Activity Report

2000/2001

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 2000/2001 (July 2000 – June 2001).

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)

Jarmo Malinen, TeknD

Gästforskare (Visiting professors)

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

Handläggare (Executive administrator)

Leena Druck

Administratör (Administrator)

Erika Appel

Doktorander (Graduate students)

Claudio Altafini (graduated (TeknD) May 2001)
Anders Blomqvist, civing
Gianantonio Bortolin
Anders Dahlén, FK, FilL (graduated (FilD) June 2001)
Per Enqvist, civing (graduated (TeknD) April 2001)
Torvald Ersson, civing
Camilla Landén, civing (graduated (TeknD) February 2001)
Ryozo Nagamune
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 and a doctoral degree in Optimization and Systems Theory from KTH in May 2001. He worked as control engineer in 1995 for ABB Industrial Systems in Västerås, Sweden and in 1996 for Cerestar Italia SpA. His main research interests are in geometric methods for nonlinear control systems.

Erika Appel has been administrator at the Division of Optimization and Systems Theory since 2000.

Anders Blomqvist was born in Täby, Sweden, in 1976. He received a civilingenjör degree in Engineering Physics from KTH in 2001 after writing his Master's thesis *"Optimal Asset Allocation of Nuclear Decommissioning Trusts"* during the fall of 2000. Since the spring of 2001 he is a graduate student at the Division of Optimization and Systems Theory. His research interest is the extension of the degree-constrained Nevanlinna-Pick interpolation theory to the multivariable case.

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.

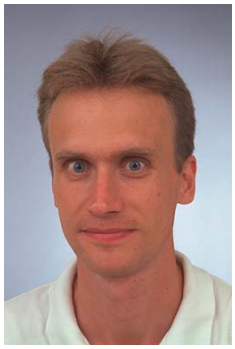
Anders Dahlén was born in Karlskrona, Sweden, in 1969. He did his undergraduate work in Mathematics of Science at the University of Växjö. He is presently a PhD student at the Division of Optimization and Systems Theory, and received in May 1998 the Teknisk Licenciat degree. His main professional interest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

Per Enqvist was born in Upplands Väsby, Sweden, in 1971. He received a civilingenjörs degree in Engineering Physics from KTH in 1994 and a TeknD (PhD) degree from the Division of Optimization and Systems Theory, KTH, in 2001. Presently he is doing a post doc at LADSEB-CNR in Padova, Italy. 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. He is now assistant professor at the Division of Optimization and Systems Theory. His current research interests include design and analysis of nonlinear and uncertain control systems, periodic system theory, hybrid Systems, 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 and a TeknD (PhD) degree in Optimization and Systems Theory from KTH in 2001. Her main research interests have been 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).

Jarmo Malinen was born in Finland, in 1970. He received a degree (MSc, with honours) in 1995, from the Dept. of Technical Physics and Mathematics, Helsinki University of Technology (HUT), Finland. He has held two 3-year assistent positions in mathematics at HUT, between 1995–2001. In 1997 Malinen obtained a three year grant for doctoral dissertation work from the Emil Aaltonen Foundation. Malinen received his doctoral degree (Dr. Tech., with distinction) at HUT in 2000, with thesis "H^∞ Algebraic Riccati Equations". After the defence, he held post doctoral positions at the Dept. of Electrical and Electronic Engineering, Imperial College, London (1/5/2000 – 31/10/2000), and at the Division of Optimization and System Theory, Dept. of Mathematics, KTH, Sweden (1/11/2000 – 31/10/2001). His current research interests are within operator theory and mathematical systems theory.

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 robust control, development of an efficient solver for Nevanlinna-Pick interpolation with degree constraint, 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 solution methods for telecommunications network design problems. In 1997 he started as an industry Ph.D. student at the department (in a project funded jointly by Ericsson and the Swedish Research Council) while maintaining a part time position at Ericsson Radio Systems AB. 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.

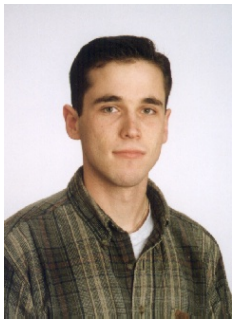
Krister Svanberg was born in Stockholm in 1950. In 1975 he got his Civilingenjör degree in Engineering Physics, in 1982 he got his TeknD degree in Optimization Theory, and in 1993 he was appointed Docent. Between 1976 and 1985 he worked for the Contract Research Group of Applied Mathematics, and since 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.



Petter Ögren was born in 1974 in Stockholm, Sweden. He recieved his Master of Science degree in Engineering Physics from KTH in 1998. He is currently a PhD-student at the division, affiliated with the Centre for Autonomous Systems. Research interests are the systems theory of mobile robotics, including mobile manipulators, hybrid systems, obstacle avoidance and multi-agent coordination.

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 Signals, Systems and Sensors, KTH
- 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, Bombardier Transportation, 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)
- NorFa Network on Structural Optimization.
- Strategic Research Consortium of Autonomous Systems, KTH

2 Research

2.1 List of projects

- ERNSI post-doctoral project
- 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 of power systems under uncertainty
- Optimization in telecommunications network design
- Path planning and control of nonlinear systems using sensor-data feedback
- Periodic systems
- Process modeling, operator training simulation and optimization applied to paper board manufactoring
- Rational Nevanlinna-Pick interpolation with degree constraints
- Reachability theory for uncertain hybrid systems
- Stochastic realization theory and identification
- The rational covariance extension problem, cepstral geometry, and global analysis of shaping filters

2.2 Description of projects

ERNSI post-doctoral project

Researcher: Jarmo Malinen.

Sponsor: ERNSI.

Jarmo Malinen was employed as an ERNSI post-doc at the Division of Optimization and Systems Theory, KTH, between November 1, 2000 and October 31, 2001. One of the objectives of his stay was to bridge the gap between the Finnish and Swedish mathematical systems theory "schools" which have communicated rather little in the past. Malinen used some four months of research time to learn background in stochastic systems theory, mainly by reading related papers by A. Lindquist, G. Picci, and others.

It is yet quite too early to speak about any new results on stochastic systems theory. One of the possible, emerging research subjects is to "stochastizise" the theory for well-posed (deterministic) linear systems (in the sense of Staffans and Weiss), but this work has hardly been started yet.

In the area of deterministic systems theory, Malinen has worked on paper [R5] (with O. Staffans and G. Weiss) on conservative (hence, well-posed) linear systems. In this work, algebraic characterizations are given for the energy balance and well-posedness for a linear system, given in the abstract differential equation form. Potential applications include e.g. classes of boundary control system of hyperbolic and parabolic evolution PDE's, of which some further results will be written in a future paper. This is continuation of the work initiated at Imperial College, London, where Malinen worked as a post-doc earlier in year 2000.

Recent operator theory works [R6], [R7] and [R8] are related to the activities of the "operator theory" group at the Helsinki University of Technology, lead by O. Nevanlinna. Work [R7] is just a manuscript of some 80 pages, parts of which may (or may not) get published at some stage. The subject of [R8] is inspired by (and a Banach space generalization of) a recent result of H. Zwart.

Manuscript [R9] (together with R. Nagamune, KTH) contains a geometric description of Fejer – Caratheodory interpolation problem, with the aid of conservative realizations and Sz.Nagy–Foias characteristic functions for contractions. The "abstract" results are more or less ready, and they are likely to be new. We hope to obtain some further insight into the nature of such interpolation problems with such techniques, in case the interpolant is rational but matrix-valued.

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 interest rates. More specifically we have considered interest rate models of Heath-Jarrow-Morton type where the forward rates are driven by a multidimensional Wiener process, and where the volatility structure is allowed to be a smooth functional of the present forward rate curve. Given that there exists a finite dimensional Markovian state space realization (FDR) for such a forward rate model, we have developed a general method for the actual construction of an FDR.

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, Henrik Rehbinder, Claudio Altafini, Torvald Ersson and Petter Ögren.

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

This project is part of an 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 complex systems such as autonomous systems. In particular, the following issues are studied.

1. Hierarchical control architechtures for autonmous systems.
2. Sensor fusion and active sensing under real-time constraints.
3. Feedback Control under sensor and communication constraints.
4. Path following, mobile manipulation and multi-agent control.

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). In 1994 it was shown by Megretski and Rantzer how Integral Quadratic Constraints (IQCs), a term originally coined by Yakubovich, can be used to unify the scaling techniques from robust control with the multiplier techniques from the input-output theory. There have 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. We have made several contributions in this area and we participated in the development of the software package IQCbeta [O3].

We are also actively working on several theoretical problems in IQC analysis. This year a powerful result for analysis of systems with multiple slope restricted nonlinearities was published in [A10].

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 Research Council (VR).

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 paper relating this research to interior methods for quadratic programming has been published [A14].

Models and methods for structural optimization

Researchers: Krister Svanberg and Mathias Stolpe.

Sponsor: The Swedish Research Council (VR).

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 identified certain intrinsic difficulties with penalization- and relaxation methods in topology optimization, see [A18], [A19], 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 [A20]. Third, we have proved global convergence of a class of optimization methods based on conservative convex approximations, see [A21]. Fourth, we have made progress in solving certain topology optimization problem to global optimum by translating them to mixed integer linear programming problems.

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. We have shown 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 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. To perform risk management, a contract portfolio is included in the model. We address these problems by *stochastic programming*, combined with advanced sampling techniques.

The first phase of this project ended in June 2001. The results are presented in the report [O2].

Optimization in telecommunications network design

Researchers: Mikael Prytz and Anders Forsgren (advisor).

Sponsor: Ericsson Radio Systems AB and the Swedish Research Council (VR).

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. The specific problems concern mainly link topology design and capacity dimensioning/provisioning in a communications backbone network with multicast traffic requirements. Network capacity is here selected from a discrete set of non-uniform levels such that total provisioning cost is minimized. Certain multicast routing constraints are also studied, in particular the case when the multicast distribution trees (source based/shortest path or core based/shared) have to be realizable by a common shortest path routing metric (e.g. when the multicast routing protocol PIM uses the unicast routing protocol OSPF to find shortest path trees). A certain shared tree multicast RP (Rendezvous Point) location problem is also studied in the project. Results have been presented [P21][P22] and a report has been written [R10].

Path planning and control of nonlinear systems using sensor-data feedback

Researchers: Xiaoming Hu, in cooperation with B. Ghosh (Washington University) and C.F. Martin (Texas Tech. Univ.).

Sponsor: The Swedish Research Council (VR).

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.

Periodic systems

Researchers: U. Jönsson, in cooperation with A. Megretski (M.I.T) and C. Kao (M.I.T).

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

Periodic phenomena can appear due to limit-cycle oscillation, forced vibration, or parametric excitation of the system. There is a rich theory for periodic systems, which addresses questions such as existence and uniqueness of solution, stability of solutions, robustness to period changing bifurcations, and many other properties. Our focus has been on various issues relating to the robustness to unmodeled dynamics, an important property of a periodic system that has largely been neglected by the research community up to recently.

Our work has been along two different directions. In the first branch of research we have considered extensions of systems analysis based integral quadratic constraints to systems consisting of a nominal linear time periodic operator in feedback interconnection with a structured operator, which represents uncertainties and nonlinearities in the system. Such feedback structures appear either directly or after linearization of the nominal system dynamics around a periodic solution. Our first contribution was to show how robust stability analysis can be performed using integral quadratic constraints [A15], which recently was published. It was in particular shown how special cutting hyperplane algorithms can be used to optimize the parameters of the IQC in order to get as flexible analysis results as possible. In a more recent work we show that IQCs also play an important role as a tool for proving existence of periodic solutions, for studying harmonic distortion in a nonlinear system, and for estimation of the magnitude of a periodic oscillation in an uncertain and/or nonlinear system [C12]. The key for success of this analysis is to consider IQCs defined on the space of square integrable periodic functions, which leads to an elegant and computationally attractive framework.

The other branch of research is robustness analysis of periodic trajectories. We are here interested in deciding whether a periodic solution remains and if it stays stable in a neighborhood of the nominal solution when the dynamics of the system changes. This problem is hard since the nominal trajectory is perturbed when we introduce uncertainty, which is in stark contrast to the traditional problems in robust control where stability is considered for equilibrium points that remain fixed for all values of the uncertainty. In [R1] we solve such a robustness problem for periodic solutions of non-autonomous systems.

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

Researchers: Per-Olof Gutman, Ander Linquist, Xiaoming Hu, Gianantonio Bortolin in cooperation with Bengt Nilsson (AssiDomän Carton Board AB, Frövi, Hilding Elmqvist (Dynasim AB, Lund), and Pontus Ryd (Solvina AB, Göteborg) .

Sponsor: The Swedish National Board for Industrial and Technical Development (Vinnova) through its KTS (Complex Technical Systems) program, and AssiDomän Carton Board AB, 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 2000/2001: 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. For more information, see http://www.math.kth.se/∼ bortolin/Nutek.html

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, Ryozo Nagamune and Anders Blomqvist 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] 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.

It is well-known that many problems in control theory, such as model matching, gain-margin maximization, robust stabilization, sensitivity shaping in feedback control, simultaneous stabilization, robust regulation, and general H_∞ control, can be formulated as Nevanlinna-Pick interpolation problems. However, the degree of the interpolating function relates to the dimension of an underlying system, and therefore it is important that the interpolant be rational with a degree which does not exceed some prescribed bound n. Applying the theory of [A4], we obtain the complete class of all such interpolants, and we may choose one which satisfies some additional design specifications.

In [A16], these ideas are applied to the well-known sensitivity reduction problem. 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. Presently the robust regulation problem is studied from the same point of view.

Reachability theory for uncertain hybrid systems

Researchers: U. Jönsson.

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

One of the primary motivations behind the hybrid control paradigm is that design complexity can be reduced significantly by decomposing the control task into a sequence of low complexity tasks. The execution of a hybrid system generally leads to switching between different dynamics. An example is fast set point control, where a time optimal controller can be used for the transition between set points while robust regulators are used for control around the set points. The design of such hybrid systems is often done based on simplified models and additional analysis is necessary to verify that unmodeled dynamics and disturbances will not threat proper operation of the real system. It is thus important to have methods to address the robustness of stationary solutions as well as the finite transitions between them.

The problem of computing the set of states that can be reached by an uncertain system goes under the name reachability analysis and is a crucial tool when verifying a hybrid system. Most of the reachability tools available today only consider coarse uncertainty descriptions such as differential inclusions, set valued disturbances, and ellipsoidal approximations. In our first contribution to this field we considered estimation of ellipsoidal sets around the nominal solution of a system, where uncertainty and disturbances are described by IQCs defined over a finite time horizon [C11],[R4]. This generally gives a very flexible uncertainty description. A related work, where a sensitivity derivative with respect to the uncertainty was used to estimate the

deviation of the perturbed trajectory from the nominal was published in [C13].

Stochastic realization theory and identification

Researchers: Anders Lindquist and Anders Dahlén, 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 [T2] we consider a multivariate version of 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. This procedure is then compared with the CCA subspace method. It is shown that the two methods are asymptotically equivalent in the sense that the difference between 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 Göran 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.

However, this optimization problem can be become badly conditioned for some parameter values. Therefore, in [T3], 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 [A8], 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: Torvald Ersson and Mikael Prytz.

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 and Mathias Stolpe.

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: Petter Ögren.

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: Claes Trygger.

Assistants: Jonas Rappe.

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.

5B1814 Applied Mathematical Programming—Linear Problems, 4 p
(*Tillämpad matematisk programmering—linjära problem)*

Instructor: Anders Forsgren.

Assistant: Göran Sporre.

The course should deepen and broaden the theoretical, methodological and modeling knowledge in linear and integer programming. Some subjects dealt with in the course are: Interior point methods for linear programming, stochastic programming, Lagrangian relaxation for integer programming, subgradient optimization. The modeling part of the course 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.

5B1816 Applied Mathematical Programming—Nonlinear Problems, 4 p
(*Tillämpad matematisk programmering—ickelinjära problem)*

Instructor: Anders Forsgren.

Assistant: Göran Sporre.

The course should deepen and broaden the theoretical, methodological and modeling knowledge in nonlinear programming. Some subjects dealt with in the course are: Interior point methods for nonlinear programming, quadratic programming, SQP methods for nonlinear programming and semidefinite programming. The modeling part of the course 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.

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

Instructor: Henrik Rehbinder.

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: Jonas Rappe.

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, oligopoly and monopoly.

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

Instructor: Ulf Jönsson.

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.

3.2 Graduate courses

5B5746 Optimization for Control and Signal Processing

Instructors: Anders Forsgren, Anders Hansson and Ulf Jönsson.

This is a new course that was developed in collaboration the Department of Signals Sensors and Systems at KTH. The goal of the course is to give an introduction to new optimization methods, in particular the interior point methods, and their application in control, systems theory, and signal processing.

5B5770 Nonlinear Systems Analysis

Instructor: Xiaoming Hu.

This course is a basic course on nonlinear dynamical systems, presented from the systems and control point of view. In the course, the analysis tools are studied. A range of topics on nonlinear systems are covered, such as approximation methods, periodic solutions, Liapunov stability, input-output stability and nonsmooth systems.

3.3 Doctoral theses

[T1] C. Altafini, *Geometric Control Methods for Nonlinear Systems and Robotic Applications*, TRITA-MAT-01-OS-04, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 2001. Advisors: X. Hu and A. Lindquist.

[T2] A. Dahlén, *Identification of Stochastic Systems: Subspace Methods and Covariance Extension*, TRITA-MAT-01-OS-06, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 2001. Advisor: A. Lindquist.

[T3] P. Enqvist, *Spectral Estimation by Geometric, Topolgical and Optimization Methods*, TRITA-MAT-01-OS-03, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 2001. Advisor: A. Lindquist.

[T4] C. Landén, *On the term structure of forwards, futures and interest rates*, TRITA-MAT-01-OS-01, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 2001. Advisor: T. Björk/A. Lindquist.

3.4 Master theses (*Examensarbeten)*

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

[T5] A. Blomqvist (F), *Optimal asset allocation of nuclear decommissioning trust funds*. Performed at NISA Investment Advisors. Advisor: A. Forsgren. (E237)

[T6] E. Bogentoft (F), *Asset liability management for pension funds using conditional value-at-risk*. Performed at University of Florida. Advisor: S. Uryasev/U. Brännlund. (E230)

[T7] K. Edén (E), *Prissättning av telekommunikationstjänster*. Performed at Ericsson Utveckling AB. Advisor: C. Trygger. (E240)

[T8] D. Eriksson (F), *Optimization algorithms and the tertiary structure prediction problem for proteins*. Performed at Mitsubishi Electric Corporation. Advisor: A. Forsgren. (E242)

[T9] M. Eriksson (F), *Increasing internet capacity using a genetic algorithm and path relinking*. Performed at University of Florida. Advisor: P. Pardalos/A. Forsgren. (E235)

[T10] T. Eriksson (F), *Obstacle avoidance for a mobile robot*. Performed at Centre for Autonomous Systems, KTH. Advisor: X. Hu. (E234)

[T11] L. Fredriksson (F), *Optimal korttidsplanering av Birka Värmes västra fjärrvärmesystem*. Performed at Birka Värme. Advisor: S. Feltenmark. (E229)

[T12] P. Hallgren (F), *The circadian rhytm in mammals*. Performed at Texas Tech. University. Advisor: A. Lindquist. (E238)

[T13] L. Henriksson (F), *Optimal placering av tillgångar och skulder*. Performed at CRM Treasury Systems. Advisor: U. Brännlund. (E228)

[T14] G. Jarder (F), *Improvement analysis of the hyper flexible assembly system Mark IV*. Performed at MIT. Advisor: D. Cochran/C. Trygger. (E241)

[T15] A. Köyluoglu (F), *Bildoptimering i IR-system*. Performed at FLIR Systems. Advisor: X. Hu. (E232)

[T16] N. Larsen (F), *Algorithms for optimization of value-at-risk*. Performed at University of Florida. Advisor: S. Uryasev/U. Brännlund. (E227)

[T17] H. Mårtensson (F), *Capacity characteristics of the hyper flexible assembly system Mark IV*. Performed at MIT. Advisor: D. Cochran/C. Trygger. (E243)

[T18] Per Sandgren (F), *Deadhead selection procedures within the aircrew scheduling problem*. Performed at RM Rocade. Advisor: Anders Forsgren. (E231)

[T19] S. Sedini (F), *Optimization of days-off distribution for aircraft crew*. Performed at RM Rocade. Advisor: K. Svanberg. (E239)

[T20] T. Sigurd (F), *Jämförelse mellan algoritmer för nätverksproblem med förluster*. Performed at Elektriska energisystem, KTH. Advisor: M. Amelin/S. Feltenmark. (E244)

[T21] J. Uhrdin (F), *Optimization of radiation therapy considering internal organ motion*. Performed at Karolinska Institutet. Advisor: A. Forsgren. (E233)

[T22] K. Westlund (F), *Error detection and estimation of swap rates*. Performed at Vattenfall Energimarknad. Advisor: S. Feltenmark. (E226)

[T23] D. Östlund (F), *En DEA analys av effekterna från den marknadsföring som bedrivits inom ramen för PIMCO*. Performed at SAS. Advisor: A. Forsgren. (E236)

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

[T24] A. Jorjani, *Analys av transferprocessen på Arlanda flygplats*. Performed at Luftfartsverket, Arlanda. Advisor: C. Trygger. (S135)

[T25] A. Hallberg (T), *Forecasting and inventory control of intermittent demand patterns*. Performed at IFS AB. Advisor: K. Svanberg. (S130)

[T26] R. Holmberg, *Spotmarknadsprissättning av bredband*. Performed at Telia AB. Advisor: S. Feltenmark. (S134)

[T27] J. Högberg, *Uplink admission control in WCDMA systems*. Performed at Telia Research AB. Advisor: C. Trygger. (S137)

[T28] N. Johansson, *The locomotive to train assignment problem*. Performed at University of Florida. Advisor: R. K. Ahuja/S. Feltenmark. (S132)

[T29] H. Klaffert (M), *Integrated Fleet Sizing and Delivery Planning: Decisions under uncertain demand*. Performed at University of Florida. Advisor: J. P. Geunes/A. Forsgren. (S133)

[T30] H. Noaksson (T), *Decision analysis under uncertainty applied to the problem of nearsightedness*. Performed at TU Berlin. Advisor: C. Trygger. (S129)

[T31] D. Vedholm (T), *Optimal gatetilldelning*. Performed at Luftfartsverket Arlanda. Advisor: U. Brännlund. (S127)

[T32] M. Werme, *Algorithms for solving non-monotone variational inequalities*. Performed at Chalmers University of Technology. Advisor: M. Patriksson/K. Svanberg. (S136)

[T33] F. Vinnå (T), *Days-off distribution for flight crew*. Performed at RM Rocade AB. Advisor: U. Brännlund. (S131)

4 Seminars at the division

- György Michaletzky, Eötvös Loránd University, Budapest, Hungary, *On the reduced rank Nevanlinna-Pick interpolation problem*, September 15, 2000.
- Alexandre Megretski, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, *Relaxations in non-convex quadratic optimization*, October 5, 2000.
- Anders Rantzer, Lund Institute of Technology, *On stability and convergence of nonlinear systems*, October 6, 2000.
- Ilya Ioslovich, Technion, Haifa, Israel, *Upper bounds for duals of positive linear programs with box-constrained uncertainties*, October 13, 2000.
- Jarmo Malinen, KTH, *On algebraic Riccati equations*, December 8, 2000.
- Andreas Wächter, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA, *An interior point algorithm for large-scale nonlinear programming*, December 15, 2000.
- Camilla Landén, KTH, *An introduction to arbitrage theory with the focus on problems related to the term structure of forwards, futures and interest rates*, February 9, 2001.
- Leonid Engelson, KTH, *Projected dynamical systems with delays: Definition, stability and applications*, March 16, 2001.
- Di Yuan, Linköping University, *Optimization of internet protocol network design and routing*, March 23, 2001.
- Per Enqvist, KTH, *Spectral estimation by geometric, topological and optimization methods*, March 30, 2001.
- Alberto Isidori, University of Rome, Rome, Italy, *Nonlinear output regulation with adaptive internal model*, April 5, 2001.
- Johan Löf, RaySearch Laboratories, Stockholm, *A framework for computation of optimal radiation therapy plans*, April 20, 2001.
- Naomi Ehrich Leonard, Princeton University, Princeton, New Jersey, USA, *Schooling autonomous vehicles with artificial potentials*, April 27, 2001.
- Olof Staffans, Åbo Akademi University, Åbo, Finland, *Well-posed linear systems*, May 4, 2001.
- Jörgen Blomvall, Linköping University, *Optimization of financial decisions using a new stochastic programming method*, May 11, 2001.
- Ilya Ioslovich, Technion, Haifa, Israel, *Optimal planning of industrial investments*, May 15, 2001.
- Claudio Altafini, KTH, *Modeling and control of redundant robotic chains on Riemannian manifolds*, May 18, 2001.
- Anders Dahlén, KTH, *Identification of stochastic systems: Subspace methods and covariance extension*, June 1, 2001.
- Erik Dotzauer, Birka Energi AB, *Energy system operation by Lagrangian relaxation*, June 8, 2001.

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, vol. 74, n.4, p. 409-424, 2001.

[A2] C. Altafini, A. Speranzon and B. Wahlberg, *A feedback control scheme for reversing a truck and trailer vehicle*, IEEE Transactions on Robotics and Automation, accepted 2001.

[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 SP-50 (April 2001), 677–693.

[A4] C. I. Byrnes, T. T. Georgiou and A. Lindquist, *A generalized entropy criterion for Nevanlinna-Pick interpolation with degree constraint*, IEEE Trans. Automatic Control AC-46 (June 2001), 822–839.

[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-49 (Nov. 2000), 3189–3205.

[A6] C. I. Byrnes, X. Hu, C. Martin and V. Shubov, *Input-output behavior for stable linear systems*, J. Franklin Inst., vol. 338, no.4, 2001.

[A7] C. I. Byrnes and A. Lindquist, *On the duality between filtering and Nevanlinna-Pick interpolation*, SIAM J. Control and Optimization 39 (2000), 757–775.

[A8] C. I. Byrnes, P. Enqvist and A. Lindquist, *Identifiability and well-posedness of shaping-filter parameterizations: A global analysis approach*, Accepted for publication in SIAM J. Control and Optimization.

[A9] C. I. Byrnes, S. V. Gusev and A. Lindquist, *From finite covariance windows to modeling filters: A convex opimization approach*, SIAM Review 43 (2001), to be published.

[A10] F. J. D'Amato and M. A. Rotea and A. V. Megretski and U. T. Jönsson, *New results for analysis of systems with repeated nonlinearities*, *Automatica*, 37(5):739–747, 2001.

[A11] M. Egerstedt and X. Hu, *A hybrid control approach to action coordination for mobile robots*, Accepted for Automatica.

[A12] M. Egerstedt, X. Hu and A. Stotsky, *Control of mobile platforms using a virtual vehicle approach*, Accepted for IEEE. Trans. Aut. Control.

[A13] M. Egerstedt and X. Hu, *Formation constrained multi-agent control*, Accepted for IEEE trans. Robotics and Automation.

[A14] A. Forsgren and G. Sporre, *On weighted linear least-squares problems related to interior methods for convex quadratic programming*, SIAM Journal on Matrix Analysis and Applications 23 (2001), 42-56.

[A15] C. Kao, A. Megretski, and U. Jönsson, *A cutting plane algorithm for robustness analysis of periodic systems*, *IEEE Transactions on Automatic Control* 46(4):579 -592, Apr 2001.

[A16] R. Nagamune and A. Lindquist, *Sensitivity shaping in feedback control and analytic interpolation theory*, Optimal Control and Partial Differential Equations,J.L. Medaldi et al(editors), IOS Press, Amsterdam, 2001, pp. 404–413.

[A17] H. Rehbinder and C. F. Martin, *A control theoretic model of the forearm*, Journal of Biomechanics, 34/6 (2001), 741-748.

[A18] M. Stolpe and K. Svanberg, *On the trajectories of the epsilon-relaxation approach for stress-constrained truss topology optimization*, Structural and Multidisciplinary Optimization 21(2001), 140-151.

[A19] M. Stolpe and K. Svanberg, *On the trajectories of penalization methods for topology optimization*, Structural and Multidisciplinary Optimization 21(2001), 128-139.

[A20] M. Stolpe and K. Svanberg, *An alternative interpolation scheme for minimum compliance topology optimization*, To appear in Structural and Multidisciplinary Optimization.

[A21] K. Svanberg, *A class of globally convergent optimization methods based on conservative convex approximations*, To appear in SIAM Journal on Optimization.

[A22] P. Ögren and C. F. Martin, *Vaccination strategies for epidemics in highly mobile populations*, Journal of Applied Mathematics and Computation, to appear.

5.2 Papers in conference proceedings (published and accepted)

[C1] C. Altafini and R. Frezza, *Motion on constrained submanifolds for a kinematic control system evolving on a matrix Lie group*, 5th IFAC Symposium "Nonlinear Control Systems", Saint-Petersburg, Russia, July 2001.

[C2] C. Altafini, *Inverse kinematics along a geometric spline for a holonomic mobile manipulator*, IEEE International Conference on Robotics and Automation, Seoul, Korea, May 2001.

[C3] C. Altafini and A. Speranzon, *Backward line tracking control of a radio-controlled truck and trailer*, IEEE International Conference on Robotics and Automation, Seoul, Korea, May 2001.

[C4] G. Bortolin, S. Borg and P.O. Gutman, *Modeling of the wet end part of a paper mill*, M2SABI'01 IMACS/IFAC, 12-14 June, Haifa, Israel.

[C5] 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.

[C6] T. Ersson and X. Hu, *Path planning and navigation of mobile robots in unknown environments*, IEEE/RSJ International Conference on Intelligent Robots and Systems, Maui, USA, Oct. 29 - Nov. 3 2001. Accepted.

[C7] T. Ersson and X. Hu, *Implicit observers and active perception*, IEEE/RSJ International Conference on Intelligent Robots and Systems, Maui, USA, Oct. 29 - Nov. 3 2001. Accepted.

[C8] T. Ersson and X. Hu, *State observers of linear control systems with nonlinear outputs*, IEEE Conference on Decision and Control, Orlando, USA, Dec. 4-7 2001. Accepted.

[C9] R. Frezza and C. Altafini, *Autonomous landing by computer vision: an application of path following in SE(3)*, Proc. of the 39th IEEE Conf. on Decision and Control, Sidney, Australia, December 2000.

[C10] X. Hu, *Nonlinear global stabilization by output feedback control*, in the proc. of Asian Control Conference, Shanghai, 2000.

[C11] U. Jönsson, *Robustness of trajectories with finite time extent*, In *Proceedings of IFAC Symposium on Nonlinear Control Systems*, (Nolcos01) pages 1157–1162, Saint-Petersburg, Russia, July 2001.

[C12] U. Jönsson, C. Kao, and A. Megretski, *A semi-infinite optimization problem in harmonic analysis of uncertain systems*, In *Proceedings of the American Control Conference 2001*, Arlington, VA, USA, 2001.

[C13] U. Jönsson, *Estimation of perturbation bounds for finite trajectories*, In *Proceedings of IEEE Conference on Decision and Control 1999*, pages 2775–2780, Sydney, Australia, December 2000.

[C14] H. Rehbinder and M. Sanfridson, *Scheduling of a limited communication channel for optimal control*, Proceedings of the 39th IEEE Conference on Decision and Control, Sydney, Australia, 2000.

[C15] H. Rehbinder and X. Hu, *Drift-free attitude estimation for accelerated rigid bodies*, Proceedings of the 2001 IEEE International Conference on Robotics and Automation, Seoul, Korea, 2001.

[C16] S. Yamamoto, M. Kimura and R. Nagamune, *Identification of a state-space model set presuming robust performance control*, 6th International Conference on Control, Automation, Robotics and Vision, TA3.4-160 (Singapore) December 2000.

[C17] 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.

[C18] P. Ögren and C. F. Martin, *Optimal vaccination strategies for the control of epidemics in highly mobile populations*, IEEE Conference on Decision and Control, Sydney, Australia, Dec. 2000.

[C19] P. Ögren, M. Egerstedt and X. Hu, *A control Lyapunov function approach to multi agent coordination*, IEEE Conference on Decision and Control, Orlando, Florida, USA, Dec. 2001. Accepted.

5.3 Other publications

[O1] U. Brännlund, *Systemteknik och transportoptimering*, Bidrag till kompendiet Introduktion till Farkostteknik, TRITA-FKT.

[O2] S. Feltenmark and J. Holst, *Optimering av kraftsystem under osäkerhet*, Final report, ITM Report 2001:5, October 2001, Swedish Institute of Applied Mathematics (ITM), Chalmers Science Park, Gothenburg, Sweden.

[O3] 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.

5.4 Technical reports and preprints

[R1] U. Jönsson, C. Kao, and A. Megretski, *Robustness analysis of periodic trajectories*, Technical Report TRITA/MAT-99-S5, Department of Mathematics, Royal Institute of Technology, November 1999, Submitted.

[R2] U. Jönsson, *Lecture notes on integral quadratic constraints*, Technical Report TRITA/MAT-00-OS12, Department of Mathematics, Royal Institute of Technology, september 2000.

[R3] U. Jönsson, *Estimation of perturbation bounds for finite trajectories*, Technical Report TRITA/MAT-00-OS16, Department of Mathematics, Royal Institute of Technology, September 2000.

[R4] U. Jönsson, *Robustness of trajectories with finite time extent*, Technical Report TRITA/MAT-00-OS21, Department of Mathematics, Royal Institute of Technology, 2000.

[R5] J. Malinen, O. Staffans and G. Weiss, *How to characterize conservative systems?*, Manuscript, 32pp., 2002.

[R6] J. Malinen, *Remarks on the Hille–Yoshida resolvent theorem*, Submitted to Banach Center Publications, 2001.

[R7] J. Malinen, *Notes on the power-boundedness of cogenerators*, Manuscript, 80pp., 2001.

[R8] J. Malinen, *On cogenerators and power bounded operators*, Manuscript, 9pp., 2001.

[R9] J. Malinen and R. Nagamune, *On the geometry of Hermite–Fejer interpolation problem with rational interpolants*, Manuscript, 2001.

[R10] M. Prytz and A. Forsgren, *Dimensioning multicast-enabled communications networks*, Report TRITA-MAT-2001-OS2, Department of Mathematics, Royal Institute of Technology, 2001.

[R11] P. Ögren M. Egerstedt and X. Hu, *A control Lyapunov function approach to multi-agent coordination*, Submitted to IEEE Transactions on Robotics and Automation.

6 Awards

The paper *"A convex optimization approach to the rational covariance extension problem"*, by **C. I. Byrnes**, **S. V. Gusev** and **A. Lindquist**, published in SIAM J. Control and Opimization, 37 (1999), 211–229, has been chosen by the editors of SIAM Review to be a "SIGEST" paper, the second paper ever from SIAM Journal of Control and Optimization.

Jarmo Malinen was chosen to receive the Nevanlinna Dissertation prize for the best Finnish mathematical dissertation published in year 2000.

7 Presentations

[P1] C. Altafini, *Motion on constrained submanifolds for a kinematic control system evolving on a matrix Lie group*, 5th IFAC Symposium "Nonlinear Control Systems", Saint-Petersburg, Russia, July 2001.

[P2] C. Altafini, *Reduction by group symmetry of a variational problem on a semidirect product of Lie groups*, SIAM Control Conference, S. Diego, California, July 2001.

[P3] C. Altafini, *A feedback control system for reversing a truck and trailer vehicle*, Caltech, California, November 2000.

[P4] C. Altafini, *Motion control for redundant robotic chains on Riemannian manifolds*, South-California Nonlinear Control Workshop, S. Barbara, California, October 2000.

[P5] G. Bortolin, *Modeling of the wet end part of a paper mill*, M2SABI'01 IMACS/-IFAC, 12-14 June, Haifa, Israel.

[P6] A. Forsgren, *Inertia-controlling factorizations for interior methods*, The 17th International Symposium on Mathematical Programming, Atlanta, Georgia, USA, August 7-11, 2000.

[P7] A. Forsgren, *Inertia-controlling factorizations for optimization algorithms*, The 19th Biennial Conference on Numerical Analysis, Dundee, Scotland, UK, June 26–29, 2001.

[P8] X. Hu, *Estimation and control of mobile systems*, Yanshan University, China, July, 2001.

[P9] X. Hu, *Input-output behavior for stable linear systems*, Russian-Swedish Control Conference, Moscow, May, 2001.

[P10] U. Jönsson, *Estimation of perturbation bounds for finite trajectories*, IEEE Conference on Decision and Control, Sydney, Australia, December 2000.

[P11] U. Jönsson, *Robustness and performance analysis of periodic systems*, Russian-Swedish Control Conference, Moscow, May 2001.

[P12] U. Jönsson, *A semi-infinite optimization problem in harmonic analysis of uncertain systems*, American Control Conference, Arlington, VA, USA, June 2001.

[P13] U. Jönsson, *Robustness of trajectories with finite time extent*, IFAC Symposium on Nonlinear Control Systems, Saint-Petersburg, Russia, July 2001.

[P14] C. Landén, *On the term structure of futures and forward prices*, 2001 Nordic Symposium on Contingent Claims, Stockholm, Sweden, May 25-26, 2001.

[P15] A. Lindquist, *Some New Methods and Concepts in High-resolution Spectral Estimation*, Plenary lecture at the Third Asian Control Conference (ASCC), Shanghai, China, July 4–7, 2000.

[P16] A. Lindquist, *Cepstral geometry and global analysis of ARMA parameterizations*, ERNSI 2000, Vadstena, Sweden, September 25–27,2000.

[P17] A. Lindquist, *Synthetic speech and modern mathematics: What is the connection?*, Math 2000 Colloquium, Royal Institute of Technology, November 28, 2000.

[P18] A. Lindquist, *Synthetic speech and modern mathematics: What is the connection?*, Stockholm University, February 14, 2001.

[P19] A. Lindquist, *Synthetic speech and modern mathematics: What is the connection?*, Uppsala University, May 29, 2001.

[P20] J. Malinen, H^∞ *algebraic Riccati equations*, Lecture for the Finnish Mathematical Society at Åbo Akademi University, December 2000.

[P21] M. Prytz, *Dimensioning Capacity in Multicast-Enabled Communications Networks*, ISMP2000 (International Symposium on Mathematical Programming), Atlanta, U.S.A., August, 2000.

[P22] M. Prytz, *Optimization of Multicast-Enabled Network Design and Dimensioning*, Department of Microelectronics and Information Technology, Royal Institute of Technology, May 28, 2001.

[P23] H. Rehbinder, *Scheduling of a limited communication channel for optimal control*, 39th IEEE Conference on Decision and Control, Sydney, Australia, 2000.

[P24] H. Rehbinder, *Drift-free attitude estimation for accelerated rigid bodies*, 2001 IEEE International Conference on Robotics and Automation, Seoul, Korea, 2001.

[P25] G. Sporre, *Nonconvexity in interior methods for nonlinear programming*, 17th International Symposium on Mathematical Programming, Atlanta, Georgia, USA, August 7-11, 2000.

[P26] M. Stolpe, *An alternative interpolation scheme for minimum compliance topology optimization*, The Fourth World Congress of Structural and Multidisciplinary Optimization, Dalian, China, June 4-8, 2001.

8 Other activities

Claudio Altafini

- Research visit to Caltech, Control and Dynamical Systems Division, California, September-December 2000.
- 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 International Journal of Control, IEEE Transactions on Robotics and Automation and CDC'01.

Gianantonio Bortolin

- ERNSI meeting, September 25-28, 2000 Vadstena, Sweden.
- Modelica 2000 Workshop, October 23-24 2000, Lund, Sweden.
- Referee for Automatica.

Ulf Brännlund

- Responsible for the line of competence (kompetensinriktning), Systems engineering, for the schools of mechanical and vehicle engineering.
- Wrote a contribution for the textbook for the introductory class in vehicle engineering called "Systemteknik och transportoptimering" (Systems engineering and transportion optimization).
- Developed new computer exercises for the course Portfolio Theory and Risk Evaluation.
- Referee for Transportation Science.

Per Enqvist

- Participated in the 9th ERNSI Workshop on System Identification in Vadstena, Sweden, September, 2000, and presented a poster.

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 30–August 5, 2000 and March 24–April 1, 2001.
- Referee for Mathematical Programming and European Journal of Operations Research.

Ulf Jönsson

- Participated in 9th ERNSI workshop on System Identification in September 2000 in Vadstena, Sweden.
- Referee for Automatica, IEEE Transactions on Automatic Control, International Journal of Control, American Control Conference, IEEE Conference on Decision and Control.
- Organized a symposium on Integral Quadratic Constraints at KTH on October 6, 2000.

Camilla Landén

- Participated in the 2001 Workshop on Finance and Insurance, Stockholm, Sweden, June 15-16, 2001.

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.

- Vice-President, Division VII (Basic and Interdisciplinary Engineering Sciences) of the 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.
- Member, 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.
- Examiner (Revisore), University of Padova, Italy.
- Member, Steering Committee of the ERCIM Working Group on Control and System Theory.
- Member, Scirentific Steering Committee of Mittag-Leffler Institute program on Mathematical Control and Systems Theory, Spring 2003.
- Member, Organizing Committee of Fourth European Mathematical Congress, Stockholm, June 27 – July 2, 2004.
- International Advisory Committee of the 32th ISCIE International Symposium on Stochastic Systems Theory and its Applications, Tottori, Japan, November 1–2, 2000.
- Member, International Scientific Committee of 2001 WSES International Conference on Speech, Signal and Image Processing, Malta, September 1 - 6, 2001.
- Member, Steering Committee of MTNS2002, University of Notre Dame, August 12-16, 2002.
- Member, International Advisory Committee of the 33th ISCIE International Symposium on Stochastic Systems Theory and its Applications, Tochigi, Japan, October 29 - 30, 2001.

Ryozo Nagamune

- Participated in 9th ERNSI Workshop in Vadstena, Sweden, September 25-28, 2000.

Mathias Stolpe

- Visited the Department of Solid Mechanics, Technical University of Denmark, September-October 2000.

Krister Svanberg

- Member of the evaluation committee in Engineering Mathematics at the Swedish Research Council for Engineering Sciences, June-Sep 2000.
- In the evaluation committee at the PhD dissertation of Jonas Eliasson, Division of Transport and Location Analysis, KTH, Oct 27, 2000.
- In the evaluation committee at the PhD dissertation of Martin Joborn, Division of Optimization, Linköping University, March 20, 2001.
- In the evaluation committee at the PhD dissertation of Nils Olsson, Division of Timber Structures, Luleå University of Technology, April 27, 2001.
- On the editorial board of Structural and Multidisciplinary Optimization.
- Referee for Computer Methods in Applied Mechanics and Engineering.
- Referee for Optimization and Engineering.
- Referee for Numerical Algorithms.