used methods of spectral estimation in signal and speech processing is linear predictive coding (LPC). LPC has some attractive features, which account for its popularity, including the properties that the resulting modeling filter (i) matches a finite window of $n+1$ covariance lags, (ii) is rational of degree at most n, and (iii) has stable zeros and poles. The only limiting factor of this methodology is that the modeling filter is "all-pole", i.e., an autoregressive (AR) model.

In [A3], we present a systematic description of all autoregressive moving-average (ARMA) models of processes which have properties (i)–(iii) in the context of cepstral analysis and homomorphic filtering. Indeed, we show each such ARMA model determines and is completely determined by its finite windows of cepstral coefficients and covariance lags. This characterization has an intuitively appealing interpretation of a characterization by using measures of the transient and the steady-state behaviors of the signal, respectively. More precisely, we show that these nth order windows form local coordinates for all ARMA models of degree n and that the pole-zero model can be determined from the windows as the unique minimum of a convex objective function. We refine this optimization method by first noting that the maximum entropy design of an LPC filter is obtained by maximizing the zeroth cepstral coefficient, subject to the constraint (i). More generally, we modify this scheme to a more well-posed optimization problem where the covariance data enters as a constraint and the linear weights of the cepstral coefficients are "positive" – in a sense that a certain pseudo-polynomial is positive – rather succinctly generalizing the maximum entropy method. This problem is a homomorphic filter generalization of the maximum entropy method, leading to the design of all stable, minimum-phase modeling filter of degree n which interpolate the given covariance window. This is the dual problem, in the sense of mathematical programming, of an optimization problem, which we previously obtained for the rational covariance extension problem, and which we revisit in [C7].

However, this optimization problem can be become badly conditioned for some parameter values. Therefore, in [C19], a modification of the optimization problem to avoid ill-conditioning is proposed. This procedure avoids spectral factorization, which is computationally expensive, as well as numerical problems that may occur close to the boundary. However, the new optimization problem is in general not globally convex, but only locally convex, so the optimization procedure has to be initiated close to the optimum to ensure convergence. To this end, a homotopy continuation method is proposed. Since the geometry of the solutions to the optimization problem for varying parameter values is well known from our previous work, it follows that there is a smooth trajectory from the LPC solution to any particular solution with the same $n+1$ first covariances. Using a predictor-corrector path-following algorithm the solution to the optimization problem can thus be found.

In [R1], we study the well-posedness of the problems of determining shaping filters from combinations of finite windows of cepstral coefficients, covariance lags, or Markov parameters. For example, we determine whether there exists a shaping filter with prescribed window of Markov parameters and a prescribed window of covariance lags. We show that several such problems are well-posed in the sense of Hadamard; that is, one can prove existence, uniqueness (identifiability) and continuous dependence of the model on the measuremnts. Our starting point is the global analysis of linear systems, where one studies an entire class of systems or models as a whole, and where one views measurements, such as covariance lags and cepstral coefficients or Markov parameters, from data as functions on the entire class. This enables one to pose such problems in a way that tools from calculus, optimization, geometry and modern nonlinear analysis can be used to give a rigorous answer to such problems in an algorithm-independent fashion. In this language, we prove that a window of cepstral coeficients and a window of covariance coefficients yields a bona fide coordinate system on the space of shaping filters thereby establishing existence, uniqueness and smooth dependence of the model parameters on the measurements from data.

3 Education

3.1 Undergraduate courses

5B1712 Optimization for F, 4 p (*Optimeringslära för F)*

Instructor: Krister Svanberg.

Assistants: Camilla Landén and Henrik Rehbinder.

The course gives knowledge about basic concepts and theory for optimization, useful models, and numerical solution methods. Some subjects dealt with in the course are: Linear programming, network flows, nonlinear programming, convexity, Lagrangean relaxation, and duality.

5B1722 Applied Optimization for T and M, 4 p (*Tillämpad optimeringslära för T och M)*

Instructor: Claes Trygger.

Assistants: Anders Dahlén, Mikael Prytz and Henrik Rehbinder.

The course gives knowledge about basic concepts and theory for optimization, useful models, and numerical solution methods. It also gives training in formulating and solving optimization problems. Some subjects dealt with in the course are: Linear programming, network flows, integer programming, deterministic dynamic programming, and nonlinear programming.

5B1742 Mathematical Systems Theory, 4 p (*Matematisk systemteori)*

Instructor: Claes Trygger.

Assistant: Henrik Rehbinder.

The course gives knowledge about basic concepts in mathematical systems theory. Some subjects dealt with in the course are: Linear control systems, realization theory, feedback, stability, linear-quadratic optimal control, and Kalman filtering.

5B1750 Optimization for E and D, 4 p (*Optimeringslära för E och D)*

Instructor: Stefan Feltenmark.

Assistants: Jonas Rappe and Petter Ögren.

The course gives knowledge about basic concepts and theory for optimization, useful models, and numerical solution methods. It also gives training in formulating and solving optimization problems. Some subjects dealt with in the course are: Linear programming, network flows, integer programming, deterministic dynamic programming, and nonlinear programming.

5B1810 Mathematical Programming, 5 p
(*Matematisk programmering*)

Instructor: Anders Forsgren.

Assistant: Göran Sporre.

The course should deepen and broaden the theoretical and methodological knowledge in mathematical programming. Some subjects dealt with in the course are: Interior point methods for linear programming, stochastic programming, quadratic programming, SQP methods for nonlinear programming, Lagrangian relaxation for integer programming, and semidefinite programming.

5B1822 Advanced Course in Mathematical Systems Theory, 4 p
(*Matematisk systemteori, fortsättningskurs*)

Instructor: Per Enqvist.

Assistant: Magnus Egerstedt.

The course should deepen and broaden the theoretical and methodological knowledge in mathematical systems theory. Some subjects dealt with in the course are: Geometric control theory, modeling of linear stochastic systems, stochastic realization theory.

5B1832 Systems Engineering, 8 p
(*Systemteknik*)

This course is equivalent to the course 5B1842 Methods of Systems Engineering together with the course 5B1846 Applied Systems Engineering.

5B1842 Methods of Systems Engineering, 4 p
(*Systemtekniska metoder*)

Instructor: Claes Trygger.

Assistant: Mathias Stolpe.

The course gives knowledge about quantitative methods in operations research. Some subjects dealt with in the course are: Queueing theory, inventory theory, stochastic dynamic programming, and Markov decision processes.

5B1846 Applied Systems Engineering, 4 p
(*Tillämpad systemteknik*)

Instructors: Ulf Brännlund and Krister Svanberg.

Assistant: Mathias Stolpe.

The course gives deeper knowledge about some quantitative methods for analysis and design of technical systems. Some subjects dealt with in the course are: LCC analysis, multi-echelon spare parts optimization, and inventory control.

5B1852 Mathematical Economics, 4 p
(*Matematisk ekonomi*)

Instructor: Claes Trygger.

Assistant: Anders Dahlén.

The course gives basic knowledge in modern mathematical microeconomics. Some subjects dealt with in the course are: Behavior of the firm, individual preferences, consumer demand, economic efficiency, competetive equilibrium, game theory, and welfare theory.

5B1862 Stochastic calculus and the theory of capital markets, 5 p
(*Stokastisk kalkyl och kapitalmarknadsteori*)

Instructors: Tomas Björk and Camilla Landén.

The course gives knowledge in the basic theory of stochastic differential equations and Ito calculus and their applications in the theory of capital markets. The focus will mainly be on arbitrage pricing of derivative securities such as options and bonds.

5B1872 Optimal Control Theory, 4 p
(*Optimal styrteori*)

Instructor: Claes Trygger.

Assistant: Petter Ögren.

The course gives knowledge in classical calculus of variations as well as in modern theory of optimal control. Some subjects dealt with in the course are: The Pontryagin maximum principle, classical theory of variations, and dynamic programming in continuous time.

5B1890 Optimization Modeling, 4 p
(*Optimeringsmodellering*)

Instructors: Stefan Feltenmark and Anders Forsgren.

The course is based on the solution of practical optimization problems. The intent is to practically model optimization problems and to apply the methodological skills that have been acquired in preceding courses. In addition, the participants in the course become acquainted with modern optimization software. The solution of the problems is carried out on a project basis in small groups. An important aspect of the course is cooperation within the group as well as presentation in talking and writing.

3.2 Graduate courses

5B5742 Topics in Control, 2 p

Instructor: Ulf Jönsson.

The course is a seminar course on various topics in control and systems theory. Topics in robust identification, geometric nonlinear control, nonlinear receeding horizon control, and hybrid systems where covered in the course.

5B5744 Input/Output Stability and Integral Quadratic Constraints, 3 p

Instructor: Ulf Jönsson.

In this course we discuss the operator approach to systems analysis. The emphasis is on the integral quadratic constraints approach to stability analysis. This approach to systems analysis unifies the classical small gain theorem and the passivity theorem in a nice way. We also discuss modeling and analysis of uncertain systems, robust stability and robust performance analysis, the S-procedure lossless theorem, and a general version of the Kalman-Yakubovich Popov lemma.

5B5770 Nonlinear Systems Analysis, 5 p

Instructor: Xiaoming Hu.

This course is a basic course on nonlinear dynamical systems presented from systems and control point of view. Topics on nonlinear systems such as approximation methods, periodic solutions, Liapunov stability, input-output stability and nonsmooth systems are covered.

5B5782 Quantitative Feedback Theory, 4 p

Instructor: Per-Olof Gutman.

The course covers robust linear control for uncertain linear and non-linear dynamical systems using Quantitative Feedback Theory (QFT) which is based on classical Bode-Nyquist-Nichols design in the frequency domain. The aim of the course is to enable the participant to design robust controllers for a large class of industrial control systems.

5B5850 Numerical Linear Programming, 5 p

Instructor: Anders Forsgren.

The course deals with theory and algorithms for linear programming problems. It covers the simplex method as well as interior methods, with the aim to reflect the development of these type of methods over the last decade. Some more advanced aspects of the simplex method are included, e.g., steepest edge, partial pricing, and of the interior-point methods, e.g., primal-dual methods, affine-scaling methods, predictor-corrector methods.

5B5870 Combinatorial Optimization, 5 p

Instructor: Anders Forsgren.

The course covers some fundamental combinatorial optimization problems: algorithms, complexity and applications. Algorithms: Maxflow-mincut-theorem. Primal-dual method for linear programming, with applications to network flows. Efficient algorithms for maxflow problems. Matching. Minimal spanning trees. Matroids. Complexity: NP-completeness, foundations and relevant examples. Applications: Heuristic methods for some interesting problem classes.

3.3 Doctoral theses

[T1] M. Egerstedt, *Motion planning and control of mobile robots*, TRITA-MAT-00-OS01, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 2000. Advisors: X. Hu and A. Lindquist.

[T2] M. Nordin, *Nonlinear backlash compensation of speed controlled elastic system*, TRITA-MAT-00-OS03, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 2000. Advisors: P.-O. Gutman and A. Lindquist.

3.4 Master theses (*Examensarbeten*)

5B1022 Master Thesis in Optimization and Systems Theory, 20 p (*Examensarbete i optimeringslära och systemteori*)

[T3] A. Broström (F), *Fixed income positions subject to market risk constraints.* Performed at Svensk Exportkredit. Advisor: S. Feltenmark. (E219)

[T4] M. Gabrielsson (F), *Optimering av arbetsfördelning mellan vattenkraftaggregat med avseende på revisionstidpunkt.* Performed at Sydkraft AB. Advisor: S. Feltenmark. (E222)

[T5] P. Göransson (F), *Simulation of queueing model for IP telephony.* Performed at Telia ProSoft AB. Advisor: C. Trygger. (E223)

[T6] J. Hedengren (F), *Performance of bond option replication.* Performed at Swedbank Markets. Advisor: T. Björk. (E221)

[T7] H. Jansson (F), *Resource constrained shortest path for air industry.* Performed at RM Rocade. Advisor: A. Forsgren. (E225)

[T8] R. Molin (F), *A tool for LPV and LFT modelling.* Performed at FOA. Advisor: X. Hu. (E218)

[T9] J. Palmquist (F), *Portfolio optimization with conditional value-at-risk objective and constraint.* Performed at University of Florida. Advisor: S. Uryasev/U. Brännlund. (E220)

[T10] G. Reiman (F), *Portfolio performance measurement and evaluation.* Performed at ABN AMRO Software. Advisor: U. Brännlund. (E224)

5B1023 Master Thesis in Systems Engineering, 20 p (*Examensarbete i systemteknik*)

[T11] F. Andersson (M), *A new approach for credit risk optimization based on conditional-value-at-risk.* Performed at University of Florida. Advisor: S. Uruyasev/U. Brännlund. (S113)

[T12] M. Ask (T), *Comparison between ATM and Gigabit Ethernet used in a router backplane.* Performed at Ericsson Utveckling AB. Advisor: C. Trygger. (S118)

[T13] N. Blomgren (M), *Optimal spares management and dimensioning system.* Performed at Systecon AB. Advisor: K. Svanberg. (S109)

[T14] S. Brundell (M), *Optimisation in aircraft scheduling with sequence-dependent separation times.* Performed at Luftfartsverket Arlanda. Advisor: U. Brännlund. (S124)

[T15] T. Bäckman (M), *A game theory approach to analysing investment strategies for an electric utility.* Performed at Universidad de la Republica, Montevideo, Uruguay. Advisor: A. Piria/S. Feltenmark. (S126)

[T16] C. Böhlin (T), *Driftsäkerhet och LCC för programvara.* Performed at FMV. Advisor: K. Svanberg. (S125)

[T17] H. Ebeling (M), *Development and evaluation of a Lagrangian relaxation approach to a mixed integer programming formulation of the block-to-train-assignment problem.* Performed at University of Florida. Advisor: R. K. Ahuja/A. Forsgren. (S115)

[T18] D. Gustavsson (M), *Improved overload handling of GSM-traffic.* Performed at Ericsson Utveckling AB. Advisor: C. Trygger. (S121)

[T19] P. Hilber (T), *Optimering av personvagnsomlopp.* Performed at SJ. Advisor: U. Brännlund. (S117)

[T20] M. Jansson (M), *A new model fot the block to train assignment problem.* Performed at University of Florida. Advisor: R. K. Ahuja/A. Forsgren. (S116)

[T21] K. Lidman (T), *Optimal spares dimensioning and management system.* Performed at Systecon AB. Advisor: K. Svanberg. (S110)

[T22] Y. Lousseief (T), *Optimalt pumpval då flera pumptyper kan kombineras.* Performed at Pepto Systems AB. Advisor: K. Svanberg. (S123)

[T23] B. Marklund (T), *Effektiva transporter med järnväg.* Performed at SJ. Advisor: K. Svanberg. (S112)

[T24] H. Sjökvist (T), *Optimering av RORO-flotta i linjetrafik.* Performed at Wallenius Wilhelmsen Lines. Advisor: C. Trygger. (S119)

[T25] L. Sturén (T), *A comparison of multivariate GARCH models.* Performed at Handelsbanken. Advisor: U. Brännlund. (S114)

[T26] G. Unger (M), *Extreme value theory approach to estimate risk.* Performed at Investor AB. Advisor: U. Brännlund. (S122)

[T27] M. von Bahr (T), *Importance of weight for life cycle costs of trains in the Crusaris family.* Performed at Adtranz. Advisor: U. Brännlund. (S111)

[T28] T. Åberg (T), *On a matrix analytical method for analysing queues with bursty Markovian traffic.* Performed at Ericsson Utveckling AB. Advisor: C. Trygger. (S120)

4 Seminars at the division

- Magnus Egerstedt, KTH, *Behavior based robotics using hybrid automata*, August 17, 1999.
- Jorge Gonçalves, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, *Global quadratic stability of limit cycles is common in relay feedback systems*, August 20, 1999.
- Alfredo Piria, Universidad de la Republica, Montevideo, Uruguay, *A dual algorithm for power production planning with uncertain data and transmission network constraints*, August 27, 1999.
- Hector J. Sussmann, Rutgers University, Piscataway, New Jersey, USA, *Generalized differentials, open mapping theorems, and transversality*, August 30, 1999.
- John C. Doyle, California Institute of Technology, Pasadena, California, USA, *Fundamental tradeoffs in robustness of complex system*, August 31, 1999.
- Yutaka Yamamoto, Kyoto University, Kyoto, Japan, *Sampled-data control and its applications to signal processing*, September 1, 1999.
- Zeljko Djurovic, University of Belgrade, Belgrade, Yugoslavia, *Robust Kalman filtering*, September 24, 1999.
- Clyde F. Martin, Texas Tech. University, Lubbock, Texas, USA, *Edge delineation, response surfaces, and optimal control*, October 8, 1999.
- Lars Eldén, Linköping University, Linköping, Sweden, *Solving constrained linear algebra problems using a differential geometric approach*, November 5, 1999.
- Claudio Altafini, KTH, *Motion generation and control for a kinematic mobile manipulator: a geometric framework*, November 11, 1999.
- Andrey Ghulchak, Lund Institute of Technology, Lund, Sweden, *Robust controller design via linear programming*, November 12, 1999.
- Ulf Jönsson, KTH, *Robustness of periodic systems*, November 26, 1999.
- Thomas Buhl, Technical University of Denmark, Lyngby, Denmark, *Topology optimization of mechanical structures*, December 17, 1999.
- Mattias Nordin, KTH, *Nonlinear backlash compensation of speed controlled elastic systems*, February 18, 2000.
- Mikhail Kitaev, Nautsilus Ltd, Moscow, Russia, *Controlled Markov jump processes with average cost criterion*, February 25, 2000.
- Yishao Zhou, Stockholm University, *Balanced parametrization of a class of positive real functions*, March 10, 2000.
- Anders Hansson, KTH, *A primal-dual interior-point method for robust optimal control of linear discrete-time systems*, March 17, 2000.
- Alessandro Chiuso, KTH, *Geometric subspace identification and stochastic realization with inputs*, March 31, 2000.
- Joachim Rosenthal, University of Notre Dame, Notre Dame, Indiana, USA and Ecole Polytechnique Fédérale de Lausanne–EPFL, Lausanne, Switzerland, *Pole placement problems, inverse eigenvalue problems and Schubert calculus*, April 5, 2000.

- Joachim Rosenthal, University of Notre Dame, Notre Dame, Indiana, USA and Ecole Polytechnique Fédérale de Lausanne–EPFL, Lausanne, Switzerland, *Reflections on Shannon's three challenges*, April 7, 2000.
- Magnus Egerstedt, KTH and Harvard University, Cambridge, Massachusetts, USA, *On the control complexity of motion languages*, April 11, 2000.
- Bijoy K. Ghosh, Washington University, St. Louis, Missouri, USA, *Control and signal processing with a population of neurons*, April 13, 2000.

5 Publications

5.1 Papers in journals and books (published and accepted)

[A1] C. Altafini, *Some properties of the general n-trailer*, International Journal of Control, accepted, 2000.

[A2] C. Altafini, *The De Casteljau algorithm on SE(3)*, A. Isidori, F. Lamnabhi-Lagarrigue and W. Respondek (eds.), Nonlinear Control in Year 2000, Springer-Verlag, 2000.

[A3] C. I. Byrnes, P. Enqvist and A. Lindquist, *Cepstral coefficients, covariance lags and pole-zero models for finite data strings*, IEEE Trans. Signal processing, to be published.

[A4] C. I. Byrnes, T. T. Georgiou and A. Lindquist, *A generalized entropy criterion for Nevanlinna-Pick interpolation: A convex optimization approach to certain problems in systems and control*, IEEE Trans. Automatic Control, to be published.

[A5] C. I. Byrnes, T. T. Georgiou and A. Lindquist, *A new approach to Spectral Estimation: A tunable high-resolution spectral estimator*, IEEE Trans. Signal processing SP-48 (Nov. 2000), to be published.

[A6] C. I. Byrnes, T. T. Georgiou and A. Lindquist, *Advances in high-resolution spectral estimation*, Systems Theory: Modeling, Analysis and Control, T. E. Djaferis and I. C. Schick (eds.), Kluwer Academic Publishers, 2000, 167–179.

[A7] C. I. Byrnes and A. Lindquist, *On the duality between filtering and Nevanlinna-Pick interpolation*, SIAM J. Control and Optimization, to be published.

[A8] A. Chiuso, R. Brockett and S. Soatto, *Optimal structure from motion: Local ambiguities and global estimates*, To appear in IJCV, International Journal on Computer Vision.

[A9] F. J. D'Amato, M. A. Rotea, A. Megretski and U. Jönsson, *New results for analysis of systems with repeated nonlinearities*, Accepted for publication in Automatica.

[A10] M. Egerstedt and C. F. Martin, *Trajectory planning in the infinity norm for linear control systems*, International Journal of Control, Vol. 72, No. 13, pp. 1139-1146, Aug. 1999.

[A11] M. Egerstedt, *Behavior based robotics using hybrid automata*, Lecture Notes in Computer Science 1790, pp. 103-116, Springer-Verlag, 2000.

[A12] A. Forsgren, *Optimality conditions for nonconvex semidefinite programming*, Mathematical Programming 88 (2000), 105–128.

[A13] K. H. Johansson, M. Egerstedt, J. Lygeros, and S. Sastry, *On the regularization of Zeno hybrid automata*, Systems and Control Letters, Vol. 38, pp. 141-150, 1999.

[A14] U. Jönsson and A. Rantzer, *Optimization of integral quadratic constraints*, In L. El Ghaoui and S-I Niculescu, editors, Advances in Matrix Inequality Methods in Control, pages 109–128, SIAM, 2000.

[A15] U. Jönsson, *Duality bounds in multiplier based robustness analysis*, IEEE Transactions on Automatic Control 44(12):2246–2256, December, 1999.

[A16] U. Jönsson and A. Megretski, *The Zames Falb IQC for systems with integrator*, IEEE Transactions on Automatic Control, 45(3):560–565, March, 2000.

[A17] C. Kao, U. Jönsson and A. Megretski, *A cutting plane algorithm for robustness analysis of periodic systems*, Accepted for publication in IEEE Transactions on Automatic Control.

[A18] C. Landén, *Bond pricing in a hidden Markov model of the short rate*, To appear in Finance and Stochastics.

[A19] A. Lindquist and V. A. Yakubovich, *Universal regulators for optimal tracking in discrete-time systems affected by harmonic disturbances*, IEEE Transactions on Automatic Control, AC-44 (Sept. 1999), 1688–1704.

[A20] R. Linker, P.-O. Gutman and I. Seginer, *Robust controllers for simultaneous control of temperature and CO2 concentration in greenhouses*, Control Engineering Practice, vol. 7, 851-62, 1999.

[A21] R. Linker, P.-O. Gutman and I. Seginer, *Robust model-based failure detection and identification in greenhouses*, Computers and Electronics in Agriculture, vol. 26, no 3, 255-270, 2000.

[A22] J. Marí, A. Dahlén and A. Lindquist, *A covariance extension approach to identification of time series*, Automatica 36 (2000), 379–398.

[A23] J. Marí and C. F. Martin, *Asymptotic output tracking with a two level hierarchical system*, Int. J. Control 72 (1999), 1116–1126.

[A24] J. Marí, P. Stoica and T. McKelvey, *Vector ARMA estimation: A reliable subspace approach*, IEEE Trans. Signal processing SP-48 (2000), 2092–2104.

[A25] C. F. Martin, S. Sun, and M. Egerstedt, *Optimal control, statistics and path planning*, To appear in Mathematical and Computer Modeling.

[A26] A. Matveev, X. Hu, R. Frezza, H.Rehbinder, *Observers for systems with implicit output*, IEEE Transactions on Automatic Control, 45(2000), 168-173.

[A27] R. Nagamune and A. Lindquist, *Sensitivity shaping in feedback control and analytic interpolation theory*, To be published in volume dedicated to Alain Bensoussan on his 60th birthday.

[A28] H. Rehbinder and C. F. Martin, *A control theoretic model of the forearm*, To appear in the Journal of Biomechanics.

[A29] H. Rehbinder and X. Hu, *Nonlinear state estimation for rigid-body motion with low-pass sensors*, Systems & Control Letters, 40(2000), 183-190.

[A30] M. Stolpe and K. Svanberg, *On the trajectories of the epsilon-relaxation approach for stress-constrained truss topology optimization*, To appear in Structural and Multidisciplinary Optimization.

[A31] M. Stolpe and K. Svanberg, *On the trajectories of penalization methods for topology optimization*, To appear in Structural and Multidisciplinary Optimization.

[A32] S. Sun, M. Egerstedt, and C. F. Martin, *Control theoretic smoothing splines*, To appear in IEEE Transactions on Automatic Control.

[A33] Y. Zhou, M. Egerstedt, and C. Martin, *Optimal approximation of functions*, To appear in Communications and Information Systems, No. 1, 2001.

5.2 Papers in conference proceedings (published and accepted)

[C1] C. Altafini, *Switching systems and scalar polysystems on matrix Lie groups*, MTNS Mathematical Theory of Networks and Systems, Perpignan, France June 2000.

[C2] C. Altafini, *On the Lie-algebraic properties of control systems in chained form*, MTNS Mathematical Theory of Networks and Systems, Perpignan, France June 2000.

[C3] C. Altafini, R. Frezza and J. Galič, *Observing the load dynamic of an overhead crane with minimal sensor equipment*, IEEE International Conference on Robotics and Automation, San Francisco, May 2000.

[C4] C. Altafini, *Zero dynamics and off-tracking bounds for the path following problem of wheeled vehicles*, Proc. of the 38th IEEE Conf. on Decision and Control, Phoenix, AZ, December 1999.

[C5] C. Altafini, *General n-trailer, differential flatness and equivalence*, Proc. of the 38th IEEE Conf. on Decision and Control, Phoenix, AZ, December 1999.

[C6] C. Altafini, *A matrix Lie group of Carnot type for filiform sub-Riemannian structures and its application to control systems in chained form*, Proc. of the summer school on Differential Geometry, Coimbra, September 1999.

[C7] C. I. Byrnes, S. V. Gusev and A. Lindquist, *A convex optimization approach to the covariance extension problem with degree constraint*, Proc. 38th IEEE Conference on Decision and Control, Phoenix, Arizona, USA, December 7–10, 1999, 1451–1457.

[C8] C. I. Byrnes, T. T. Georgiou and A. Lindquist, *Analytic interpolation with degree constraint: A constructive theory with applications to control and signal processing*, Proc. 38th IEEE Conference on Decision and Control, Phoenix, Arizona, USA, December 7–10, 1999, 982–988.

[C9] A. Chiuso and G. Picci, *Subspace identification by orthogonal decomposition*, Proc. 14th IFAC World Congress, Pechino, Cina, July, 1999, Volume H, pp. 241-246.

[C10] A. Chiuso and G. Picci, *Error analysis of certain subspace methods*, Proc. of IFAC International Symposium on System Identification, Santa Barbara, June 2000.

[C11] A. Chiuso, H. Jin, P. Favaro and S. Soatto, *"MFm" : 3-D motion and structure from 2-D motion causally integrated over time: Implementation*, Proc. of the Sixth European Conf. on Computer Vision, Dublin, Ireland, June 2000.

[C12] A. Chiuso and G. Picci, *Probing inputs for subspace identification*, To appear in the Proc. of the IEEE 39th Conference on Decision and Control, Sydney, Australia, December 2000.

[C13] A. Chiuso and S. Soatto, *Monte Carlo filtering on Lie groups*, To appear in the Proc. of the IEEE 39th Conference on Decision and Control, Sydney, Australia, December 2000.

[C14] M. Egerstedt and X. Hu, *Coordinated trajectory following for mobile manipulation*, IEEE International Conference on Robotics and Automation, San Francisco, CA, Apr. 2000.

[C15] M. Egerstedt, K.H. Johansson, J. Lygeros, and S. Sastry, *Behavior based robotics using regularized hybrid automata*, IEEE Conference on Decision and Control, Phoenix, AZ, Dec. 1999.

[C16] M. Egerstedt, J. Koo, F. Hoffmann, and S. Sastry, *An integrated approach to path planning and flight controller scheduling for autonomous helicopters*, Proceedings of the 7th Mediterranean Conference on Control and Automation, Haifa, Israel, Aug. 1999.

[C17] M. Egerstedt and C. Martin, *Control theoretic monotone smoothing splines*, Mathematical Theory of Networks and Systems, Perpignan, France, June 2000.

[C18] M. Egerstedt, P. Ögren, O. Shakernia, and J. Lygeros, *Toward optimal control of switched linear systems*, IEEE Conference on Decision and Control, Sydney, Australia, Dec. 2000. Accepted.

[C19] P. Enqvist, *Solving the covariance extension problem using a continuation method*, MTNS Mathematical Theory of Networks and Systems, 2000.

[C20] X. Hu, *Nonlinear global stabilization by output feedback control*, in the proc. of Asian Control Conference, Shanghai, 2000.

[C21] K. H. Johansson, J. Lygeros, S. Sastry, and M. Egerstedt, *Simulation of Zeno hybrid automata*, IEEE Conference on Decision and Control, Phoenix, AZ, Dec. 1999.

[C22] U. Jönsson and A. Megretski, *IQC characterizations of signal classes*, Proceedings of the European Control Conference 99, Karlsruhe, Germany, 1999.

[C23] U. Jönsson, C. Kao and A. Megretski, *Robustness analysis of periodic systems*, Proceedings of IEEE Conference on Decision and Control 1999, pages 1839–1844, Phoenix, AZ, USA, 1999.

[C24] U. Jönsson, C. Kao and A. Megretski, *Robustness of periodic trajectories*, Proceedings of the American Control Conference 2000, pages 1307–1311, Chicago, Illinois, USA, 2000.

[C25] U. Jönsson and F.J. D'Amato, *Stability and performance analysis of systems with multiple repeated nonlinearities*, Preprints Reglermöte 2000, Uppsala, Sweden, 2000.

[C26] U. Jönsson and A. Megretski, *Performance analysis of uncertain systems with stochastic disturbances*, Proceedings CD of the Fourteenth International Symposium of Mathematical Theory of Networks and Systems, Perpignan, France, 2000.

[C27] I. Ioslovich and P.-O. Gutman, *Robust redundancy determination and evalutaiton of the dual variables of linear programming problems in the presence of uncertainty*, 3rd IFAC Symposium on Robust Control Design (ROCOND 2000), paper no. 115, Prague, Czech Republic, 21-23 June, 2000.

[C28] C. Kao, A. Megretski and U. Jø"nsson, *An algorithm for solving special frequency dependent LMIs*, Proceedings of the American Control Conference 2000, pages 307–311, Chicago, Illinois, USA, 2000.

[C29] R. Linker and P.-O. Gutman, *Robust failure detection and isolation for input-output non-linear systems*, SafeProcess Conference, Budapest, June 2000.

[C30] J. Lygeros, K. H. Johansson, S. Sastry, and M. Egerstedt, *On the existence of executions of hybrid automata*, IEEE Conference on Decision and Control, Phoenix, AZ, Dec. 1999.

[C31] A. Megretski and U. Jönsson and C. Kao, *Estimation of sensitivity of periodic trajectories with respect to structured uncertainty*, Proceedings of the American Control Conference 2000, pages 3101–3105, Chicago, Illinois, USA, 2000.

[C32] R. Nagamune, *A new approach to shaping of the sensitivity function*, Reglermöte 2000 in Uppsala, June 7-8, pp. 67-72.

[C33] R. Nagamune, *Sensitivity reduction for SISO systems using the Nevanlinna-Pick interpolation with degree constraint*, MTNS 2000 in Perpignan, June 2000.

[C34] L. Petersson, M. Egerstedt, and H. I. Christensen, *A hybrid control architecture for mobile manipulation*, Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, Kyongju, Korea, Oct. 1999.

[C35] H. Rehbinder, C. Ridderström, *Attitude estimation for walking robots*, 2nd International Conference on Climbing and Walking Robots, Portsmouth, 1999.

[C36] H. Rehbinder and X. Hu, *Nonlinear pitch and roll estimation for walking robots*, IEEE International Conference on Robotics and Automation, San Francisco, 2000.

[C37] H. Rehbinder and X. Hu, *A nonlocal nonlinear observer for rigid body motion with low-pass sensors*, MTNS, Mathematical Theory of Networks and Systems, Perpignan, 2000.

[C38] H. Rehbinder and M. Sanfridson, *Integration of off-line scheduling and optimal control*, ECRTS, European Conference on Real Time Systems, Stockholm, 2000.

[C39] A. Serebrennikov and P.-O. Gutman, *A QFT design for the EDF benchmark problem*, 14th World Congress of the International Federation of Automatic Control, Beijing 5-9 July, 1999.

[C40] M. Stolpe and K. Svanberg, *Some intrinsic difficulties with relaxation- and penalization methods in topology optimization*, Proceedings of the NATO ARW on Topology Optimization, Budapest, May 2000.

[C41] P. Ögren, M. Egerstedt, and X. Hu, *Reactive mobile manipulation using dynamic trajectory tracking*, IEEE International Conference on Robotics and Automation, San Francisco, CA, Apr. 2000.

[C42] P. Ögren, M. Egerstedt, L. Petersson, and X. Hu, *Reactive mobile manipulation using dynamic trajectory tracking: Design and implementation*, IEEE Conference on Decision and Control, Sydney, Australia, Dec. 2000. Accepted.

5.3 Other publications

[O1] A. Chiuso and S. Soatto, *3-D motion and structure causally integrated over time: Analysis*, Lecture notes for a Tutorial Workshop at the IEEE Intl. Conf. on Robotics and Automation, San Francisco, April 2000.

[O2] S. Feltenmark and J. Holst, *Optimering av kraftsystem under osäkerhet*, Annual report 1999, ITM Report 1999:5, April 2000, Swedish Institute of Applied Mathematics (ITM), Chalmers Science Park, Gothenburg, Sweden.

5.4 Technical reports and preprints

[R1] C. I. Byrnes, P. Enqvist and A. Lindquist, *Identifiability and well-posedness of shaping-filter parameterizations: A global analysis approach*, Submitted for publication.

[R2] A. Chiuso and G. Picci, *On the ill-conditioning of certain subspace identification methods*, Preprint, to be submitted.

[R3] A. Chiuso and G. Picci, *Geometric stochastic realization with inputs*, Preprint, to be submitted.

[R4] Anders Dahlén and Wolfgang Scherrer, *The relation of CCA subspace method to a balanced reduction of an autoregressive model*, To be submitted for publication.

[R5] M. Egerstedt and X. Hu, *A hybrid control approach to action coordination for mobile robots*, submitted to Automatica.

[R6] M. Egerstedt, X. Hu and A. Stotsky, *Control of mobile platforms using a virtual vehicle approach*, submitted to IEEE Trans. Aut. Control.

[R7] S. Feltenmark, R. Halldin, J. Holst, and J. Rappe, *A model for seasonal planning in a hydro-thermal power system*, Report TRITA/MAT-00-OS9, Department of Mathematics, KTH, 2000.

[R8] A. Forsgren and G. Sporre, *On weighted linear least-squares problems related to interior methods for convex quadratic programming*, Report TRITA-MAT-2000-OS11, Department of Mathematics, KTH, 2000.

[R9] K. H. Johansson, M. Egerstedt, J. Lygeros, and S. Sastry, *On the regularization of Zeno hybrid automata*, Technical Report, UCB/ERL M99/23, Department of Electrical Engineering and Computer Science, UC Berkeley, CA, Jan. 1999.

[R10] U. Jönsson, C. Kao and A. Megretski, *Robustness analysis of periodic trajectories*, Report TRITA-MAT-99-OS5, Department of Mathematics, KTH, 1999, Submitted for publication.

[R11] U. Jönsson and C. Martin, *Approximation with the output of linear control systems*, Report TRITA-MAT-00-OS10, Department of Mathematics, KTH, 2000, Submitted for publication.

[R12] A. Megretski, C. Kao, U. Jönsson and A. Rantzer, *A guide to IQC-beta: Software for robustness analysis*, http://www.mit.edu/people/cykao/home.html.

[R13] R. Nagamune and A. Lindquist, *Sensitivity shaping in feedback control and analytic interpolation theory*, Report TRITA-MAT-2000-OS17, Dept of Mathematics, KTH, 2000.

[R14] M. Stolpe and K. Svanberg, *An alternative interpolation scheme for minimum compliance topology optimization*, Report TRITA-MAT-2000-OS13, Dept of Mathematics, KTH, 2000, Submitted for publication.

[R15] K. Svanberg, *A new globally convergent version of the method of moving asymptotes*, Report TRITA-MAT-1999-OS2, Dept of Mathematics, KTH, 1999.

[R16] K. Svanberg, *A class of globally convergent optimization methods based on conservative convex approximations*, Report TRITA-MAT-1999-OS7, Dept of Mathematics, KTH, 1999, Submitted to SIAM Journal on Optimization.

6 Presentations

[P1] C. Altafini, *Switching systems and scalar polysystems on matrix Lie groups*, MTNS Mathematical Theory of Networks and Systems, Perpignan, France June 2000.

[P2] C. Altafini, *On the Lie-algebraic properties of control systems in chained form*, MTNS Mathematical Theory of Networks and Systems, Perpignan, France June 2000.

[P3] C. Altafini, *Observing the Load Dynamic of an Overhead Crane with Minimal Sensor Equipment*, IEEE International Conference on Robotics and Automation, San Francisco, May 2000.

[P4] C. Altafini, *Zero dynamics and off-tracking bounds for the path following problem of wheeled vehicles*, 38th IEEE Conf. on Decision and Control, Phoenix, AZ, December 1999.

[P5] C. Altafini, *General n-trailer, differential flatness and equivalence*, 38th IEEE Conf. on Decision and Control, Phoenix, AZ, December 1999.

[P6] C. Altafini, *A matrix Lie group of Carnot type for filiform sub-Riemannian structures and its application to control systems in chained form*, Summer school on Differential Geometry, Coimbra, September 1999.

[P7] C. Altafini, *Motion generation and control for a mobile manipulator: a geometric framework*, FOA Swedish Defence Institute, Stockholm, November, 1999.

[P8] C. Altafini, *Motion generation and control for a mobile manipulator: a geometric framework*, University of Berkeley, California, November 16, 1999.

[P9] C. Altafini, *Geometric methods in the control of mobile manipulators*, University of Padova, Italy, December 15, 1999.

[P10] C. Altafini, *The De Casteljau algorithm on SE(3)*, Nonlinear Control Network workshop, Paris, France, June 5, 2000.

[P11] C. Altafini, *On the bilinearity of linear switching systems*, Workshop on Mathematical Control Theory and Robotics, SISSA-International School for Advanced Studies, Trieste, Italy, June 25, 2000.

[P12] A. Chiuso, *On the ill conditioning of certain subspace identification methods*, ERNSI Workshop, Theoule, September 1999.

[P13] A. Chiuso, *Error analysis of certain subspace methods*, International Symposium on System Identification, SYSID 2000, Santa Barbara, June 2000.

[P14] A. Chiuso, *"MFm": 3-D motion and structure from 2-D motion causally integrated over time: Implementation*, Sixth European Conference on Computer Vision, Dublin, Ireland, June 2000.

[P15] A. Dahlén, *Consistency and Asymptotic Normality of the Maximum Entropy Solution followed by Stochastically Balanced Truncation*, MTNS Mathematical Theory of Networks and Systems, Perpignan, June 19-23 2000.

[P16] M. Egerstedt, *An integrated approach to path planning and flight controller scheduling for autonomous helicopters*, The 7th Mediterranean Conference on Control and Automation, Haifa, Israel, Aug. 1999.

[P17] M. Egerstedt, *ISR: The KTH autonomous, mobile, intelligent service robot*, Department of Electrical Engineering and Computer Science, University of California at Berkeley, Berkeley, CA, Sept. 1999.

[P18] M. Egerstedt, *Behavior based robotics using hybrid automata*, College of Computing, Geogia Institute of Technology, Atlanta, GA, Dec. 1999.

[P19] M. Egerstedt, *Behavior based robotics using regularized hybrid automata*, IEEE Conference on Decision and Control, Phoenix, AZ, Dec. 1999.

[P20] M. Egerstedt, *On the regularization of Zeno hyrbid automata*, Division of Engineering and Applied Sciences, Harvard University, Cambridge, MA, Feb. 2000.

[P21] M. Egerstedt, *Behavior based robotics using hybrid automata*, Hybrid Systems: Computation and Control, Pittsburgh, PA, March 2000.

[P22] M. Egerstedt, *Coordinated trajectory following for mobile manipulation*, IEEE International Conference on Robotics and Automation, San Francisco, CA, Apr. 2000.

[P23] M. Egerstedt, *On the instruction complexity of motion description languages*, Department of Electrical Engineering and Computer Science, University of California at Berkeley, Berkeley, CA, Apr. 2000.

[P24] M. Egerstedt, *Control theoretic monotone smoothing splines*, Mathematical Theory of Networks and Systems. Perpignan, France, June 2000.

[P25] P. Enqvist, *Solving the Covariance Extension Problem using a Continuation Method*, MTNS Mathematical Theory of Networks and Systems, Perpignan, June 19-23 2000.

[P26] X. Hu, *Estimation and control of robotic systems*, Linköping University, May, 2000.

[P27] X. Hu, *Nonlinear global stabilization by output feedback control*, Asian Control Conference, Shanghai, 2000.

[P28] U. Jönsson, *Robustness of periodic systems*, Division of Automatic Control, Department of Signals, Sensors, and Systems, KTH, November 1999.

[P29] U. Jönsson, *Robustness of periodic systems*, Swedish National Defense Research Establishment, November 1999.

[P30] U. Jönsson, *IQC characterizations of signal classes*, European Control Conference 99, Karlsruhe, Germany, September 1999.

[P31] U. Jönsson, *Robustness analysis of periodic systems*, IEEE Conference on Decision and Control, Phoenix, AZ, USA, December 1999.

[P32] U. Jönsson, *Performance analysis of uncertain systems with stochastic disturbances*, Symposium of Mathematical Theory of Networks and Systems, Perpignan, France, June 2000.

[P33] U. Jönsson, *Estimation of sensitivity of periodic trajectories with respect to structured uncertainty*, American Control Conference, Chicago, Illinois, USA, July 2000.

[P34] U. Jönsson, *Robustness of periodic trajectories*, American Control Conference, Chicago, Illinois, USA, July 2000.

[P35] C. Landén, *On inversion of the yield curve for short rate models, using forward rate volatilities*, 26th Meeting of the European Finance Association, Helsinki, Finland, August 25-28, 1999.

[P36] C. Landén, *Spot price realizations of futures price term structures*, First AMS-Scandinavian International Mathematics Meeting, Odense, Denmark, June 13-16, 2000.

[P37] A. Lindquist, *Analytic interpolation with degree constraints, with applications to systems and control*, Plenary lecture at the Sixth St. Petersburg Symposium on Adaptive Systems Theory, St. Petersburg, Russia, September 7-9, 1999.

[P38] A. Lindquist, *Analytic interpolation with degree constraint with application to identification and high-resolution spectral estimation*, ERNSI Workshop System Identification, Villa Sainte-Camille, Théoule, France, 27-29 September 1999.

[P39] A. Lindquist, *Advances in high-resolution spectral estimation*, Advances in Systems Theory: A workshop in honor of S. K. Mitter, Cambridge, Mass., USA, October 15–16, 1999.

[P40] A. Lindquist, *Analytic interpolation with degree constraints, with applications to systems and control*, Recent Advances in Systems and Control Theory: A Seminar Day at Washington University in honor of C. I. Byrnes Washington University, St. Louis, December 1, 1999.

[P41] A. Lindquist, *Analytic interpolation with degree constraint: A constructive theory with applications to control and signal processing*, 38th Conference on Decision and Control, Phoenix, Arizona, USA, December 7-10, 1999.

[P42] A. Lindquist, *A convex optimization approach to the covariance extension problem with degree constraint*, 38th Conference on Decision and Control, Phoenix, Arizona, USA, December 7-10, 1999.

[P43] A. Lindquist, *Why Nevanlinna-Pick interpolation theory is important in applications to systems and control and how it can be modified to be more useful*, Colloquium, March 16, 2000.

[P44] A. Lindquist, *Analytic interpolation with degree constraint with applications to systems and control and signal processing*, Zaborszky Lecturer for the year 2000, a series of three lectures at Washington University, St. Louis, May 8, 9, and 10, 2000.

[P45] A. Lindquist, *Why Nevanlinna-Pick interpolation theory is important in systems and control and how it can be modified to be more useful*, The Eleventh Annual Zaborszky Lecture Series, May 8, 2000.

[P46] A. Lindquist, *The geometry of positive real functions*, The Eleventh Annual Zaborszky Lecture Series, May 9, 2000.

[P47] A. Lindquist, *A convex optimization approach to analytic interpolation with degree constraint*, The Eleventh Annual Zaborszky Lecture Series, May 10, 2000.

[P48] A. Lindquist, *Covariances, cepstral coefficients and pole-zero models for signal processing*, MTNS2000, Perpignan, France, June 19–23, 2000.

[P49] A. Lindquist, *Recent results on Interpolation in the class of positive real functions: A geometric approach*, MTNS2000, Perpignan, France, June 19–23, 2000.

[P50] R. Nagamune, *A new approach to shaping of the sensitivity function*, Reglermöte in Uppsala, June 7, 2000.

[P51] R. Nagamune, *Sensitivity reduction for SISO systems using the Nevanlinna-Pick interpolation with degree constraint*, MTNS 2000 in Perpignan, June 2000.

[P52] M. Prytz, *Dimensioning Capacity in Multicast-Enabled Communications Networks*, 9th Stockholm Optimization Days, Stockholm, June 2000.

[P53] J. Rappe, *A model for seasonal planning in a hydro-thermal power system*, 9th Stockholm Optimizetion Days, Stockholm, June 2000.

[P54] H. Rehbinder, *Attitude estimation for walking robots*, 2nd International Conference on Climbing and Walking Robots, Portsmouth, 1999.

[P55] H. Rehbinder, *State estimation for walking robots, Limited communication control and the Centre for autonomous systems*, Dept. of Systems Science and Mathematics, Washington University, Saint Louis, U SA, 2000.

[P56] H. Rehbinder, *Nonlinear pitch and roll estimation for walking robots*, IEEE International Conference on Robotics and Automation, San Francisco, 2000.

[P57] H. Rehbinder, *A nonlocal nonlinear observer for rigid body motion with low-pass sensors*, MTNS, Mathematical Theory of Networks and Systems, Perpignan, 2000.

[P58] M. Stolpe, *On the trajectories of the epsilon-relaxation approach for stress-constrained truss topology optimization*, ICM Workshop on Optimization in Solid and Fluid Mechanics, Linköping, Sweden, February 9, 2000.

[P59] M. Stolpe, *On an alternative interpolation scheme for minimum compliance topology optimization*, 9th Stockholm Optimization Days, June 26-27, 2000.

[P60] K. Svanberg, *A new globally convergent version of the MMA*, Universitaire Leonard de Vinci, Paris, Nov 15, 1999.

[P61] K. Svanberg, *Some intrinsic difficulties with relaxation- and penalization methods in topology optimization*, NATO ARW on Topology Optimization, Budapest, May 8-12, 2000.

7 9th Stockholm Optimization Days

The 9th Stockholm Optimization Days were held at KTH in Stockholm, June 26–27, 2000. The conference was focused on various aspects of optimization, with an emphasis on applications, in areas such as power systems, finance, telecommunications and structural optimization. The format was similar to the previous years with approximately 60 participants, coming from many different countries. The organizing committee consisted of U. Brännlund, S. Feltenmark (head), A. Forsgren and K. Svanberg.

In total 25 talks were given, among them 14 invited presentations. The following is a list of presentations, where the speakers' names are given in boldface:

Wolfgang Achtziger*, University of Erlangen-Nuremberg, Erlangen, Germany, *Prediction of material degradation and its application to optimal design.*

Cesar Beltran, Technical University of Catalonia, Barcelona, Spain, *The radar subgradient method.*

Daniel Bienstock*, Columbia University, New York, New York, USA, *Approximately solving large-scale linear programs: Theory and (growing) practice.*

Kai-Uwe Bletzinger*, Technische Universität München, München, Germany, *Methods of form optimization for shell and membrane structures.*

Thomas Borrvall and Joakim Petersson, Linköping University, Linköping, Sweden, *Topology optimization using regularized intermediate density control.*

Oleg Burdakov and Boris Merkulov, Linköping University, Linköping, Sweden, *A new vector norm for nonlinear data fitting and optimization problems.*

Thomas F. Coleman*, Cornell University, Ithaca, New York, USA, *Computing a smooth volatility function.*

Sjur Didrik Flåm, University of Bergen, Bergen, Norway, *Avenues to equilibrium in the CAPM model.*

Jörg Fliege, University of Dortmund, Dortmund, Germany, *A general modeling system to optimize the location of an air polluting facility.*

Jean-Baptiste Hiriart-Urruty*, Université Paul Sabatier, Toulouse, France, *Global optimality conditions in maximizing a convex quadratic function under convex quadratic constraints.*

Ilya Ioslovich, Technion, Haifa, Israel, *Optimal attitude maneuvering of a space vehicle.*

Thomas F. Coleman*, **Yuying Li** and Arun Verma, Cornell University, Ithaca, New York, USA, *Pricing American options with an interior point method.*

Per Olov Lindberg and **Jörgen Hansson**, Linköping University, Linköping, Sweden, *Financial risk management with derivative securities - A stochastic programming application.*

Abdel Lisser*, France Telecom, R&D, Issy les Moulineaux Cedex, France, *Design of backbone telecommunication networks.*

David G. Luenberger*, Stanford University, Stanford, California, USA, *Projection pricing.*

Anna Nagurney*, University of Massachusetts, Amherst, Massachusetts, USA,

*Invited speaker.

International financial networks.

Joakim Petersson, Linköping University, Linköping, Sweden, *On continuity of the design–to–state mappings for trusses with variable topology.*

Anders Forsgren and **Mikael Prytz**, Royal Institute of Technology, Stockholm, Sweden, *Dimensioning capacity in multicast-enabled communications networks.*

Jonas Rappe and Stefan Feltenmark, Royal Institute of Technology, Stockholm, Sweden, *A model for seasonal planning in a hydro-thermal power system.*

Richard Freling, Dolores Romero Morales, **Edwin Romeijn**, and Albert Wagelmans, University of Florida, Gainesville, Florida, USA, *A branch-and-price algorithm for the multi-period single-sourcing problem.*

J. Bergman, **Mikael Rönnqvist**, T. Schönbeck, and T. Sjögren, Linköping University, Linköping, Sweden, *Roll cutting at paper mills.*

H. A. Eiselt, W. Liu, and **Carl-Louis Sandblom**, Dalhousie University, Halifax, Canada, *Value probing with the external column in the simplex method for linear programming.*

Ole Sigmund*, Technical University of Denmark, Copenhagen, Denmark, *Topology optimization and requirements to math programming.*

Rüdiger Schultz*, Gerhard-Mercator University Duisburg, Duisburg, Germany, *Scenario decomposition of stochastic integer programs in power optimization.*

Mathias Stolpe and Krister Svanberg, Royal Institute of Technology, Stockholm, Sweden, *On an alternative interpolation scheme for minimum compliance topology optimization.*

*Invited speaker.

8 Other activities

Claudio Altafini

- Participated in the International workshop on Lie theory and its applications, Wurzburg University, August 2-4 1999.
- Participated in the CAS-organized visit to the following Californian Scientific Institutions: Stanford University, SRI, University of Berkeley, Xerox Park, JPL Laboratory, University of Southern California, November 14-19, 1999.
- Co-supervision of Master thesis at the Department of Signal, Sensors and Systems, KTH: A. Speranzon, Feedback control of backward manoeuvres for a truck and trailer: experimental results.
- Referee for IEEE Trans. on Automatic Control, IEEE Trans. on Robotics and Automation, IROS'00, ACC'00 and CDC'00.

Ulf Brännlund

- Developed a new course 5B1574 Portfolio theory and risk evaluation (*Portföljteori och riskvärdering*) for the Division of Mathematical Statistics, Department of Mathematics, KTH. Main lecturer and examiner of this course.
- Participated in ICM Workshop on Optimization in Solid and Fluid Mechanics, Linköping University, Linköping, Sweden, Febuary 9, 2000.
- Cofounded the company Optimization Partner Stockholm AB in April 2000.
- Developed a portfolio optimization model with a GUI for Fondmarknaden.se, a web-based broker of the mutual funds.
- Developed a transportation model in Excel for a Swedish chemistry company.

Alessandro Chiuso

- Referee for Automatica, CDC'00.

Anders Dahlén

- Predoctoral fellow at Technische Universität Wien, Institut für Ökonometrie, Operations Research und Systemtheorie in Austria for three months during March 1–May 1, 2000, and May 16–June 16, 2000.
- Participated in the 8th ERNSI Workshop on System Identification in Theoule, France, September 27-29, 1999.
- Referee for Automatica.

Magnus Egerstedt

- Postdoctoral fellow at Harvard University since January 2000.
- Spent September 1999 at the University of California at Berkeley.
- Went on the CAS lab tour in California, Nov. 1999.
- Vice president of IEEE student branch at KTH, 1999.
- Referee for IEEE Transactions on Automatic Control, Autonomous Robots, and CDC'00.

Per Enqvist

- Participated in the 9th ERNSI Workshop on System Identification in Theoule, France, September 27-29, 1999.
- Participated in Reglermöte 2000, in Uppsala, Sweden, June 7-8, 2000.
- Participated in Stockholm Optimization Days, Stockholm, June 26-27, 2000.

Torvald Ersson

- Participated in MTNS 2000, Mathematical Theory of Networks and Systems, in Perpignan, France, June 2000.

Stefan Feltenmark
- Referee for SIAM Journal on Optimization.

Anders Forsgren
- Associate editor for Mathematical Programming, Series A.
- Member of editorial board for Computational Optimization and Applications.
- Visited the University of California, San Diego, California, USA, July 31–August 9, 1999.
- Referee for Mathematical Programming and SIAM Journal on Optimization.

Ulf Jönsson
- Participated in the Åström Symposium of Control, Lund, August 28, 1999.
- Participated in 8th ERNSI workshop on System Identification in September 27-29, 1999 in Theoule, France.
- Visited Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, July 3–July 7, 2000.
- Referee for International Journal of Control (1), Automatica (3), International Journal of Robust and Nonlinear Control (1), IEEE Transactions on Automatic Control (2), UKACC International Conference on Control 2000, ACC00, CDC00.

Camilla Landén
- Participated in the first world congress of the Bachelier Finance Society, Paris, France, June 28–July 1, 2000.

Anders Lindquist
- Chairman, Department of Mathematics, Royal Institute of Technology.
- Member Central Faculty Board ("Centrala fakultetsnämnden"), KTH.
- Board Member, Strategic Center for Autonomous Systems, KTH.
- Member, Royal Swedish Academy of Engineering Sciences (IVA).
- Affiliate Professor, Washington University, St Louis, USA.
- Advisory Board of the Institute for Mathematics of the Life Sciences, Texas Tech University, Texas, USA.
- Team Leader, European Research Network for System Identification (ERNSI), TMR network.
- Member Editorial Board, *Adaptive Control and Signal Processing*, journal published by John Wiley & Sons.
- Editorial Board, *Applied and Computational Control, Signals, and Circuits*, book series published by Birkhäuser, Boston.
- Referee for several other journals, for NATO, STINT, KVA and Italian National Research Foundation.
- Opponent at PhD thesis defense in Helsinki, Finland, March 17, 2000.
- Member, Steering Committee of the ERCIM Working Group on Control and System Theory.
- International Program Committee, International Symposium on the Mathematical Theory of Networks and Systems (MTNS2000), Perpignan, France, June 19–23, 2000.
- International Advisory Committee of the 31th ISCIE International Symposium on Stochastic Systems Theory and its Applications, Yokohama, Japan, November 11–12, 1999.
- International Advisory Committee of the 32th ISCIE International Symposium on Stochastic Systems Theory and its Applications, Tottori, Japan, November 1–2, 2000.

Ryozo Nagamune

- Participated in ERNSI Workshop, Theoule, France, September 27-29, 2000.
- Participated in Stockholm Optimization Days, KTH, June 26-27, 2000.
- Referee for Conference on Decision and Control (CDC2000), International Conference on Control, Automation, Robotics and Vision (ICARCV2000), IEEE Transactions on Automatic Control.

Henrik Rehbinder

- Participated in the IFAC World Congress 1999, Beijing, China, July, 1999.
- Visited the department of Systems Science and Mathematics, Washington University, Saint Louis, USA, February–May, 2000.

Mathias Stolpe

- Visited the Department of Solid Mechanics, Technical University of Denmark, August 1999.

Krister Svanberg

- In the evaluation committee at the PhD dissertation of P. Carlsson, Dept of Building Sciences, KTH.
- On the editorial board of Structural and Multidisciplinary Optimization.
- Referee for International Journal for Numerical Methods in Engineering.
- Referee for AIAA Journal.

Claes Trygger

- Instructor for the graduate course *2D5217 Mathematical Modelling, Analysis and Simulation, part 1*, Department of Numerical Analysis and Computer Science, KTH, autumn 1999.