Activity Report

1997/1998

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

KUNGL TEKNISKA HÖGSKOLAN

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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 1997/1998 (July 1997 – June 1998).

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.

Contents

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

Universitetslektor (Senior lecturer)

Ulf Brännlund, TeknD
Claes Trygger, TeknD

Forskare (Researchers)

Stefan Feltenmark, TeknD
Andreas Nõu, TeknD (graduated October 1997)

Postdoktorstipendiat (Postdoctoral fellow)

Alexander Stotsky, PhD

Gästforskare (Visiting professors)

Per-Olof Gutman, professor
Vladimir Yakubovich, professor

Intendent (Administrator)

Leena Druck

Doktorander (Graduate students)

Claudio Altafini
Anders Dahlén, FK, TeknL
Magnus Egerstedt, civing
Per Enqvist, civing
Torvald Ersson, civing
Camilla Landén, civing
Jorge Marí, MS, TeknD (graduated May 1998)
Ryozo Nagamune
Mattias Nordin, civing, TeknL
Mikael Prytz, civing
Henrik Rehbinder, civing
Göran Sporre, civing
Mathias Stolpe, civing

1.2 Biographies

Claudio Altafini was born in Salara, in the nearby of Ferrara, Italy, in 1969. He 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 motion planning and navigation for mobile robots and mobile manipulation.

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. 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 is the administrator at the Division of Optimization and Systems Theory since 1992.

Magnus Egerstedt was born in 1971 in Täby, Stockholm, Sweden. He recieved his Master of Science-degree in Engineering Physics at the Royal Institute of Technology in 1996. Besides the MSc-degree, he also has a BA-degree from Stockholm's University, majoring in Theoretical Philosophy. He works on the problem of how to structure a robotic navigation system. This problem involves motion planning and control as well as coordination of different actions, using for instan ce a hybrid systems approach. His main interests lie in the

control theoretical aspects of this area, such as robustness and stability.

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. At the moment he is studying the covariance extension problem and applications to speech processing.

Torvald Ersson was born in Västerås, Sweden, in 1973. He received a Master of Science degree in Engineering Physics at KTH in 1998. He is presently a PhD student at the Division of Optimization and Systems Theory. His main research interests are autonomous systems and robotics.

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.

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. Since 1990 he holds the position of Senior Lecturer with the Faculty of Agricultural Engineering, Technion — Israel Institute of Technology, Haifa. 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.

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.

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 interest is financial mathematics. Presently she is working with a regime-switching interest rate model.

Anders Lindquist was born in Lund, Sweden, in 1942. He received the civiling., TeknL and TeknD degrees from the Royal Institute of Technology, Stockholm, Sweden, and in 1972 he was appointed a Docent of Optimization and Systems Theory there.

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 presently a Professor at the Royal Institute of Technology, where in 1982 he was appointed to the Chair of Optimization and Systems Theory, and an Affiliate Professor at Washington University, St Louis. He has also held visiting positions at University of Padova, Italy, University of Arizona, USSR Academy of Sciences, Moscow, East China Normal University, Shanghai, and Technion, Haifa, Israel. He is the author of many papers in the area of systems and control, especially stochastic control, filtering, stochastic systems theory, realization theory, and applications of nonlinear dynamics in estimation and control.

Anders Lindquist is a Member of the Royal Swedish Academy of Engineering Sciences, a Foreign Member 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 Advisory Board Member of the Institute for Mathematics of the Life Sciences, Texas Tech University and a Communicating Editor of the *Journal of Mathematical Systems, Estimation, and Control* (published by Birkhäuser Boston) and, until 1993, he was an Associate Editor of *Systems and Control Letters* (North-Holland). He also serves on the editorial boards of *Adaptive Control and Signal Processing* (John Wiley & Sons) and of the book series *Systems and Control: Foundations and Applications* and *Applied and Computational Control, Signals, and Circuits* (Birkhäuser Boston). Until 1993, he also served on the editiorial board of the book series *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).

Jorge Marí became Electrical Engineer in 1992, after a six-year programme at the Facultad de Ingeniería in Montevideo, Uruguay. He also studied optimization and dynamical systems at the Facultad de Ciencias, and worked as assistant at the Math department. Later he joined the telephone company ANTEL where he worked as advisor in power supply systems. Since early 1993 he was engaged in a KTH-industry project in Stockholm, concerning modelling and optimal control of fermentation processes. During this time he started as PhD student at Optimization and Systems Theory, KTH, and received in January 1995 the Teknisk Licenciat degree. He spent half year in 1995 at the Institute for Robotics and System Dynamics, German Aerospace Research Establishment in Oberpfaffenhofen, where he became involved in control applications to automobiles and aircraft. From 1996 to 1998 he worked among other topics in modelling of time series, completing his PhD in May 1998. His main interests include engineering systems, systems identification and control theory applications.

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 interest is the application of Nevanlinna-Pick interpolation theory with degree constraint to control systems and circuit theory.

Mattias Nordin received his civilingenjör degree in Engineering Physics from KTH in 1992, where his Masters Thesis: *Robust Control of Rolling Mills* was awarded with the VOLVO Royal Institute Technologist of 1992 as one of two that year. Subsequently he started as a Graduate Student at the Division of Optimization and Systems Theory in the project Robust Control of Electrical Drives, where his main research interest is systems with backlash or gear play. He also works in the area of robust control, especially Quantitative Feedback Theory (QFT). In 1995 he received his Licentiate Thesis: *Uncertain Systems with Backlash, Modelling, Estimation and Synthesis.* He has also published several designs for Benchmark Problems, and is generally interested in applying theoretical results to practical problems. His research is in cooperation with ABB Industrial Systems AB, Västerås, where he currently spends most of the week.

Andreas Nõu received his civilingenjör degree in Engineering Physics from KTH in 1991 and his doctorate degree in Optimization and Systems Theory from KTH in 1997. His main research interests are methods for large-scale combinatorial optimization problems, arising e.g. in various transportation science applications.

Mikael Prytz was born in 1969 in Stockholm, Sweden. He received his Master of Science-degree in Engineering Physics at the Royal Institute of Technology in 1993 and a Master of Science-degree in Engineering-Economic Systems and Operations Research at Stanford University in 1998. From 1993 to 1996 he was employed at Ericsson Telecom developing models and methods for telecommunications network design problems as well as performing network design assignments. He is currently an industry PhD student at the department in a project that is jointly funded by Ericsson Telecom and the Swedish Research Council for Engineering Sciences. His research interests are in optimization methods for telecommunications network design problems.

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 Centre for Autonomous Systems. His research interests are in sensor fusion and sensor planning for state estimation focused on walking machines for rough terrain. Particular reference is paid to the real-time aspects of this.

Göran Sporre was born in Järfälla, Sweden, in 1972. He recieved 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.

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.

Alexander Stotsky was born in St.Petersburg, Russia, in 1960. He received the M.S. and Ph.D degrees from Leningrad Mechanical Institute in 1983 and 1989 respectively. In 1990 he joined Institute for Problems of Mechanical Engineering, Academy of Sciences of Russia as a senior researher. In 1993-1994 he was Visiting Scholar at the Center of Advanced Transportation Technologies, University of Southern California. His main research interests are in the field of nonlinear control theory with application to transportation systems.

Krister Svanberg was born in Stockholm in 1950. He received his civilingenjör degree in Engineering Physics in 1975, and his TeknD degree in Optimization Theory in 1982, both from KTH. 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 (Universitetslektor) of Optimization and Systems Theory. 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 Jürgen Ackermann, Institute for Robotics and System Dynamics, DLR, German Aerospace Research Establishment, Wessling, Germany
- 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
- Professor Jacques Desrosiers, GERAD and HEC, Montréal, Québec, Canada
- Professor Leonid Faybusovich, Department of Mathematics, University of Notre Dame, Notre Dame, Indiana, USA
- Professor A. L. Fradkov, Department of Mathematics and Mechanics, St. Petersburg State Technical University, Russia
- Professor Ruggero Frezza, Dipartimento di Elettronica, Universita di Padova, Padova, Italy
- 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
- Professor Krzysztof C. Kiwiel, Systems Research Institute, Warsaw, Poland
- Professor P. O. Lindberg, Division of Optimization, Department of Mathematics, Linköping Univervsity
- Professor Alexei S. Matveev, Department of Mathematics and Mechanics, St. Petersburg State University, St. Petersburg, Russia
- Professor György Michaletzky, Department of Probability Theory and Statistics, Eötvös Lorand University, Budapest, Hungary
- Professor Walter Murray, Department of Engineering Economic Systems and Operations Research, Stanford University, Stanford, California, USA
- Professor Jan-Eric Nilsson, Dalarna University, Borlänge, Sweden
- Professor Giorgio Picci, Department of Electronics and Informatics, University of Padova, Padova, Italy
- Professor Alfredo Piria, Department of Mathematics, Facultad Ingeneria, Montevideo, Uruguay
- Professor Francois Soumis, GERAD and École Polytechnique de Montréal, Montréal, Québec, Canada

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

- Advanced optimization methods for crew and vehicle scheduling
- Allocation of scarce track capacity
- Autonomous systems
- Financial economics
- Geometric theory of linear stochastic systems
- Hybrid control of autonomous system
- 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
- Railway timetabling on track networks
- Rational Nevanlinna-Pick interpolation with degree constraints
- Robust control of electrical drives
- Robust quality control for paper manufacturing
- 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

2.2 Description of projects

Advanced optimization methods for crew and vehicle scheduling

Researchers: Andreas Nõu, in cooperation with K. C. Kiwiel, Systems Research Institute, Warsaw, Poland and P. O. Lindberg, Linköping University.

Sponsor: The Swedish Transport Research Board (TFB).

In this project we use advanced dual methods to solve large-scale 0-1 problems. The problems we have in mind are very large, sparse, set covering problems that arise e.g. in airline crew scheduling. The dual multipliers are used heuristically to generate near optimal 0-1 solutions.

We have tried two alternative methods. The first is a differentiable dual approach which uses a probabilistic feasibility heuristic to generate primal solutions. Please refer to [R10] for details. In the second we apply a recent extension of the Bregman proximal method for convex programming to LP relaxations of 0–1 problems. Approximate relaxed solutions are used to construct primal feasible solutions via a randomized heuristic. Encouraging preliminary experience is reported in [R9].

Allocation of scarce track capacity

Researchers: Ulf Brännlund and Andreas Nõu, in cooperation with P. O. Lindberg, Linköping University, and Jan-Eric Nilsson, Dalarna University.

Sponsors: The Swedish Transport Research Board (TFB) and the Swedish National Rail Administration (Banverket).

Industrial contacts: The Swedish National Rail Administration.

This is a project concerning the optimal allocation of scarce track capacity between a number of different railway companies. It is assumed that the companies can provide utility functions giving their monetary values of different time tables.

For the problem of allocating the capacity so that the total utility is maximized, we have set up an optimization model and devised an algorithm based on dual methods. The resulting model is extremely large. A typical case with 25 trains, 17 stations and one-minute discretization gives on the order of 400 000 binary variables and constraints. Our method uses the structure of the model and does not have to treat these variables explicitly.

During the year the report [A1] has been accepted for publication in Transportation Science. As part of his thesis work Andreas Nõu has looked into more advanced primal feasibility heuristics. The most promising heuristic is an enhanced priority list heuristic, utilizing a tabu search procedure to update the priority list. Please refer to [R12] for details.

We gave a presentation on the subject at the 16th International Symposium on Mathematical Programming, Lausanne, Switzerland, in August 1997, [P24].

Autonomous systems

Researchers: Anders Lindquist, Xiaoming Hu, P.-O. Gutman, Daniele Galardini, Alexander Stotsky, Magnus Egerstedt, Henrik Rehbinder och Claudio Altafini within the framework of the Center for Autonomous Systems.

Sponsor: The Strategic Research Foundation (Stiftelsen för strategisk forskning).

This is a broad and long-term project in collaboration with the Division of Computer Vision and Active Perception, (Numerical Analysis and Computing Science),

Department of Mechatronics and Machine Elements, and Department of Signals, Sensors and Systems, which together with the Division of Optimization and Systems Theory form a research consortium supported by a grant from the Strategic Research Foundation. By autonomous systems is meant technical systems (such as mobile robots) that are capable of performing advanced tasks in unpredictable environments. Specific subprojects are reported separately.

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 studied a diffusion type model for the short rate where the drift and diffusion coefficients are modulated by an underlying Markov process. We have derived sufficient conditions on the drift and diffusion coefficients for the model to possess a semi-affine term structure. For a special case we can give a closed form expression for bond prices.

Furthermore we consider the pricing problem when the modulating process can not be directly observed. It turns out that pricing in this context may be viewed as a filtering problem.

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.Å. 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, P.-O. Gutman, Alexander Stotsky, Magnus Egerstedt, Henrik Rehbinder and Claudio Altafini.

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

This project is part of the research effort of the Center for Autonomous Systems, which consists of four divisions at KTH, and is sponsored by the Swedish Foundation for Strategic Research. In this project we use a hybrid system approach to study some issues concerning the integration of control and sensor systems for a mobile robot. In particular, the following issues are studied. 1. Path planning. We study the problem of path planning and obstacle avoidance for systems with possibly nonholonomic constraints. 2. Robust motion control. We study the problem of designing motion control algorithms which are robust to disturbances and uncertainties. Naturally, besides kinematic models, dynamic models for robots are also needed. 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 tailormaking filter algorithms for our applications as well as more general filtering problems for sensors in distributed control systems. 4. System integration. We approach this issue by integrating the hierarchical control architecture into the more general scheme of hybrid dynamic systems (HDS).

KTH optimization laboratory

Researchers: Ulf Brännlund, Stefan Feltenmark, Anders Forsgren, Andreas Nõu, Mikael Prytz, 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, Göran Sporre and Mikael Prytz, in cooperation with Philip E. Gill (UCSD).

Sponsors: The Swedish Natural Science Research Council (NFR) and the Swedish Research Council for Engineering Sciences (TFR).

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 [A7]. Suitable optimality conditions for nonconvex semidefinite programming have been derived [R7], that are of high importance when extending the interior-point methodology also to this class of problems.

Two graduate students are involved in this project, Mikael Prytz and Göran Sporre. Prytz is an industrial graduate student, who spent the academic year 1997/1998 at Stanford University. The purpose of Prytz' project is to utilize nonlinear-programming based relaxations to solve combinatorial optimization problems of interest in telecommunications design. Sporre's research is focused on method development.

Models and methods for structural optimization

Researchers: Krister Svanberg, Ulf Brännlund, 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.

During the year, we have developed a primal-dual optimization method for topology design of load-carrying truss structures. Test problems with more than 50.000 design variables have been successfully solved, see [R1]. The research continues with more general problem.

We also try to further improve our ten years old method of moving asymptotes, MMA, both regarding global convergence properties and speed. MMA, which is a general method for inequality-constrained nonlinear optimization, is today frequently used in various research projects and applications of structural optimization.

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. 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 [A12][A13] 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 also show that any OUR for this (deterministic) problem is an optimal regulator for a class of stochastic control problems of similar structure. In [A11] we consider the case of complete state feedback, in which case an OUR always exists. The problem of optimal tracking is considered in [A13]. Nonrationals solutions are also being studied.

We stress that our solutions are optimal in the sense stated above only, and that other desirable design specifications may not be satisfied for an arbitrary universal optimal regulator. Therefore it is an important 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: S. Feltenmark and J. Holst (Lund University).

Sponsors: 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. The project runs from January 1998.

Railway timetabling on track networks

Researchers: Andreas Nõu, in cooperation with Jan-Eric Nilsson, Dalarna University.

Industrial contacts: The Swedish National Rail Administration.

This is a project concerning the optimal allocation of scarce track capacity between a number of different railway companies offering various services on a track network (allowing an arbitrary number of parallel tracks on each segment; in Sweden mainly single or double line segments).

In a previous project *Allocation of scarce track capacity*, we restricted ourselves to a line of single track. Please refer to [A1] for details. The current project aims to extend the present optimization algorithms to cope with *networks* of track and to increase the model accuracy when compared to current operating practice in Sweden. We gave a talk on the subject at the CORS/INFORMS spring meeting in Montréal, Canada, in April 1998, [P25].

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 Foundtion.

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. Software based on state space concepts is being developed, and the computational methods are applied to several problems in systems and control.

Robust control of electrical drives

Researchers: P. O. Gutman, Mattias Nordin, Xiaoming Hu and Anders Lindquist, in cooperation with Johann Galić (ABB Industrial Systems AB, Västerås.

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK) and 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. Some of the hitherto achieved results are:

- New models for backlash and gear play has been developed, verified by measurements and simulation in an industrial environment.
- Systematic design methods, based partly on the Horowitz robust design methodology and the describing function method, has been and are being developed for uncertain systems including hard nonlinearities, such as friction and backlash.
- Methods to identify the backlash gap has been developed.
- Methods were developed to compute value sets for uncertain transfer functions.
- Tuning rules for PI and PID controllers, have been developed for resonant systems.

Robust quality control for paper manufacturing

Researchers: P. O. Gutman, in cooperation with Bo Wahlberg, Torsten Bohlin, Alf Isaksson, and Jens Pettersson (Division of Automatic Control, KTH), and with Bengt Nilsson (Assi-Domän Frövifors Bruk AB, Frövi).

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK) through its REGINA program, and Assi-Domän Frövifors Bruk AB.

The aim of the project is to find dynamic models of a paper board machine, connecting variables that are manipulated by the operators with central laboratory measured quality variables, such as bending stiffness and surface coarseness, in order to to predict the quality variables on-line. The predictors will be used as an operator aid, as an optimization tool, and possibly in automatic quality control. To reach the aim, several difficult theoretical and methodological problems are addressed, such as handling missing data and outliers, the time variability of the process and other process changes, the influence of the unmeasurable variability of the raw material, etc. The industrial process on which this program is conducted is the paper board manufacturing machine at Assi-Domän Frövifors Bruk AB, Frövi.

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, L. Faybusovich (Univ. of Notre Dame) R. Frezza (Univ. of Padova) and C.F. Martin (Texas Tech. Univ.).

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

This project is devoted to several key issues arising from navigation and motion control of an autonomous vehicle, which are also important in their own right, to nonlinear control, robust control and nonlinear programming. The following topics are studied.

1.We study the problem of pathing planning. The problem of finding a feasible trajectory and generating the corresponding control action for nonlinear dynamical control systems, even without a drift vector field, is in general difficult. In some application fields, such as mobile robotics, fast and efficient algorithms are required and one has to sometimes sacrifice optimality in order to follow a reasonable path in

an efficient way. In this methodology, spline functions are very useful in generating a path.
2. we study navigation and motion control algorithms for nonlinear control systems because many autonomous system models are nonlinear. The key issue here is robustness. It is a robustness problem because of large variations in the vehicle mass and velocity and the force generation mechanism, and because of disturbances and noises in the output measurements. We also study the related problem of global stabilization of nonlinear systems.
3. Planning an optimal path for systems with kinematic constraints such as a car-like robot requires dealing with nonconvex programming. We will study the related issues on nonconvex programming, Hamiltonian structure and control.

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. In [A4] we describe 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 [R11] we present a three-step procedure for identification of time series, based on covariance extension and model reduction. 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 reduction. 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 model reduction is done properly. Some recent results on the dynamics of fast filtering algorithms and their connection to the autocorrelation coefficients or Schur parameters enable us to present a self-contained asymptotic analysis of the maximum entropy model. In particular, it is shown that the high-order mod-

els inherit those poles of the true system which lie outside a disc in the complex plane containing all of the zeros of the true system, while the other poles cluster inside the perimeter of this circle. This property provides a justification for choosing stochastically balanced model reduction rather than deterministic. The former has better statistical properties with variances closer to the Cramér-Rao bounds, as simulations show. The special structure of the maximum-entropy model allows us to develop a balancing procedure which only requires linear algebra. Thus no algebraic Riccati equation needs to be solved. Simulations show that our procedure compares favorably to the subspace methods.

The rational covariance extension problem

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

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

The minimal rational covariance extension problem is a fundamental problem in systems theory, control theory, and signal processing, many aspects of which have remain unsolved for a long time.

In a recent series of papers we formalized the observation that filtering and interpolation induce complementary, or "dual" decompositions of the space of positive real rational functions of degree less than or equal to n. From this basic result about the geometry of the space of positive real functions, we were able to deduce two complementary sets of conclusions about positive rational extensions of a given partial covariance sequence. On the one hand, by viewing a certain fast filtering algorithm as a nonlinear dynamical system defined on this space, we are able to develop estimates on the asymptotic behavior of the Schur parameters of positive rational extensions. On the other hand we were also able to provide a characterization of all positive rational extensions of a given partial covariance sequence. Indeed, motivated by its application to signal processing, speech processing and stochastic realization theory, this characterization is in terms of a complete parameterization using familiar objects from systems theory and proves a conjecture made by Georgiou. However, our basic result also enabled us to analyze the robustness of this parameterization with respect to variations in the problem data.

In [A2] we describe this parameterization in terms of a nonstandard matrix Riccati equation, which we call the Covariance Extension Equation. We also compute the dimension of partial stochastic realizations in terms of the rank of the unique positive semi-definite solution to the Covariance Extension Equation, yielding some insights into the structure of solutions to the minimal partial stochastic realization problem. By combining this parameterization with some of the classical approaches in partial realization theory, we are able to derive new existence and robustness results concerning the degrees of minimal stochastic partial realizations. As a corollary to these results, we note that, in sharp contrast with the deterministic case, there is no generic value of the degree of a minimal stochastic realization of partial covariance sequences of fixed length.

In [A3] we present a convex optimization problem for solving the rational covariance extension problem. Given a partial covariance sequence and the desired zeros of the modeling filter, the poles are uniquely determined from the the minimum of the corresponding optimization problem. In this way we obtain an algorithm

for the covariance extension problem, as well as a constructive proof of Georgiou's conjecture.

In [R2] we apply these principles to the design of cetain ARMA filters. Because these filters can be realized in lattice-ladder form, and because one can prescribe the "notches" in the power spectrum of the ARMA model, these filters are referred to as "lattice-ladder notch" filters, or LLN filters. It is shown that LLN filters are the most general class of modeling filters of degree at most n, which shape white noise into a process with the observed covariance data. Moreover, in terms of entropy integrals, we sketch a derivation of a convex optimization problem, which leads to an effective computation of the parameters in the lattice-ladder filter realization of the general ARMA model of the finite data. These techniques are then applied to design explicit LLN filters for speech processing.

3 Education

3.1 Undergraduate courses

Number	Course name	Instructor	Credit
5B1712	Optimization for F *(Optimeringslära för F)*	K. Svanberg	4 p
5B1722	Applied Optimization for T and M *(Tillämpad optimeringslära för T och M)*	C. Trygger	4 p
5B1742	Mathematical Systems Theory *(Matematisk systemteori)*	C. Trygger	4 p
5B1750	Optimization for E and D *(Optimeringslära för E och D)*	C. Trygger	4 p
5B1810	Mathematical Programming *(Matematisk programmering)*	A. Forsgren	5 p
5B1822	Advanced Course in Mathematical Systems Theory *(Matematisk systemteori, fortsättningskurs)*	A. Lindquist/ P. Enqvist	4 p
5B1832	Systems Engineering *(Systemteknik)*	U. Brännlund/ C. Trygger	8 p
5B1842	Methods of Systems Engineering *(Systemtekniska metoder)*	C. Trygger	4 p
5B1846	Applied Systems Engineering *(Tillämpad systemteknik)*	U. Brännlund/ K. Svanberg	4 p
5B1852	Mathematical Economics *(Matematisk ekonomi)*	U. Brännlund	4 p
5B1862	Stochastic calculus and the theory of capital markets *(Stokastisk kalkyl och kapitalmarknadsteori)*	T. Björk	5 p
5B1872	Optimal Control Theory *(Optimal styrteori)*	C. Trygger	4 p
5B1890	Optimization Modeling *(Optimeringsmodellering)*	U. Brännlund/ A. Forsgren	4 p

3.2 Graduate courses

Number	Course name	Instructor	Credit
5B5720	Convexity and Optimization in Linear Spaces	K. Svanberg	5 p
5B5770	Nonlinear System Analysis	X. Hu	5 p

3.3 Doctoral theses

[T1] J. Marí, *Rational modeling of time series and applications of geometric control*, TRITA-MAT-98-OS04, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1998. Advisor: A. Lindquist.

[T2] A. Nõu, *Large-scale combinatorial optimization with transportation science applications*, TRITA-MAT-98-OS15, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1997. Advisor: P. O. Lindberg.

3.4 Licentiate thesis

[T3] A. Dahlén, *What is wrong with subspace identification of time series, and what can be done instead?*, TRITA-MAT-98-OS05, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1998. Advisor: A. Lindquist.

3.5 Master theses (Examensarbeten)

[T4] M. Adenfelt (T) and G. Spalding (T), *Reparationsnivåbestämning med samtidig reservmaterieloptimering.* Advisor: U. Brännlund. Performed at FMV.

[T5] J. Björklund (T) and R. Carlens (T), *Dynamic spares management.* Advisor: K. Svanberg. Performed at Systecon.

[T6] A. Claesson (T), *Analysis of ground time for simulation of aircraft rotations.* Advisor: A. Forsgren. Performed at SAS.

[T7] M. Edenhammar (T), *Optimal control of a tandem production system with demand and cost fluctuations.* Advisor: C. Trygger. Performed at University of Florida.

[T8] A. Eriksson (F), *Performance of a telecommunications system using trunk reservation.* Advisor: A. Forsgren. Performed at Ericson Telecom AB.

[T9] S. Ericson (T), *A global optimization heuristic for the maximum clique problem.* Advisor: A. Forsgren. Performed at University of Florida.

[T10] A. Gratte (F), *Pricing country spreads and Kalman filtering techniques.* Advisor: T. Björk. Performed at Erik Penser Fondkommission.

[T11] A. Hiller (F), *Data envelopment analysis of effects of sales training.* Advisor: A. Forsgren. Performed at SAS.

[T12] A. Hörnedal (T), *Var är flaskhalsarna?.* Advisor: C. Trygger. Performed at FMV.

[T13] J. Larsson (F), *Statistical analysis of block time in aircraft scheduling.* Advisor: A. Forsgren. Performed at SAS.

[T14] C. Lundell (M), *A dynamic network model for minimizing the exposure dose in emergency evacuations.* Advisor: K. Svanberg. Performed at University of Florida.

[T15] A. Martin-Löf (F), *Credit risk.* Advisor: T. Björk. Performed at Skandia Investment Management.

[T16] J. Paulsson (F), *Heuristic methods for frequency planning in cellular networks.* Advisor: A. Forsgren. Performed at Ericsson Radio Systems AB.

[T17] P. Raicevic (F), *Fiberoptic guided missiles—Optimization of flightpath.* Advisor: C. Trygger. Performed at FOA.

[T18] J. Rappe (T), *An exact parallel algorithm for the maximum clique problem.* Advisor: A. Forsgren. Performed at University of Florida.

[T19] P. Sarv (F), *A branch and bound approach to solving concave quadratic problems.* Advisor: U. Brännlund. Performed at University of Florida.

[T20] K. Sigurd (F), *Rules of thumb: A control theoretic model of the human thumb and forefinger.* Advisor: A. Lindquist. Performed at Texas Tech.

[T21] A. Smith (F), *Stochastic programming applied to hydro power planning with random inflow.* Advisor: S. Feltenmark. Performed at Vattenfall AB.

[T22] M. Stolpe (T), *Algorithms for convex multiquadratic programming.* Advisor: U. Brännlund. Performed at University of Florida.

[T23] C. Wallmark (T), *Optimering av gasturbinbaserat drivsystem för hybridbussar.* Advisor: K. Svanberg. Performed at Elkraftcentrum, KTH.

[T24] K. Östlund (T), *Lot streaming in a stochastic environment.* Advisor: U. Brännlund. Performed at University of Florida.

4 Publications

4.1 Papers in journals and books (published and accepted)

[A1] U. Brännlund, P. O. Lindberg, A. Nõu and J.-E. Nilsson, *Railway timetabling using Lagrangian relaxation*, Accepted for publication in Transportation Science.

[A2] C. I. Byrnes and A. Lindquist, *On the partial stochastic realization problem*, IEEE Transactions on Automatic Control, AC-42 (August, 1997), 1049–1069.

[A3] C. I. Byrnes, S. V. Gusev and A. Lindquist, *A convex optimization approach to the rational covariance extension problem*, SIAM J. Control and Optimization, to be published.

[A4] A. Dahlén, A. Lindquist and J. Marí, *Experimental evidence showing that stochastic subspace identification methods may fail*, Systems & Control Letters, to be published.

[A5] M. Egerstedt and C. F. Martin, *A control theoretic model of the combined planar motion of the human head and eye*, Journal of Applied Mathematics and Computation, (90) 61-95, 1998.

[A6] M. Egerstedt and C. F. Martin, *A control theoretic model of the muscular actions in human head-eye coordination*, Journal of Mathematical Systems, Estimation, and Control, Vol 8, No 2, 1998.

[A7] A. Forsgren and P. E. Gill, *Primal-dual interior methods for nonconvex nonlinear programming*, To appear in SIAM Journal on Optimization.

[A8] P.-O. Gutman and B. Nilsson, *Modelling and prediction of bending stiffness for paper board manufacturing*, Journal of Process Control, 1998 (in press).

[A9] X. Hu, *Global nonlinear feedback stabilization and nonpeaking conditions*, To appear in Automatica.

[A10] X. Hu and C. Martin, *Linear reachability versus global stabilization*, To appear in IEEE Trans. Auto. Control.

[A11] A. Lindquist and V. A. Yakubovich, *Universal controllers for optimal damping of forced oscillations in linear discrete systems*, Doklady Mathematics, vol. 88, N 1, 1997, pp. 156–159.

[A12] A. Lindquist and V. A. Yakubovich, *Universal regulators for optimal tracking in linear discrete systems*, Dokl. Akad. Nauk, vol. 361, N 2, 1998 (in Russian).

[A13] A. Lindquist and V. A. Yakubovich, *Universal regulators for optimal tracking in discrete-time systems affected by harmonic disturbances*, IEEE Transactions on Automatic Control, to be published.

[A14] R. Linker, I. Seginer and P.-O. Gutman, *Optimal CO_2-control in a greenhouse modeled with neural networks*, Computers and Electronics in Agriculture, 1998.

[A15] A. Matveev, X. Hu, R. Frezza and H. Rehbinder, *Observers for systems with implicit output*, To appear in IEEE Transactions on Automatic Control.

[A16] H. Rotstein, N. Galperin, P.-O. Gutman, *Set membership approach for reducing value sets in the frequency domain*, IEEE Transactions on Automatic Control, September 1998.

4.2 Papers in conference proceedings (published and accepted)

[C1] C. Altafini and M. Furini, *Robust control of a starch flash dryer plant*, Proceedings of IEEE Conference on Control Applications, pp. 785-788, Hartford CN, October 1997.

[C2] C. Altafini, *The general n-trailer problem: conversion into chained form*, to be presented at CDC'98, Tampa FL.

[C3] C. Altafini and P.-O. Gutman, *Path following with reduced off-tracking for the n-trailer system*, To be presented at CDC'98, Tampa FL.

[C4] M. Egerstedt, X. Hu and A. Stotsky, *Control of a car-like robot using a dynamic model*, Proceedings of the 1998 IEEE Conference on Robotics and Automation, Leuven, Belgium, 1998.

[C5] M. Egerstedt, X. Hu and A. Stotsky, *Control of a car-like robot using a virtual vehicle approach*, Proceedings of the 5th International Advanced Motion Control Workshop, Coimbra, Portugal, 1998.

[C6] S. Feltenmark and P. O. Lindberg, *A finite branch-and-bound method for bilinear hydro power scheduling*, To appear in proceedings of workshop in honor of Prof. Hoang Tuy, Linköping, August 20-22, 1997.

[C7] D. Galardini, M. Nordin and P.-O. Gutman, *Robust PI tuning for an elastic two-mass system*, European Control Conference 1997, Brussels, Belgium, 1-4 July 1997.

[C8] A. Liberzon, D. Rubinstein, P.-O. Gutman, *Active control for a single wheel station of a track vehicle*, 27th Israel Conference on Mechanical Engineering, Technion, Haifa, May 9-10 1997.

[C9] A. Lindquist and Gy. Michaletzky, *Output-induced subspaces, invariant directions and interpolation in linear discrete-time stochastic systems*, Proc. 36th IEEE Conf. Decision and Control, San Diego, CA, December 1997, pp. 2815-2820.

[C10] R. Linker, P.-O. Gutman and I. Seginer, *Simultaneous control of temperature and CO_2 concentration in greenhouses*, IFAC/ISHS International workshop on mathematical and control applications in agriculture and horticulture, Hannover, Germany, 28 Sept. - 2 Oct. 1997.

[C11] R. Linker, I. Seginer and P.-O. Gutman, *Neural networks for failure detection and identification in greenhouses*, IFAC-CAEA'98 Control applications in ergonomics and agriculture, Athens, Greece, 14-17 June, 1998.

[C12] J. Marí, *System Identification via High-Order Autoregressive Model*, Proceedings Nordic Matlab Conference '97, pp. II103-II10.

[C13] J. Marí and J. P. Axelsson, *Stability issues in Fedbatch Fermentation*, Proc. 5th DYCOPS Congress, June 8-10, 1998, pp. 638-643.

[C14] J. Marí and P. Enqvist, *Controller design for an unstable non-minimum phase aircraft*, Preprints Reglermöte 98, pp. 23-27.

[C15] A. Matveev, X. Hu and R. Frezza, *Observers for systems with implicit output*, Proceedings of IEEE 5th Med. Control Conference, Paphos, Cyprus, July, 1997.

[C16] R. Nagamune and S. Yamamoto, *Model set validation and update for time-varying SISO systems*, 1998 American Control Conference, 2361-2365.

[C17] J. Pettersson, T. Bohlin, P.-O. Gutman and B. Nilsson, *A grey box bending stiffness model for paper board manufacturing*, IEEE Conference on Control Applications, Hartford, U.S.A., October, 1997.

[C18] H. Rotstein, N. Galperin, P.-O. Gutman, *Set membership approach for reducing value sets in the frequency domain*, International symposium on Quantitative Feedback Theory and other frequency domain methods and applications, University of Strathclyde, Glasgow, Scotland, 21-22 Aug. 1997.

[C19] A. Stotsky and X. Hu, *Control of car-like robots using sliding observers for steering angle estimation*, Proceedings of 1997 CDC, San Diego, USA, December, 1997.

[C20] A. Stotsky and X. Hu, *Stability analysis of robustly decoupled car steering system with nonlinear tire model*, Proceedings of 1997 CDC, San Diego, USA, December, 1997.

4.3 Other publication

[O1] U. Brännlund, *Transportplaneringsproblemet och andra optimeringsproblem*, Bidrag till kompendiet Introduktion till Farkostteknik, TRITA-FKT Kompendium 1998:25.

4.4 Technical reports and preprints

[R1] U. Brännlund and K. Svanberg, *Optimization of truss topology by a primal-dual method*, Report TRITA-MAT-1997-OS16, Department of Mathematics, KTH, 1997. Submitted for publication.

[R2] C. I. Byrnes, P. Enqvist and A. Lindquist, *Lattice-ladder-notch-filter design: An enhancement of linear predictive coding*, Submitted for publication.

[R3] C. I. Byrnes, X. Hu and C. F. Martin, *Stability and square integrability*, Submitted to Systems and Control Letters.

[R4] 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*, Submitted for publication.

[R5] S. Feltenmark and K. C. Kiwiel, *Dual applications of proximal bundle methods including Lagrangian relaxation of nonconvex problems*, Report TRITA-MAT-1998-OS1, Department of Mathematics, Royal Institute of Technology, 1998. Submitted to SIAM Journal on Optimization.

[R6] A. Forsgren, *A note on maximum-smoothness approximation of forward interest rate*, Report TRITA-MAT-1998-OS3, Department of Mathematics, KTH, 1998.

[R7] A. Forsgren, *Optimality conditions for nonconvex semidefinite programming*, Report TRITA-MAT-1998-OS6, Department of Mathematics, KTH, 1998.

[R8] X. Hu, C. Martin and V. Shubov, *Input tracking for stable linear systems*, Preprint.

[R9] K. C. Kiwiel, P. O. Lindberg and A. Nõu, *Bregman proximal relaxation of large-scale 0–1 problems*, Report TRITA/MAT-97-OS18, Department of Mathematics, KTH, 1997, Submitted for publication.

[R10] P. O. Lindberg and A. Nõu, *A combined probabilistic and differentiable dual approach to large-scale binary optimization problems*, Report TRITA/MAT-97-OS13, Department of Mathematics, KTH, 1997.

[R11] J. Mari, A. Dahlén and A. Lindquist, *A covariance extension approach to identification of time series*, Submitted to Automatica.

[R12] A. Nõu, *Railway timetabling - Lagrangian heuristics*, Report TRITA/MAT-97-OS12, Department of Mathematics, KTH, 1997.

5 Seminars at the division

Aug. 14, 1997 Prof Panos M. Pardalos, Center for Applied Optimization, ISE Department, University of Florida, Gainesville, USA. *Global Optimization Approaches for the Maximum Clique Problem on General Graphs.*

Aug. 15, 1997 Prof Panos M. Pardalos, Center for Applied Optimization, ISE Department, University of Florida, Gainesville, USA. *Recent Approaches for Solving Quadratic Assignment Problems.*

Aug. 22, 1997 Professor Leonid Faybusovich, Department of Mathematics, University of Notredame, USA. *Jordan-Algebraic Generalization of the Projective Method.*

Sep. 12, 1997 Andreas Nõu, Optimeringslära och Systemteori, Matematiska Institutionen, KTH. *Large-Scale Combinatorial Optimization with Transportation Science Applications.*

Oct. 10, 1997 Professor Krzysztof C. Kiwiel, Systems Research Institute, Polish Academy of Sciences. *Ballstep Subgradient Level Methods for Convex Optimization.*

Oct. 17, 1997 Docent Tomas Björk, Inst. för Finansiell Ekonomi, Handelshögskolan i Stockholm. *Minimal Realizations of forward Rates.*

Oct. 24, 1997 Professor Vladimir A. Yakubovich, St. Petersburg State University, Russia. *Abstract Theory of Optimal Control.*

Nov. 14, 1997 Dr. Brett Ninness, Department of Electrical and Computer Engineering, Centre for Integrated Dynamics and Control (CIDAC) University of Newcastle, Australia. *Generalised Fourier and Toeplitz Results for Rational Orthonormal Bases.*

Nov. 21, 1997 Dr. Andrea Gombani, LADSEB-CNR, Padova, Italy. *On a Hardy Space Approach to the Analysis of Spectral Factors.*

Nov. 28, 1997 Docent Michael Patriksson, Matematiska Institutionen, Chalmers Tekniska Högskola, Göteborg. *Adaptive Sequential Quadratic Programming (SQP) Algorithms for Non-strictly Monotone Variational Inequality Problems.*

Dec. 11, 1997 Dr. Ilya Ioslovich, Faculty of Agricultural Engineering, Technion, Haifa, Israel. *Optimal Control of Rigid Body Reorientation: Closed Form Solution and ¡¡synthesis.*

Jan. 30, 1998 Professor Ioannis Kanellakopoulos, Department of Electrical Engineering, University of California, Los Angeles, USA. *Nonlinear and Adaptive Control for Advanced Vehicles.*

Feb. 6, 1998 Dr. Håkan Ekblom, Department of Mathematics, Luleå University of Technology. *Algorithms for M-Estimates.*

Mar. 13, 1998 Yssa DeWoody, Department of Mathematics, Texas Tech. University, Lubbock, USA. *A Direct Approach Utilizing Musculoskeletal Dynamics and Neuromuscular Control to Determine Stress Development in Bone.*

Mar. 20, 1998 Jöran Petersson, Mälardalen University. *How to Find Initial Values for the Least Squares Problem when Estimating Parameters in Exponential Sums?.*

Apr. 3, 1998 Professor Kurt Jörnsten, Norwegian Institute of Economics and Business Administration, Bergen, Norway (Visiting professor at Stockholm School of Economics, spring 1998. *Optimal Relinquishment According to the Norwegian Petroleum Law: A Combinatorial Optimization Approach.*

May 8, 1998 Jorge Marí, Optimeringslära och Systemteori, Matematiska Institutionen, KTH. *Rational Modeling of Time Series and Applications of Geometric Control.*

May 15, 1998 Professor Ji-Guang Sun, Department of Computing Science, Umeå University. *Perturbation Theory for Algebraic Riccati Equations.*

May 18, 1998 Professor Jan C. Willems, Mathematics Institute, University of Groningen. *A Behavioral Approach to Robust Control.*

May 29, 1998 Anders Dahlén, Optimeringslära och Systemteori, KTH. *What is wrong with Subspace Identification of Time Series, and what can be done instead?*

Jun. 9, 1998 Professor Clyde F. Martin, Department of Mathematics, Texas Tech. University, Lubbock, USA. *Trajectory Planning and Smoothing Splines.*

Jun. 16, 1998 Mattias Nordin, Optimeringslära och Systemteori, Matematiska Institutionen, KTH. *Switching Controllers for Elastic Systems with Backlash.*

6 Awards and appointments

Anders Lindquist was elected a Foreign Member of the Russian Academy of Natural Sciences.

7 Presentations by staff

[P1] U. Brännlund, *Semidefinite programming formulations and an interior point method for truss topology design*, 16th International Symposium on Mathematical Programming, Lausanne, Switzerland, August 24-29, 1997.

[P2] A. Dahlén, *Why stochastic subspace identification methods may fail*, European Research Network for Systems Identification meeting, Stockholm, September 15-17, 1997.

[P3] A. Dahlén, *Experimental evidence showing that stochastic subspace identification methods may fail*, Reglermöte '98, Lund, June 11-12, 1998.

[P4] M. Egerstedt, *Path planning and robust tracking for a car-like robot*, 5th Symposium on Intelligent Robotic Systems, Stockholm, Sweden, Jun. 1997.

[P5] M. Egerstedt, *Control of the planar rotation in human head-eye coordination*, 5th IEEE Mediterranean Conference on Control and Systems, Paphos, Cyprus, Jul. 1997.

[P6] M. Egerstedt, *Control of a car-like robot using a dynamic model*, IEEE Conference on Robotics and Automation, Leuven, Belgium, May 1998.

[P7] P. Enqvist and J. Marí, *Controller design for an unstable non-minimum phase aircraft*, Reglermöte '98, Lund, June 11-12, 1998.

[P8] P. Enqvist, *Solving the rational covariance extension problem*, 8th Stockholm Optimization Days, KTH, Stockholm, Sweden, June 25, 1998.

[P9] S. Feltenmark, *Solving the unit commitment problem*, 8th Stockholm Optimization Days, KTH, Stockholm, Sweden, June 26, 1997.

[P10] A. Forsgren, *Primal-dual interior methods for nonconvex nonlinear programming*, EURO XV/INFORMS XXXIV Joint International Conference, Barcelona, Spain, July 14–17, 1997.

[P11] A. Forsgren, *Inertia-controlling primal-dual interior methods for nonconvex nonlinear programming*, The 16th International Symposium on Mathematical Programming, Lausanne, Switzerland, August 24–29, 1997.

[P12] A. Forsgren, *Optimality conditions for nonconvex semidefinite programming*, The 8th Stockholm Optimization Days, Stockholm, Sweden, June 25–26, 1998.

[P13] C. Landén, *Bond pricing in a regime-switching short rate model*, 4th Nordic Symposium on Contingent Claims in Finance and Insurance, Copenhagen, Denmark, May 22-23, 1998.

[P14] A. Lindquist, *Stochastic realization theory*, Two-hour Tutorial Lecture at 11th IFAC Symposium on System Identification, Fukuoka, Japan, July 8–11,1997.

[P15] A. Lindquist, *On duality between filtering and interpolation*, University of Tokyo, Japan, July 14,1997.

[P16] A. Lindquist, *On the covariance extension problem*, 5th IEEE Mediterranean Conference on Control and Systems, Cyprus, July 21–23, 1997.

[P17] A. Lindquist, *Universal regulators for optimal damping and tracking in discrete-time systems with harmonic external disturbances*, Plenary lecture at International Conference on Control of Oscillations and Chaos, St. Petersburg, Russia, August 27–29, 1997.

[P18] A. Lindquist, *Recent progress on the partial stochastic realization problem*, Plenary lecture at Operators, Systems, and Linear Algebra: Three Decades of Algebraic Systems Theory, workshop in honor of Paul A. Fuhrmann on his 60th birthday, Kaiserslautern, Germany, September 24–26, 1997.

[P19] A. Lindquist, *Why subspace identification algorithms sometimes don't work and what we can do instead*, Washington University, St. Louis, March 10, 1998.

[P20] A. Lindquist, *What is Optimization and Systems Theory, and what are we doing at KTH?*, Physics Colloquium, KTH, April 3, 1998.

[P21] A. Lindquist, *Covariance extension and speech processing*, Third Russian-Swedish Control Conference, Stockholm, May 12, 1998.

[P22] R. Nagamune, *Identification, validation and update of the smallest transfer function set with parametric uncertainties*, ERNSI workshop, KTH, Stockholm, Sweden, September, 1997.

[P23] R. Nagamune, *Model set validation and update for time-varying SISO systems*, American Control Conference in Philadelphia, USA, June 24-26, 1998.

[P24] A. Nõu, *Railway Timetabling using Lagrangian relaxation*, 16th International Symposium on Mathematical Programming, Lausanne, Switzerland, August 24-29, 1997.

[P25] A. Nõu, *Railway timetabling on Networks*, CORS/INFORMS Mon tréal - Spring 1998, Montréal, Canada, April 26-29, 1998.

[P26] K. Svanberg, *Optimization of truss topology by a primal-dual method*, ISMP97 in Lausanne, August 1997.

[P27] K. Svanberg, *The Method of Moving Asymptotes – Modelling aspects and solution schemes*, Invited lectures for the graduate course Advanced Topics in Structural Optimization, DTH, Lyngby, Denmark, June 1998.

8 Workshop and conferences

8.1 1997 ERNSI Workshop System Identification

The European Research Network on System Identification (ERNSI) is a TMR network project, funded by the European Union, with nine research teams from seven European countries. The 1997 ERNSI Workshop on System Identification was held at KTH, September 8-10, 1997, and was organized by Anders Lindquist, Lennart Ljung and Jan van Schuppen. The aim of the workshop was to bring together researchers from ERNSI so as to discuss current research developments in system identification. The scientific program was divided into sessions, each devoted to a particular topic, consisting of a tutorial lecture followed by shorter lectures. Each session was concluded by a discussion of the topic.

List of the sessions and presentations:

System identification and signal processing, Anders Lindquist, KTH (Chair)
P. Stoica, Uppsala University, *Spectral estimation and radar imaging.*
J.J. Fuchs, Institut de Recherche en Informatique et Systèmes Aléatoires, France, *Joint detection and estimation of superimposed signals in noise.*
F. Gustafsson, Linköping University, *Identification in signal processing applications.*

System identification with grey boxes, Lennart Ljung, Linköping University (Chair)
T. Bohlin, KTH, *Grey box identification.*
A. Stenman, Linköping University, *Non-parametric dynamics models—Just in time.*

System identification with nonlinear systems, Jan van Schuppen, Centrum voor Wiskunde en Informatica, The Netherlands (Chair)
L. Baratchart, INRIA, France, *System identification with nonlinear systems.*
Wouter Favoreel, Université Catholique de Louvain, Belgium, *Subspace identification of bilinear systems.*
Monika Dörfler, Technische Universität Wien, Austria, *Identification of recurrent (dynamic) recurrent nets.*
Cathrien De Cock, Université Catholique de Louvain, Belgium, *Stochastic system identification for ATM network traffic models.*

System Identification of linear systems: Subspace and frequency domain, Lennart Ljung, Linköping University (Chair)
T. McKelvey, Linköping University, *Subspace and/or frequency domain.*
A. Dahlén, KTH, *Experimental evidence showing that subspace identification may fail.*
J. Marí, KTH, *Some alternatives to subspace identification which guarantee positivity.*
D. Bauer, Technische Universität Wien, Austria, *Asymptotic distributions in subspace algorithms.*
N. Chui, University of Cambridge, United Kingdom, *An alternate subspace identification algorithm.*

Various topics of system identification, Anders Lindquist, KTH (Chair)
T. Söderström, Uppsala University, *Identifying continuous-time processes using delta operators.*
A. Gombani, Instituto di Sistemistica e Bioingegneria, Consiglio Nazionale delle Richerche, Italy, *A new parametrization of rational inner functions of fixed degree:*

Schur parametrizations and realizations.
P.-O. Gutman, KTH, *A membership approach for robust non-parametric identification.*
R. Nagamune, KTH, *Identification, validation and update of the smallest transfer function set with parametric uncertainties.*

8.2 The Russian-Swedish Control Conference

The Russian-Swedish Control Conference was held at KTH, May 10-13 1998. It is a small workshop with invited speakers organized every third year with the purpose of stimulating contacts between researchers active in the areas of systems and control in Russia and Sweden. This year it was organized on the Swedish side by Anders Lindquist (KTH) and Lennart Ljung (Linköping University) and on the Russian side by Alexander L. Fradkov (St. Petersburg State Technical University). The workshop was financially supported by KTH and by Linköping University. The scope on the conference includes all the aspects of systems and control ranging from fundamental research to engineering applications. List of the presentations:

V.A. Yakubovich, St. Petersburg State, University, Russia, *Quadratic criterion of absolute stability.*

Karl Johan Åström, Lund University, *Singularities in a system with switching.*

F.L. Chernousko, Institute for Problems in Mechanics, Moscow, Russia, *Ellipsoidal bounds on attainable sets.*

A. B. Kurzhanskii, Moscow State University, Russia, *The optimality principle under incomplete information.*

T. Söderström, Uppsala University, *Some approaches on how to use yhe delta operator when identifying continuous-time processes.*

A. A. Pervozvanskii, St. Petersburg State Technical University, Russia, *Stability of nonlinear systems with quasilogic control.*

A. L. Fradkov, St. Petersburg State Technical University, *What can be done by a small control?*

T. Glad, Linköping University, *Moving between the equilibria of a nonlinear system.*

A. S. Matveev, St. Petersburg State University, Russia, *Towards a qualitative theory of hybrid dynamical systems.*

G. A. Leonov, St. Petersburg State University, Russia, *Stability and oscillations of pendulum-like feedback systems.*

B. Bernhardsson, Lund University, *Some real-time control problems.*

S. V. Gusev, St. Petersburg State University, Russia, *Sampled-data control of uncertain mechanical systems.*

B. T. Polyak, Institute of Control Sciences, Moscow, Russia, H^∞ *optimization via low-order controllers.*

A. Isaksson, KTH, *Identifiability of processes subject to missing data.*

A. Pogromskii, Linköping University, *On destabilization of dynamical systems via diffusive coupling.*

A. Lindquist, KTH, *Covariance extension and speech processing.*

N. Barabanov, St. Petersburg Electrotechnical University, *On the static* H^∞ *control problem.*

A. Rantzer, Lund University, *Harmonic oscillations in nonlinear and uncertain systems.*

L. Ljung, Linköping University, *Closed-loop identification revisited.*

A. V. Krazhimskii, Moscow State University, Russia, *Constraint aggregation technique for convex optimal control problems with state constraints.*

A. Medvedev, Lule University of Technology, *On robust stability of two flux observers for induction machines.*

V. N. Bukov, Department of the Zhukovsky Military Air-Force Engineering Academy, Russia, *The algebraic theory of systems: An enclosure's method.*

H. Hjalmarsson, KTH, *Iterative feedback tuning.*

D. Rockityanskii, Institute of Problems in Mechanics, Moscow, Russia, *State estimation in linear systems with perturbed matrices.*

A. S. Shiriaev, Norwegian University of Science and Technology, Norway, *Detectability of invariant set of nonlinear system with stable dynamics.*

K. Nordström, Uppsala University, *On the multi-input pole placement control problem.*

G. Kronin, St. Petersburg State University, Russia, *Optimal regulators for the control problem with non-quadratic quality functional.*

N. Yu. Lukoyanov, Institute of Mathematics and Mechanics, Russia, *Optimal regulators for the control.*

8.3 8th Stockholm Optimization Days

The 8th Stockholm Optimization Days were held at KTH in Stockholm, June 25–26, 1998. The format was similar to the previous years with approximately 60 participants, coming from many different countries. The conference was financially supported by the Göran Gustafsson Foundation. The organizing committee consisted of U. Brännlund, S. Feltenmark, A. Forsgren (head), A. Nõu and K. Svanberg.

In total 27 talks were given, among them 13 invited presentations. The following is a list of presentations, where the speakers' names are given in boldface:

Francisco Barahona* and Ranga Anbil, IBM T. J. Watson Research Center, Yorktown Heights, New York, USA, *The volume algorithm: producing primal solutions with a subgradient method.*

John T. Betts*, Boeing Information and Support Services, Seattle, Washington, USA, *Very low thrust trajectory optimization.*

Luise Blank, RWTH Aachen, Aachen, Germany, *State estimation using wavelet techniques.*

Dan Borglund, Royal Institute of Technology, Stockholm, Sweden, *Integrated design optimization of a beam subject to fluid-dynamic forces.*

Marcos Augusto dos Santos, Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil and Paulo Roberto Oliveira, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil, *Interior-point algorithms for decomposition of Dantzig-Wolfe.*

Per Enqvist, Royal Institute of Technology, Stockholm, Sweden, *Solving the covariance extension problem.*

*Invited speaker.

Stefan Feltenmark, Royal Institute of Technology, Stockholm, Sweden, *Solving the unit commitment problem.*

Roger Fletcher*, University of Dundee, Dundee, United Kingdom, *Filter methods for nonlinear programming.*

Anders Forsgren, Royal Institute of Technology, Stockholm, Sweden, *Optimality conditions for nonconvex semidefinite programming.*

Pedro Freitas, Instituto Superior Tecnico, Lisbon, Portugal and Peter Lancaster, University of Calgary, Calgary, Canada, *Optimal decay of energy for a system of linear oscillators.*

Philip E. Gill*, University of California, San Diego, La Jolla, California, USA, *An SQP method for the optimal control of large-scale dynamical systems.*

Kenneth Holmström, Mälardalen University, Västerås, Sweden, *Using MATLAB in the development of optimization algorithms and software.*

Krzysztof C. Kiwiel*, Systems Research Institute, Warsaw, Poland, *The efficiency of proximal bundle methods.*

Martin Alvehus and **Per Olov Lindberg**, Linköping University, Linköping, Sweden, *Production scheduling by Lagrangean relaxation.*

Jorge Marí, Royal Institute of Technology, Stockholm, Sweden, *User experience in solving some less common LMIs arising in problems of systems identification and control.*

William Behrman and **Walter Murray***, Stanford University, Stanford, California, USA, *A gradient flow method for unconstrained optimization.*

Erik Boman and **Walter Murray***, Stanford University, Stanford, California, USA, *Computing a good direction of negative curvature.*

Jose Niño-Mora, Universitat Pompeu Fabra, Barcelona, Spain, *On the throughput-WIP trade-off in queueing systems, diminishing returns and the threshold property: a linear programming approach.*

Madhu Nayakkankuppam and **Michael L. Overton***, New York University, New York, New York, USA, *Degeneracy and conditioning of semidefinite programs.*

Kenneth Holmström and **Jöran Petersson**, Mälardalen University, Västerås, Sweden, *Initial values for two classes of exponential sum least squares fitting problems.*

Francisco J. Prieto*, Universidad Carlos III de Madrid, Madrid, Spain, *Optimisation problems for deregulated electricity generation.*

Michael Saunders*, Stanford University, Stanford, California, USA, *Computing search directions in barrier methods for optimization.*

John Dennis, Rice University, Houston, Texas, USA and **Trond Steihaug**, University of Bergen, Bergen, Norway, *Weighted linear least squares problems and parallel computing.*

Tibor Illés, Jiming Peng, Cornelis Roos and **Tamás Terlaky***, Delft University of Technology, Delft, The Netherlands, *A strongly polynomial rounding procedure yielding a maximally complementary solution for $P_*(\kappa)$ linear complementarity problems.*

Lieven Vandenberghe*, University of California, Los Angeles, Los Angeles,

*Invited speaker.

California, USA, *Second-order cone programming.*

Nina Detlefsen and **Stein W. Wallace***, Norwegian University of Science and Technology, Trondheim, Norway, *Basis structures for multi-commodity networks.*

Mathias Henningsson, Kaj Holmberg, Mikael Näsberg and **Di Yuan**, Linköping University, Linköping, Sweden, *Cost-efficient bandwidth expansion of a cable TV network for interactive broadband services.*

*Invited speaker.

9 Other activities

Claudio Altafini

- Visited Techion-Israel Institute of Technology, Haifa, from October 1997 to February 1998.
- Participated in the 5th Symposium on Intelligent Robotic Systems, Stockholm, July 1997.
- Participated in the 11th Haifa Matrix Theory Conference, December 1997.
- Participated in "Reglermöte 98", Lund, June 1998.
- Refree for Automatica.

Ulf Brännlund

- Referee for SIAM Journal on Optimization and Annals of Operations Research.

Magnus Egerstedt

- Participated in the international workshop on "Hybrid systems: computation and control" in Berkeley, USA, April, 1998.
- Participated in the "Workshop on intelligent unmanned aerial vehicles" in Linköping, Sweden, May, 1998.
- Participated in "Reglermöte 1998" in Lund, Sweden, Jun. 1998.
- Spent 5 months at University of California, Berkeley as a visiting scholar.
- Reviewed an article for the Journal of Mathematical Systems, Estimation, and Control, and one for IEEE Transactions on Automatic Control.

Per Enqvist

- Referee for IEEE Transactions on Automatic Control.
- Participated in the 3rd Russian-Swedish Control Conference in Stockholm, Sweden, May, 1998.
- Participated in the 7th ERNSI Workshop on System Identification in Stockholm, Sweden, September, 1997.

Stefan Feltenmark

- Participated in 16th Symposium on Mathematical Programming, Lausanne, Switzerland, August 24-29, 1997.

Anders Forsgren

- Member of editorial board for *Computation Optimization and Applications*.
- Referee for Mathematical Programming and SIAM Journal on Optimization.

Camilla Landén

- Visited Humboldt Universität, Berlin, Germany, October 15-23, 1997 and May 4-15, 1998.
- Visited Stockholm School of Economics, Stockholm, Sweden, January 19-July 24, 1998.

Anders Lindquist

- Communicating Editor, *Mathematical Systems, Estimation and Control*, journal published by Birkhäuser Boston.
- Member Editorial Board, *Adaptive Control and Signal Processing*, journal published by John Wiley & Sons.
- Associate Editor, *Systems and Control: Foundations and Applications*, book series published by Birkhäuser, Boston.
- Editorial Board, *Applied and Computational Control, Signals, and Circuits*, book series published by Birkhäuser, Boston.
- Referee for several other journals, for STINT and for NATO.

- Vice Chairman, Appointment Committee for School of Engineering Physics (Tjänsteförslagsnmnden), KTH.
- Vice-chair, Department of Mathematics, KTH.
- Member Central Faculty Board ("Centrala fakultetsnämnden), KTH.
- Board Member, Strategic Center for Autonomous Systems, KTH.
- PhD Committee (betygsnämnd), Lund University and KTH (S3 and Geodesy).
- Member of the Committee for IIASA, Systems Analysis and Risk Analysis, FRN (Swedish Council for Planning and Coordination of Research).
- Member of the Evaluation Committee for the Mathematical Sciences, NFR (Natural Science Foundation).
- 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.
- Vice-Chairman, International IFAC Committee on Stochastic Systems.
- Steering Committee, International Symposium on the Mathematical Theory of Networks and Systems (MTNS).
- Member, International IFAC Committee for Mathematics in Control.
- Member, Steering Committee of the ERCIM Working Group on Control and System Theory.
- International Advisory Committee of the 29th ISCIE International Symposium on Stochastic Systems Theory and its Applications, Kyoto, Japan, November 14–16, 1997.
- Chairman, ERNSI Workshop (European Research Network for System Identification), Stockholm, Sweden September 8–10, 1997.
- Program Committee, 1998 International Symposium on the Mathematical Theory of Networks and Systems (MTNS98), Padova, Italy, July 6–10, 1998.
- International Advisory Committee of the 30th ISCIE International Symposium on Stochastic Systems Theory and its Applications, Kyoto, Japan, November 4–6, 1998.

Ryozo Nagamune

- Participated in the Russian-Swedish control conference, KTH, Stockholm, Sweden, May 11-13, 1998.
- Participated in Reglermöte'98 in Lund, Sweden, June 11-12, 1998.

Andreas Nõu

- Opponent at a licentiate thesis defense, Division of Optimization, Department of Mathematics, Linköping University, Sweden, June 10, 1998.
- Organizing committee of 8th Stockholm Optimization Days, Stockholm, Sweden, June 25–26, 1998.

Mikael Prytz

- Spent the academic year 1997/1998 at Stanford University as an M.S. student in Engineering Economic Systems and Operations Research.

Henrik Rehbinder

- Participated in the 7th ERNSI Workshop on System Identification in Stockholm, Sweden, September, 1997.
- Participated in the 3rd Russian-Swedish Control Conference in Stockholm,

Sweden, May, 1998.

- Participated in the "Reglermöte '98" in Lund, Sweden, June 11-12, 1998.

Krister Svanberg

- On the editorial board of Structural Optimization.
- Referee for International Journal for Numerical Methods in Engineering.