Activity Report

1996/1997

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

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 1996/1997 (July 1996 – June 1997).

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

Postdoktorstipendiater (Postdoctoral fellows)

Daniele G. Galardini, PhD (until February 1997)
Alexander Stotsky, PhD

Gästforskare (Visiting professors)

Per-Olof Gutman, docent
Ilya Ioslovich, professor (autumn 1996)
Clyde Martin, professor (spring 1997)
Anna Nagurney, professor (autumn 1996)
Vladimir Yakubovich, professor

Intendent (Administrator)

Leena Druck

Doktorander (Graduate students)

Patrik Alfredsson, civing (graduated (TeknD) June 1997)
Claudio Altafini
Anders Dahlén, FK
Magnus Egerstedt, civing
Per Enqvist, civing
Stefan Feltenmark, civing (graduated (TeknD) April 1997)
Camilla Landén, civing
Jorge Marí, MS, TeknL
Takahiro Matsui (visiting from University of Tokyo 1996/1997)
Mattias Nordin, civing, TeknL
Andreas Nõu, civing
Mikael Prytz, civing
Henrik Rehbinder, civing

1.2 Biographies

Patrik Alfredsson was born in Södertälje, Sweden, in 1967. He received a civilingenjör degree in Engineering Physics from KTH in 1991 and a PhD degree in Optimization and Systems Theory in 1997. His main research interests are systems engineering and systems efficiency, concentrated on spare parts optimization problems. As part of his PhD program, Alfredsson has spent nine months at Virginia Polytechnic Institute and State University during the fall of 1992 and the spring of 1994.

Claudio Altafini was born in Salara, in the nearby of Ferrara, Italy, in 1969. He received a degree ("laurea") in Electronic 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 of Optimization and Systems Theory, affiliated with the Center for Autonomous Systems organized by the Royal Institute of Technology. His main interests are robust control, path planning and navigation for autonomous robots.

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. 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.

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.

Stefan Feltenmark was born in Boden in 1968. He received a civilingenjör degree in Engineering Physics from KTH in 1991 and a PhD degree at the Division of Optimization and Systems Theory in 1997. Main research interests are dual methods for large-scaled problems, particularly applied to short-term power production planning problems.

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.

Daniele G. Galardini was born in Colle di Val d'Elsa, a mediaeval town in the middle of Tuscany, Italy, in 1962. He received the "laurea" in electronic engineering (1989) from the University of Pisa, Italy, the MSc in Robotics (1990) and the PhD in Automatic Control (1993) both from the Université catholique de Louvain, Belgium. From 1989 to 1990 he served as researcher the Italian Research Council and from 1990 to 1995 he was university assistant at the Center for Systems Engineering and Applied Mathematics (Cesame), Universitè catholique the Louvain. During 1994 he has hold positions at the European Commission and at EUROCONTROL. From 1995 to 1997 he was a post-doctoral fellow at KTH.

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, 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 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.

Ilya Ioslovich was born in Moscow, Russia, in 1937. He received his MS in Mechanics from the Faculty of Mechanics and Mathematics, Moscow State University (MSU), in 1960 and the PhD degree in Physics and Mathematics from the Moscow Institute of Physics and Technology (MFTI - PhysTech) in 1967. He served as a senior research engineer at the Moscow Research Institute of Equipment Design in 1960-1965 and he was working at the Institute of Applied Mathematics, Soviet Academy of Sciences, in 1965-1966, as a PhD student. In 1966-1968 he was with the Research Institute of Economics, State Planning Committee, as a research fellow, and in 1968-1972 he held the position of senior research fellow with the Research Institute of Control Systems, Ministry of Defense Industry. In 1972-1976 he was the Head of Laboratory and Head of Department with the Moscow Research Institute of Network Scheduling. Since 1976 he served as a Head of Department with the Research Institute of Control and Automation Systems, Soviet Cooperation (Centrosoyuzsystema). He has awarded two silver medals from All-Union Exhibition for Industrial Achievements, Moscow (1976, 1983). He immigrated to Israel in 1991 and since 1992 he has been with the Technion Research and Development Foundation, the Faculty of Agricultural Engineering, Technion - Israel Institute of Technology. He has more then 50 scientific publications. His research interests include theory of screws and its application to design of spatial mechanisms, optimal control theory and its applications to space research and radio-electronics, linear programming and macroeconomics, neural networks, control of agricultural systems, transportation systems and their optimization. He has visited INRA Bioclimatological Station, Montfavet, France, in 1994, and Division of Optimization and Systems Theory, Department of Mathematics, Royal Institute of Technology (KTH), Stockholm, Sweden in 1996. He is also known as a participant of the "samizdat" journal "Syntaxis" of A. Ginzburg (1960), see the Soviet newspaper "Izvestia", 2.09.1960.

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.

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. From 1975 to 1976 he was a SIAM Visiting Lecturer. 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, and he is an editor of four research volumes.

Lindquist is a member of the Royal Swedish Academy of Engineering Sciences, a Fellow of the IEEE, and an honorary member the Hungarian Operations Research Society. He is 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). He is also on the Advisory Board of the Institute for Mathematics of the Life Sciences, Texas Tech University, Texas, USA.

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. Since june 1996 he has been working in modelling of time series. His main interests include engineering systems, systems identification and control theory applications.

Clyde Martin was born Wichita Kansas, USA in 1943. Clyde F. Martin's research interests include control theory, the applications of algebraic and differential geometry to problems in numerical analysis, and the development and analysis of mathematical models in agriculture and medicine. Among his more significant technical contributions have been the application of algebraic geometry and grassmannian techniques to linear system theory, the introduction of geometric methods into the analysis of the matrix Riccati equation, the geometric analysis of the QR-algorithm and other algorithms for determining eigenvalues of matrices, the systematic development of the theory of observability and the related numerical algorithms, the development of models for the analysis of localized epidemics and endemic diseases and the systematic development of models of human motion. He has collaborated with engineers and scientists in a number of areas including aeronautics, bioengineering, plant science, soil physics, epidemiology and chemical engineering on a variety of scientific topics. In 1983 he was appointed the Ex-Students Association Distinguished Visiting Professor of Mathematics at Texas Tech University, in 1988 he was appointed as the Ex-Students Association Distinguished Professor of Mathematics and in 1991 was appointed as the Paul Whitfield Horn Professor by the Board of Regents of Texas Tech University. He is a member of the American Mathematical Society, Institute of Electrical and Electronic Engineers, Institute of Mathematical Statistics and the Society of Industrial and Applied Mathematics and has served on numerous committees within these organizations. He is a Fellow of the Institute of Electrical and Electronic Engineers. He is a member of the statistics group at Texas Tech University. He has organized or co-organized ten international conferences and has served on the program committee or board of directors of several others. He is vice chair of the SIAG activity group in control theory and has been appointed to the IEEE USAB Health Care Engineering Policy Committee. Professor Martin was a Visiting distinguished Professor at KTH from January 1997–July 1997.

Anna Nagurney is a Professor at the School of Management at the University of Massachusetts at Amherst and also holds an appopintment in the Department of Mechanical and Industrial Engineering there. She received her PhD in Applied Mathematics from Brown University with a specialization in operations research. She has held visiting appointments at MIT, both at the Center for Transportation Studies and at the Sloan School, as well as in the Division of Applied Mathematics at Brown University. She is an Associate Editor of the journals: Operations Research Letters, NETWORKS, Annals of Regional Science, and The International Journal of Supercomputer Applications. She is also a co-editor of the book series, "Advances in Computational Economics." Anna is the author of 3 books and over 50 refereed publications. Her awards include the National Science Foundation Visiting Professorship for Women, the National Science Foundation Faculty Award for Women, as well as the Kempe Prize awarded by the University of Umeå in Sweden.

Her research interests are in variational inequalities and applications to transportation, economics, and finance.

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 was born in Stockholm in 1967. He recieved a civilingenjör degree in Engineering Physics from KTH in 1991. He is presently a PhD studentat the Division of Optimization and Systems Theory. His main research interests are various applications within the transportation sector. Many of the corresponding problems are large-scale combinatorial optimization problems.

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. 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.

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.

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
- Docent 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 University, Russia
- Professor Ruggero Frezza, Dipartimento di Elettronica, Universita di Padova, Padova, Italy
- Johann Galić, Department HUB, Metals Division, ABB Industrial Systems AB, Västerås, Sweden
- 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 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 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 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
- Biomechanical control
- Financial economics
- Hybrid control of autonomous system
- KTH Optimization Laboratory
- Large-scale nonlinear programming
- Linear stochastic systems theory
- Locomotive scheduling
- Optical dynamics
- Optimal damping of forced oscillations in discrete-time systems
- Optimization of power systems
- Optimization of spare parts inventory systems
- Robust control of electrical drives
- Robust feedback control of nonlinear and uncertain systems
- Robust quality control for paper manufacturing
- Robust reduction of large scale linear programming problems
- Some problems in navigation and motion control of nonlinear systems
- Stability analysis
- Stochastic realization theory and identification
- Structural optimization
- Switching systems
- The rational covariance extension problem
- The structure of linear discrete-time stochastic systems
- Trajectory planning

2.2 Description of projects

Advanced optimization methods for crew and vehicle scheduling

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

Sponsor: Swedish Transport and Communications Board (KFB).

This project aims at using advanced dual methods on crew and vehicle scheduling problems. Typically, these problems are solved through Dantzig-Wolfe decomposition. The master problem is solved (usually using an LP-solver) to generate dual multipliers. We are looking at using advanced dual methods in this framework, since the solution of the master problem may be very time consuming.

The problems we have in mind are very large, sparse, set covering problems that arise e.g. in airline crew scheduling. Our computational results are promising.

Allocation of scarce track capacity

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

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 modelling has been done in close cooperation with Jan-Eric Nilsson at the Centre for Research in Transportation and Society at Borlänge. 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 a technical report [R1] has been written and submitted for publication to Transportation Science.

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.

Biomechanical control

Researchers: Clyde Martin, Henrik Rehbinder, Lawrence Schovanec (TTU), Yssa DeWoody(TTU), Karin Sigurd.

Sponsors: TARP(Texas Advanced Research Projects), NASA.

The initial project under this program was the development of models of the lower leg that incorporates the forces generated by the muscles acting on the long bones. The goal of this research is to be able to predict the development of stress fractures in the tibia. This project has proven to be very instructive in that it forced us to consider the mechanics of the muscle as well as the mechanics of the bone. The group involved has become quite knowledgeable about the physiology of the leg and how th bone and muscle interact. The project has been expended to include models of the forearm and of the hand. While the forearm would have seemed to be quite simple in fact it is not. The muscles that control the flexion of the forearm cause rotation as well as flexion and this rotation is countered by other muscles. This leads to significant compilations in the mathematical model. The hand is quite complex and the model is restricted to the thumb and forefinger. However, with the tools that have been developed it is now possible to develop full models in relatively short times. One significant product of this line of research is the need for the development of experiments to determine parameters related to muscle, bone and tendon.

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 two topics in particular. The first is a market where asset prices are driven by a general marked point process as well as by a diffusion term. For the case when the marked point process has a finite mark space we are now able to give sufficient conditions on a parameterized family of simple contingent claims in order for that family to complete the market.

The second topic we have studied is a diffusion type model for the short rate of interest 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 an affine term structure.

Hybrid control of autonomous system

Researchers: Anders Lindquist, Xiaoming Hu, 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 will be 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. An interesting approach to this problem is combining statistical filtering and hypothesis testing techniques to exploit efficiently available a priori knowledge of the system configuration and of the operating environment. 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: Patrik Alfredsson, Ulf Brännlund, Stefan Feltenmark, Anders Forsgren, Andreas Nõu, Mikael Prytz, Krister Svanberg.

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK) and the Swedish Council for Planning and Coordination of Research (FRN).

Industrial contacts: ABB Network Control, AlfGam Optimering AB, Ericsson Telecom AB.

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 Mikael Prytz, in cooperation with Philip E. Gill (UCSD) and Walter Murray (Stanford University).

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 joint work with Walter Murray has been focused on the development of modified Newton methods of the linesearch type for linearly constrained optimization. The methods utilize both descent directions and directions of negative curvature. A paper, dealing with strategies suitable for large-scale problems has been published [A12].

The joint work with Philip E. Gill 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 [A11].

A new subproject concerning design of telecommunactions networks has been initiated during 1996. Mikael Prytz is an industrial graduate student in this area. The intent is to utilize nonlinear-programming based relaxations to solve combinatorial optimization problems of interest in telecommunications design.

Linear stochastic systems theory

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

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

A comprehensive theory for state-space modelling of vector-valued (stationary and stationary-increment) stochastic processes has been developed within the framework of the geometric Hilbert space theory of Markovian splitting subspaces developed by Lindquist and Picci and others. It will be presented in detail in a forthcoming monograph, which is under preparation. This geometric theory should be regarded as a natural and logically consistent way of building up linear stochastic systems theory. Traditionally there has been little attention paid even to the most elementary structural concepts in linear stochastic systems, like, for example, minimality. This has led to derivations of filtering algorithms by formula manipulations without deeper understanding of why the estimates satisfy recursive equations and whether the algorithms obtained are of minimal complexity, etc. In fact, many structural properties important in dynamic estimation, such as, for example, the existence of recursive (i.e. differential-equation type) solutions, the minimality of filtering algorithms, and processing of specific observed signals, possibly with a non-causal information pattern, are best formulated and understood in a coordinate-free form, using the geometric language of Hilbert space theory, as the use of coordinates may sometimes only obscure the basic issues.

Locomotive scheduling

Researchers: Andreas Nõu, in cooperation with Jacques Desrosiers and Francois Soumis (Montréal, Canada).

Sponsor: Swedish Transport and Communications Board (KFB).

Industrial contacts: Swedish State Railways, SJ.

This is a project concerning the construction of periodic locomotive schedules, needed e.g. at a planning stage at the Swedish State Railways.

The objective is to find cyclic locomotive schedules, who minimize operational costs while respecting maintenance and availability constraints on each type of locomotive. The locomotive requests might have restrictions on the type of locomotive to be used. Maintenance constraints are expressed in terms of accumulated traveled distance by each locomotive. The modeling has been done in close cooperation with Anders Jönsson at the Swedish State Railways, SJ.

A realistic size problem has been supplied to us by SJ. The problem has, after preprocessing, more than 2400 locomotive requests. The results of the project have been reported in [R22].

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 [A20][R17] 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 [A19] we consider the case of complete state feedback, in which case an OUR always exists. The problem of optimal tracking is considered in [R17].

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.

Optical dynamics

Researchers: Clyde Martin, Magnus Egerstedt, Lawrence Schovanec, Pamela Lockwood.

Sponsors: NASA, NSF.

This project is concerned with the dynamics of eye movement. The eye is quite simple when compared to they moving parts of the human body. The motion is controlled by a complex of six muscles, two of which control the horizontal movement and four ow which control the vertical movement. The vertical moment is complicated by the fact that the primary muscles cause rotation which is counteracted by a pair of muscles whose primary function is to cause rotation. There is a feedback effect in these four muscles. The primary work has been done on the horizontal movement. Models have been developed that produce the best results that have been reported in the literature for saccadic movement. These models are physiologically correct and develop forces in the muscle that are comparable to experimental data.

Optimization of power systems

Researchers: Stefan Feltenmark, in cooperation with P. O. Lindberg (Linköping University) and Krzysztof C. Kiwiel (Systems Research Institute, Warsaw, Poland).

This project is devoted to the application of advanced optimization methods to problems arising in power production planning, with particular emphasis on short-term planning. The basic problem in short-term planning is to schedule the generating units of a power system over some planning horizon, to meet the predicted demand for electric power, and so that operational costs are minimized. This leads to large combinatorial optimization problems, for which our aim is to develop efficient methods. A common theme in our approach is that we solve these complex problems by dual methods, taking special problem structure into account.

Within this project, several different optimization problems have been addressed, e.g., the unit commitment problem and the hydro-power scheduling problem. Recent development in our work on the unit-commitment problem include efficient procedures for generating primal feasible solutions from certain convexified solutions [C4]. For the variable-head hydroelectric planning problem, we have shown how to compute local optima to this non-convex, network flow problem by modifying algorithms for the linear case [C5].

Also some more theoretical issues, concerning the relation between a non-convex problem and its dual, have been studied [R8], [T2]. The work in this project resulted in 1997 in the thesis of Feltenmark [T2], in which the above results are presented.

Optimization of spare parts inventory systems

Researchers: Patrik Alfredsson in cooperation with P. O. Lindberg (Linköping University).

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK) and the Swedish Defense Material Administration (FMV).

Industrial contact: Swedish Defense Material Administration (FMV).

The aim of this project to develop techniques to improve the behavior of logistics support systems. A natural problem of interest is the spare parts optimization

problem, where the objective is to allocate spares within the support system so as to achieve optimum performance while satisfying a budget constraint. We have studied this problem, and also extended our models to include decisions regarding level of repair and test equipment necessary to perform repair of faulty items.

However, the number of spares at various stock points is not the only parameter that influences the overall support system performance. Therefore, we have developed techniques to efficiently compute the sensitivity of the performance with respect to other system parameters (variables), e.g. transportation and repair times. In connection, we have studied robustness issues and have developed techniques to obtain more robust solutions (spare parts allocations).

Also, we have studied the problem of modeling supply flexibility. Most popular models (OPUS, VMetric) assume a prescribed supplier from which additional spares are sent. Nonetheless, it could sometimes be beneficial to use other means of supply, in particular in an emergency situation. We have therefore developed a model where both lateral supply and direct (faster) deliveries are available.

During the academic year, Alfredsson has completed his doctoral thesis [T1], in which the above results are presented.

Robust control of electrical drives

Researchers: P. O. Gutman, Xiaoming Hu, Daniele G. Galardini, Mattias Nordin 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 and/or adaptive control elements, implemented in a microprocessor, that alleviate the effects of the process nonlinearities. In particular are electrical drives with friction, backlash and uncertain loads and disturbances studied.

The project has been running since January 1992, and funding ended in June 1997. The project will conclude with Mattias Nordin's Ph.D-thesis expected during the academic year 1997/98.

In the activity report for 1995/96 we reported the development of a backlash compensating speed controller based on rapid gain scheduling between different linear control laws, depending on the estimated load torque. Unexpected difficulties were encountered when attempting to program the ABB 60 kW laboratory system to perform tests of the new controller. We expect to overcome the difficulties shortly. Closed loop stability with the new controller has been proved under certain assumptions using circle and Popov criteria. We have also been working on a survey article on backlash compensation methods. The experimental results, the proofs, and the survey are to be published in Nordin's forthcoming Ph.D.-thesis.

Work has been performed on the modelling, identification and control of mine hoisting systems. This topic constitutes an extension of the results achieved previously for two-mass systems and was requested by ABB-ISY. A complete model to simulate the entire mine hoisting process was set up. A reduced-order model has been verified in order to design a robust controller. See the reports [R9][R10][R11].

Other published or submitted papers during the year from the project include [A19] [C6] [R12] [R13] [A31] [A2] [A32] [R14]. These papers cover topics that were reported in previous activity reports.

Since the project is coming to an end, it might be possible to draw some conclusions. The results of the project are very satisfactory both from the academic and industrial point of view. The control design problem for elastic two mass systems with nonlinearities such as backlash and friction was treated very exhaustively, with conclusions concerning performance limitations.

Robust feedback control of nonlinear and uncertain systems

Researchers: Xiaoming Hu.

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

In this project we study the problems of feedback stabilization and output regulation for nonlinear control systems possibly with uncertainties and apply the results to some practical systems, such as servo systems affected by friction forces and motion control of mobile robots. We have also studied the problem of "linear controllability" versus global stabilizability of nonlinear control 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 will have to be solved, 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. A fuller description of the project is found in last year's activity report.

The industrial process on which this program is conducted, including experiments and test, is the paper board manufacturing machine at Assi-Domän Frövifors Bruk AB, Frövi.

The started by modelling the laboratory measured quality variable bending stiffness index, as reported in [C7][A13]. where the use of an ARMA model with input non-linearities resulted in an on line predictor with a prediction error less than half the laboratory measurement error. The predictor was tested on-line at Assi-Domän Frövifors Bruk AB, Frövi, and was found to have a 12-minutes ahead prediction accuracy of over 75% within 0.6 mN, whereas the bending stiffness index lies in the range 11-16 mN.

The project's Ph.D.-student, Jens Petterson, has continued developing so called grey-box models following the ideas of Prof. Torsten Bohlin. The results are very promising, and have been reported in [C10]. In particular, new physical insight has been achieved about the influence of calendering on tensile strength and density.

Robust reduction of large scale linear programming problems

Researcher: Ilya Ioslovich.

Sponsor: Wenner-Gren Foundation.

This project concerns the advanced approach to presolving analysis of large scale linear programming (LP) problems. The aim is to detect and remove redundant rows and columns, thus reducing the size of the problem. A set of new tests are described. All of them based on the solution of some auxiliary LP problem with one constraint and upper limits on the variables. It is shown that primal tests are more effective then Klein - Holm test. The primal tests in addition generate evaluations for dual variables and the tests are applied iteratively to the primal and dual LP problem. The whole procedure is very convenient for the parallel computing. The robust variant of the tests is described, which can be applied to a set of LP problems with coefficients in some range of uncertainty, providing a robust procedure for the scale reduction. Programs on MATLAB are written and the numerical example is considered. Results are presented in technical report [R16] and submitted to publication.

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 will be studied. 1. we will study motion control algorithms for nonlinear control systems, not only because many autonomous system models are nonlinear, but also because for systems with nonholonomic constraints, the path planning problem actually can be converted into a motion control problem for a nonlinear control system. Besides, global stabilization of nonlinear systems will also be studied. 2. We will study robust motion control and vehicle steering. The task of robust motion control is then to generate forces and torques on the vehicle such that it follows the reference trajectory. It is a robustness problem because of large variations in the vehicle mass and velocity and the force generation mechanism. 3. Planing 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.

Stability analysis

Researchers: Clyde Martin, Xiaoming Hu, Christopher Byrnes, W. Dayawansa.

Sponsors: NSF, NASA.

This project is ongoing. The goal of the project is to develop an understanding of the stability of nonlinear systems based on the behavior of output functions. It is known that for linear systems that under certain conditions the system is stable if and only if the output function is integrable. It is known that in general this theorem fails in the nonlinear setting. The major goal of this research is to understand when the result holds in the nonlinear case.

Stochastic realization theory and identification

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

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

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

We have demonstrated that there is no guarantee that several popular subspace identification procedures will not fail to produce a positive extension, unless some rather stringent assumptions are made which, in general, are not explicitly stated. These assumptions are equivalent to the condition that the positive and algebraic degrees of a certain estimated covariance sequence coincide. We have 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 particular we have shown that model reduction of high-order maximum entropy entensions leads to good solutions, as well as satisfies the positivity constraint mentioned above. Extensive simulations have been performed.

Structural optimization

Researchers: Krister Svanberg and Ulf Brännlund.

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

The aim of this project is to develop mathematical models and efficient numerical methods for optimizing the topology and the element sizes of different load-carrying structures.

During the year, we have shown that certain so called truss topology design (TTD) problems can be formulated as semidefinite programming (SDP) problems in which the structural stiffness matrix and the given load vectors appear in a natural way. We have then proved some theoretical results concerning perturbations and conservative approximations of these problems. Based on these theoretical results, a globally convergent numerical method for certain TTD problems has been developed and successfully applied to test problems with more than 4000 design variables, see [R2]. We have also developed a potential reduction method for the SDP formulation of certain other (slightly more general) TTD problems, see [R3].

Switching systems

Researchers: Clyde Martin, W. Dayawansa, Jorge Marí.

Sponsors: NASA, NSF.

Systems are said to switch when the dynamics that govern the movement changes during the course of controlled motion. This occurs in a very large variety of systems, ranging from the movement of the human body, and there is caused by the fact that muscles can only pull and can never push; in aircraft such as the Harrier jet, and there it is caused by the redundancy of the control; in the movement of insects to avoid capture and in almost every other form of complex motion. The goal of the research is to establish a paradigm by which such systems can be studied and efficient use can be made of the ability of the system to switch dynamics. Major questions remain to be answered: when is such a system stable? when is the motion smooth? what switching strategies lead to intrinsically stable systems? what switching strategies lead to intrinsically unstable systems? etc.

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 [A4] 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 [R5] 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.

The structure of linear discrete-time stochastic systems

Researchers: Anders Lindquist, in cooperation with Gy. Michaletzky (Eötvös Lorand University, Budapest).

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

In this project we establish for discrete-time systems a useful connection between the geometric theory of splitting subspaces and geometric control theory in the style of Wonham and Basile and Marro. This has been done previously in the continuous-time case in collaboration with Giorgio Picci. However, the discrete-time case is more complicated due to the possibility of the occurrence of invariant directions, and therefore, in addition to the the notion of *output-induced subspace*, we need to introduce the stronger concept of *strictly output-induced subspace*. In [A18] we discuss the role of invariant directions, zeros of spectral factors and output-induced subspaces in determining the systems-theoretical properties of stochastic systems. We demonstrate that the maximal output-induced subspace can be decomposed as a direct sum of the subspace of invariant direction over the future, the subspace of invariant direction over the past, and the maximal strictly output-induced subspace, corresponding to the zeros at zero, the zeros at infinity, and the remaining zeros respectively. The maximal strictly output-induced subspace can be determined by algorithms akin to that used in geometric control theory for determining the maximal output-nulling subspace. A basic tool in this analysis is a pair $(\sigma, \bar{\sigma})$ of shift operators on the family of minimal splitting subspaces, which produces a family of totally ordered splitting subspaces. We show that these splitting subspaces are tied together by Kalman filtering recursions in the sense that we can pass from one state process to the next by Kalman filtering, an interesting fact that enables us actually to compute these spaces.

As a by-product of this analysis we solve the following estimation problem: Consider a linear stochastic system where both the state process and the output process is observed, but there is a "black out" of state information during a finite interval of time. A problem considered in [A18] is to reconstruct the lost state information from the remaining observations. This gives a systems theoretical interpretation to *each* minimal stochastic realization akin to that of a minimum-phase solution in the classical theory. When the interval with the lost information grows, this pair of realizations converge to "the tightest internal bounds".

Trajectory planning

Researchers: Clyde Martin, Magnus Egerstedt, Jack Tomlinson (TTU).

Sponsors: NASA, NSF.

The initial problem considered under this program was the control of aircraft in the terminal region. The basic problem is that the aircraft are very closely controlled during the last few kilometers of the approach (100k) and any deviation from the flight plan can result in the plane being required to leave the queue and this results in long delays for the passengers. The flight path is given to the aircraft in the form of way points that that must be met at specific times. This problem was solved by the introduction of spline like trajectories based on linear control systems. During the last year we were able to relax the conditions that the way points had to be met exactly at exact times and introduced what is the equivalent of smoothing splines based on linear control theory. We were able to construct three types of spline like trajectories based on linear control theory and optimization techniques. These three formulations can be combined to yield more complicated situations. The solutions to all three problems have very computable solutions even for very large numbers of data points.

3 Education

3.1 Undergraduate courses

Number	Course name	Instructor	Credit
5B1712	Optimization, General Course for F *(Optimeringslära för F)*	K. Svanberg	4 p
5B1722	Applied Optimization, General Course for T and M *(Tillämpad optimeringslära för T och M)*	C. Trygger	4 p
5B1742	Mathematical Systems Theory *(Matematisk systemteori)*	A. Lindquist/ P. Enqvist	4 p
5B1750	Optimization, General Course for E and D *(Optimeringslära för E och D)*	A. Forsgren	4 p
5B1810	Mathematical Programming *(Matematisk programmering)*	A. Forsgren	5 p
5B1822	Advanced Course in Mathematical Systems Theory *(Matematisk systemteori, fortsättningskurs)*	A. Lindquist/ J. Marí	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

3.2 Graduate courses

Number	Course name	Instructor	Credit
5B5760	Introduction to Nonlinear Control Systems	X. Hu	5 p
	Switching Systems	C. Martin	5 p
5B5875	Variational Inequalities and Projected Dynamical Systems: Theory and Applications	A. Nagurney	5 p

3.3 Doctoral theses

[T1] P. Alfredsson, *On the optimization of support systems*, TRITA-MAT-1997-OS3, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1997. Advisor: P. O. Lindberg.

[T2] S. Feltenmark, *On optimization of power production*, TRITA-MAT-1997-OS1, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1997. Advisor: P. O. Lindberg.

3.4 Master theses (Examensarbeten)

[T3] J. Andersson (T), *Optimal allokering av utbytesenheter inom kärnkraftsindustrin.* Advisor: K. Svanberg. Performed at Sydkraft.

[T4] S. Andersson (T), *Calculating cost of quality using activity-based costing.* Advisor: D. Schaub/U. Brännlund. Performed at University of Florida.

[T5] S. Authén (T), *Optimal reservdelsallokering med lateral försörjning.* Advisor: K. Svanberg. Performed at Sydkraft.

[T6] J. Carlsson (T), *Systemering av ett nytt hjälpmedel för transportplanekonstruktion.* Advisor: U. Brännlund. Performed at SJ.

[T7] M. Egerstedt (F), *A model of the combined planar motion of the human head and eye.* Advisor: C. F. Martin/A. Lindquist. Performed at Texas Technical University.

[T8] A.-C. Eriksson (F), *A heuristic algorithm for clustering nodes in a telecommunications network.* Advisor: A. Forsgren. Performed at Ericsson Telecom.

[T9] J. Fischerström (E), *Quanto interest rate derivatives.* Advisor: T. Björk. Performed at Front Capital Systems AB.

[T10] E. Kjølberg (T), *A new heuristic for multi-item lot-sizing and single-item lot-sizing with polyhedral optimization.* Advisor: D. Hearn/U. Brännlund. Performed at University of Florida.

[T11] J. Lann (T) and A. Lindell (T), *Evaluation of the effects of corporate market communication.* Advisor: A. Forsgren. Performed at SAS.

[T12] N. Lidström (T), *A greedy randomized adaptive search procedure (GRASP) for the three-index assignment problem.* Advisor: P. Pardalos/A. Forsgren. Performed at University of Florida.

[T13] P. Lilja (T), *Cost analysis modelling of hybrid fibre Coax (HFC).* Advisor: K. Svanberg. Performed at Ericsson Business Networks.

[T14] F. Lindell (F), *Economical experimental design.* Advisor: D. Schaub/U. Brännlund. Performed at University of Florida.

[T15] E. Lundin (T), *Experimenting with the LP dual active set algorithm.* Advisor: W. Hager/A. Forsgren. Performed at University of Florida.

[T16] M. Merz (T) and D. Santoro (F), *Modelling of a hub-and-spokes system adapted for Scania's future transport flow.* Advisor: K. Svanberg. Performed at SCANIA.

[T17] C. Modigh (F), *Computer-generated experimental designs for heteroscedastic linear models.* Advisor: D. Schaub/U. Brännlund. Performed at University of Florida.

[T18] H. Rehbinder (F), *An anatomically detailed control theoretic model of the dynamics of the forearm.* Advisor: C. F. Maratin/A. Lindquist. Performed at Texas Technical University.

[T19] J. Sandström (T), *Combined pipeline and truck transportation system.* Advisor: K. Svanberg. Performed at TU Delft Holland.

[T20] P. Sarban (T) and M. Poorjomeh (F), *Modeller av korta räntan och arbitragefri prissättning av caps & floors.* Advisor: T. Björk.

[T21] J. Tuft (T), *Alternative crew rosters for Scandinavian Airlines System cabin attendants*. Advisor: A. Forsgren. Performed at SAS.

[T22] K.-J. Wahnberg (T), *Shortest pair of constrained node-disjoint paths in a network*. Advisor: A. Forsgren. Performed at Ericsson Telecom AB.

4 Publications

4.1 Book

[B1] A. Nagurney and S. Siokos, *Financial Networks: Statics and Dynamics*, Springer-Verlag, Heidelberg, 1997. ISBN 3-540-63116-X.

4.2 Papers in journals and books (published and accepted)

[A1] P. Alfredsson, *Optimization of multi-echelon repairable item inventory systems with simultaneous location of repair facilities*, European Journal of Operational Research 99 (1997), 584-595.

[A2] C. Baril and P.-O. Gutman, *Performance enhancing adaptive friction compensation for uncertain systems*, IEEE Transactions on Control Systems Technology, 1997 (in press).

[A3] G. Bartolini, A. Ferrara and A. Stotsky, *Robustness and performance of indirect adaptive control scheme in the presence of bounded disturbances*, Accepted to IEEE Transactions on Automatic Control.

[A4] C. I. Byrnes and A. Lindquist, *On the partial stochastic realization problem*, IEEE Transations on Automatic Control, AC-42 (August 1997), 1049–1069.

[A5] C. I. Byrnes and A. Lindquist, *On a duality between filtering and interpolation*, in *Systems and Control in the Twenty-First Century*, C.I. Byrnes, B.N. Datta, C.F. Martin and D.S. Gilliam (editors), Birkhäuser Boston, 1997, pp. 101–136.

[A6] C. I. Byrnes, H. J. Landau and A. Lindquist, *On the well-posedness of the rational covariance extension problem*, in *Current and Future Directions in Applied Mathematics*, M. Alber, B. Hu and J Rosenthal (editors), Birkhäuser Boston, 1997, pp. 81–108.

[A7] K. Dhanda and A. Nagurney, *A variational inequality approach for marketable pollution permits*, Computational Economics 9 (1996), 363-384.

[A8] K. Dhanda and A. Nagurney, *Variational inequalities for marketable pollution permits with technological investent opportunities: the case of oligopolistic markets*, To appear in Mathematical and Computer Modelling.

[A9] K. Dhanda, A. Nagurney and J. Stranlund, *A general multiproduct multipollutant market pollution permit model: A variational inequality approach*, Energy Economics 19 (1997), 57-76.

[A10] M. Egerstedt and C. F. Martin, *A control theoretic model of the combined planar motion of the human head and eye*, To appear in the Journal of Applied Mathematics and Computation (accepted 1996).

[A11] A. Forsgren and P. E. Gill, *Primal-dual interior methods for nonconvex nonlinear programming*, To appear in SIAM Journal on Optimization.

[A12] A. Forsgren and W. Murray, *Newton methods for large-scale linear inequality-constrained minimization*, SIAM Journal on Optimization 7 (1997), 162–176.

[A13] P.-O. Gutman and B. Nilsson, *Modelling and prediction of bending stiffness for paper board manufacturing*, Journal of Process Control, 1997 (accepted).

[A14] P.-O. Gutman, *Transfer function parameter interval estimation using recursive least squares in the time and frequency domains*, Chapter 7 in: M. Milanese, J. Norton, H Piet-Lahanier, and E Walter (eds): Bounding Approaches in System Identification, Plenum Publishing Co., London, UK, 1996..

[A15] P.-O. Gutman and M. Velger, *Tracking targets using adaptive Kalman filtering*, In: M. Masten, L. A. Stockum (eds): Precision Stabilization and Tracking Systems for Acquisiton, Pointing, and Control Applications. SPIE Milestone Series, Bellingham, WA, USA, 1996, pp. 183-190.

[A16] X. Hu and C. Martin, *Linear reachability versus global stabilization*, To appear in IEEE Trans. Auto. Control.

[A17] I. Ioslovich, P.-O. Gutman, I. Seginer, *A non-linear optimal greenhouse control problem with heating and ventilation*, Optimal Control, Applications and Methods, 17(1996), 157-169.

[A18] A. Lindquist and Gy. Michaletzky, *Output-induced subspaces, invariant directions and interpolation in linear discrete-time stochastic systems*, SIAM J. Control and Optimization, 35 (1997), 810–859.

[A19] A. Lindquist and V. A. Yakubovich, *Optimal damping of forced oscillations in discrete-time systems*, IEEE Transactions on Automatic Control, AC-42 (June 1997), 786–802.

[A20] A. Lindquist and V. A. Yakubovich, *Optimal damping of forced oscillations by output feedback*, in Stochastic Differential and Difference Equations, Imre Csiszár and György Michaletzky, editors, Progress in Systems and Control Theory, Vol. 23, Birkhäuser, 1997, pp. 203–231.

[A21] A. Lindquist and V. A. Yakubovich, *Universal controllers for optimal damping of forced oscillations in linear discrete systems*, Dokl. Akad. Nauk (Transactions of the Russian Academy of Sciences) vol. 88, N 1, 1977, pp. 156–159.

[A22] A. Nagurney, *Female doctorates in science and engineering: Challenges and opportunities on the cusp of the new millennium*, To appear in festschrift volume in honor of Janne Carlsson, rector of KTH, Ingmar Grenthe, editor.

[A23] A. Nagurney, *Parallel computation of variational inequalities and projected dynamical systems with applications*, in Parallel Computing in Optimization, A. Migdalas, P. M. Pardalos, and S. Storøy, editors, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1997, pp. 343-411.

[A24] A. Nagurney and S. Siokos, *Dynamic multi-sector, multi-instrument financial networks with futures: modeling and computation*, To appear in Networks.

[A25] A. Nagurney and S. Siokos, *Projected dynamical systems for international financial policy modeling and computation*, in Computational Approaches to Economic Problems, H. Amman, B. Rustem, and A. Whinston, editors, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 175-191.

[A26] A. Nagurney and S. Siokos, *Variational inequalities for international general financial equilibrium modeling and computation*, Mathematical and Computer Modelling 25 (1997), 31-49.

[A27] A. Nagurney and D. Zhang, *Massively parallel computation of dynamic traffic networks modeled as projected dynamical systems*, in Network Optimization, Lecture Notes in Economics and Mathematical Systems, P. M. Pardalos, D. W. Hearn, and W. W. Hager, editors, Springer-Verlag, Heidelberg, Germany, pp. 374-396, 1997.

[A28] A. Nagurney and D. Zhang, *Formulation, stability, and computation of traffic network equilibria as projected dynamical systems*, Journal of Optimization Theory and Applications 93 (1997), 417-444.

[A29] A. Nagurney and D. Zhang, *Projected dynamical systems in the formulation, stability analysis and computation of fixed demand traffic network equilibria*, Transportation Science (1997).

[A30] A. Stotsky, J. K. Hedrick and P. Yip, *Universal regulator for uncertain dynamical systems*, Accepted for publication in Russian Physics Doklady.

[A31] M. Nordin, J. Galić and P.-O. Gutman, *New models for backlash and gear play*, Int. J. of Adaptive Control and Signal Processing 11(1997), 49-63.

[A32] H. Rotstein, N. Galperin and P.-O. Gutman, *Set membership approach for reducing value sets in the frequency domain*, IEEE Transactions on Automatic Control, 1997 (in press).

4.3 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 Application, 1997, to appear.

[C2] M. Egerstedt and C. F. Martin, *Control of the planar rotation in human head-eye coordination*, Proceedings of the 5th IEEE Mediterranean Conference on Control and Systems, Paphos, Cyprus, 1997.

[C3] M. Egerstedt, X. Hu, H. Rehbinder and A. Stotsky, *Path planning and robust tracking for a car like robot*, Proceedings of the 5th Symposium on Intelligent Robotic Systems, Stockholm, Sweden, 1997.

[C4] S. Feltenmark, K. C. Kiwiel and P. O. Lindberg, *Solving unit commitment problems in power production planning*, In Operations Research Proceedings, (U. Zimmermann, Ed.), Springer-Verlag, Berlin, 1997. Germany, 1996..

[C5] S. Feltenmark and P. O. Lindberg, *Network methods for head-dependent hydro power planning*, Network Optimization, by P. M. Pardalos, D. W. Hearn, and W. W. Hager (eds.), Lecture Notes in Economics and Mathematical Systems, Springer-Verlag, 1997.

[C6] D. Galardini, M. Nordin and P.-O. Gutman, *Robust PI tuning for an elastic two-mass system*, Proc. European Control Conference 1997, Brussels, Belgium, 1-4 July 1997.

[C7] P.-O. Gutman and B. Nilsson, *Modelling and prediction of bending stiffness for paper board manufacturing*, 13th IFAC World Congress, San Francisco, June 30 - July 5, 1996.

[C8] X. Hu, *Global nonlinear feedback stabilization and nonpeaking conditions*, Proceedings of 2nd Chinese World Congress on Intelligent Control, Xian, China, June, 1997.

[C9] A. Matveev, X. Hu and R. Frezza, *Observers for systems with implicit output*, Proceedings of IEEE 5th Med. Control Conference, Paphos, Cyprus, July, 1997.

[C10] J. Pettersson, T. Bohlin, P.-O. Gutman and B. Nilsson, *Modelling of bending stiffness for paper board manufacturing*, Nordic Process Control Workshop, Lillehammar, Norway, 1997.

[C11] A. A. Stotsky, *Adaptive roadway controller for automated highway system*, Proc of the 35-th CDC, Kobe, Japan, December, 1996, pp. 2277-2282.

[C12] A. A. Stotsky, *Stability of traffic flow: Lyapunov analysis*, IFAC Symposium on Transportation Systems, Crete, Greece, June 1997.

[C13] A. A. Stotsky, *Roadway controller for automated highway system*, ECC97, Brussels, Belgium, July, 1997.

[C14] A. Stotsky, J. K. Hedrick and P. Yip, *The use of sliding modes to simplify the backstepping control method*, ACC 1997, Albuquerque, New Mexico.

[C15] A. A. Stotsky and X. Hu, *Lateral robustly decoupling and longitudinal VSS control for autonomous vehicle*, ECC97, Brussels, Belgium, July, 1997.

[C16] A. A. Stotsky and X. Hu, *Control of car-like robots using sliding observers for steering angle estimation*, To be presented at 36-th CDC, San Diego, CA, 1997.

[C17] A. A. Stotsky and X. Hu, *Stability analysis of robustly decoupled car steering system with nonlinear tire model*, To be presented at 36-th CDC, San Diego, CA,1997.

4.4 Technical reports and preprints

[R1] U. Brännlund, P. O. Lindberg, J.-E. Nilsson, and A. Nõu, *Railway timetabling using Lagrangian relaxation*, Report TRITA-MAT-96-OS7, Department of Mathematics, KTH, 1996, Submitted for publication.

[R2] U. Brännlund and K. Svanberg, *Optimal truss topology, semidefinite programming, and a method based on conservative approximations*, Report TRITA-MAT-1997-OS7, Department of Mathematics, KTH, 1997.

[R3] U. Brännlund and K. Svanberg, *Semidefinite programming formulations and an interior point method for truss topology design*, Report TRITA-MAT-1997-OS8, Department of Mathematics, KTH, 1997.

[R4] C. I. Byrnes, X. Hu and C.F. Martin, *Stability and square integrability*, Submitted to Systems and Control Letters.

[R5] C. I. Byrnes, S. V. Gusev and A. Lindquist, *A convex optimization approach to the rational covariance extension problem*, Submitted to SIAM J. Control and Optimization.

[R6] A, Dahlén, A. Lindquist and J. Marí, *Experimental evidence showing that stochastic subspace identification methods may fail*, Report TRITA/MAT-1997-OS10, Department of Mathematics, KTH, 1997, Submitted for publication.

[R7] K. Dhanda and A. Nagurney, *Noncompliant oligopolistic firms and marketable pollution permits: statics and dynamics*, Submitted to Annals of Operations Research.

[R8] S. Feltenmark and K. C. Kiwiel, *Generalized linear programming solves the relaxed primal*, Report TRITA-MAT-1997-OS11, Department of Mathematics, Royal Institute of Technology, 1997.

[R9] D. Galardini, *Modelling of a mine hoisting system*, ABB ISY, Internal Report, November 1996.

[R10] D. Galardini, *Frequency analysis of a mine hoisting system*, ABB ISY Internal Report, December 1996.

[R11] D. Galardini, *Robust control of a mine hoisting system*, ABB ISY Internal Report, February 1997.

[R12] D. Galardini and X. Hu, *Variable structure control of two-mass systems based on output measurements*, Submitted to International Journal of Control.

[R13] D. Galardini, M. Nordin, P.-O. Gutman, *Robust direct PI tuning for elastic two mass system*, Submitted to IEEE Transactions on Control Systems Technology.

[R14] N. Galperin, P.-O. Gutman, and H. Rotstein, *Value set identification using Lissajou figure sets*, Submitted to SIAM Journal on Control and Optimization.

[R15] X. Hu, *Global nonlinear feedback stabilization and nonpeaking conditions*, Submitted to Automatica.

[R16] I. Ioslovich, *Robust reduction of large scale linear programming problems*, Report TRITA/MAT-96-OS6, Department of Mathematics, KTH, 1996, Submitted for publication.

[R17] A. Lindquist and V. A. Yakubovich, *Universal regulators for optimal tracking in discrete-time systems affected by harmonic disturbances*, Submitted to IEEE Transactions on Automatic Control.

[R18] T. Matsui, *On optimal scheduling of an open-pit mine*, Report TRITA-MAT-97-OS5, Department of Mathematics, KTH, 1997.

[R19] A. Matveev, X. Hu, R. Frezza and H. Rehbinder, *Observers for systems with implicit output (revised)*, Preprint.

[R20] A. Nagurney and S. Siokos, *Network modeling of international financial equilibria with hedging*, Submitted to Annals of Operations Research.

[R21] A. Nõu, *An algorithm for a singly constrained quadratic program subject to lower bounds*, Report TRITA/MAT-97-OS2, Department of Mathematics, KTH, 1997, Submitted for publication.

[R22] A. Nõu, J. Desrosiers and F. Soumis, *Weekly locomotive scheduling at Swedish State Railways*, Report TRITA/MAT-97-OS4, Department of Mathematics, KTH, 1997.

5 Seminars at the division

Aug. 30, 1996	Professor Michael Taksar, Department of Applied Mathematics, State University of New York at Stony Brook, USA. *Continuous time optimal control models in insurance.*
Sep. 13, 1996	Guest visiting professor Anna Nagurney, Division of Regional Planning and Division of Optimization and Systems Theory, KTH. *Variational inequalities and projected dynamical systems: from transportation to finance.*
Oct. 11, 1996	Dr. Alexander Stotsky, Optimization and Systems Theory, KTH. *On Roadway control for automated highway system.*
Oct. 17, 1996	Dr. Roger Germundsson, Stanford University, USA. *Symbolic systems theory, computation and applications.*
Oct. 18, 1996	Dr. Erling D. Andersen, Department of Management, Odense University, Denmark. *Interior-point methods for linear programming.*
Oct. 25, 1996	Dr. Ilya Ioslovich, Faculty of Agricultural Engineering, Technion, Haifa, Israel. *Optimal control of the axial symmetric rigid body, rotating around its center of mass: sufficient conditions and method of passive integrals.*
Nov. 19, 1996	Professor Hector Sussmann, Department of Mathematics, Rutgers University, New Brunswick, USA. *Lie brackets and impulse controls.*
Nov. 22, 1996	Professor Hector Sussmann, Department of Mathematics, Rutgers University, New Brunswick, USA. *A tale of two Hamiltonians.*
Nov. 29, 1996	Dr. Sergei Gusev, St. Petersburg State University, Department of Mathematics, Russia. *Solution of general minimax control problem for linear plant with additive stochastic disturbances.*
Dec. 6, 1996	Professor Ruggero Frezza, Department of Electronics and Informatics, University of Padova, Italy. *Large navigation by controlling shape.*
Dec. 6, 1996	Dr. Reinhart D. Kühne, Stierwald Schonharting und Partner GmbH, Stuttgart, Germany. *Practical traffic control based on continuum modelling.*
Jan. 24, 1997	Professor Clyde F. Martin, Department of Mathematics, Texas Tech. University, Lubbock, USA. *Control, interpolation, identification and vision.*
Jan. 31, 1997	Professor György Michaletzky, Eötvös University, Budapest, Hungary. *Maximization of the sum of heterogeneous quadratic forms.*
Feb. 7, 1997	Dr. Ann-Brith Strömberg, Department of Mathematics, University of Linköping. *Ergodic, primal convergence in dual subgradient schemes for convex programming.*

Feb. 14, 1997 Associate Professor Geir Dahl, Institute of Informatics, University of Oslo. *Optimization in telecommunications.*

Mar. 11, 1997 Enrico di Bernardo, University of Padova, Italy. *A system for tracking the human body in 30 from a sequence of monocular views.*

Mar. 14, 1997 Stefan Feltenmark, Optimization and Systems Theory, KTH. *Optimization of power production.*

Mar. 18, 1997 Professor Bill Gragg, Department of Mathematics, Naval postgraduate School, Monterey, USA. *Stabilization of the unitary Hessenberg QR algorithm.*

Mar. 21, 1997 Docent Tomas Björk, Department of Finance, Stockholm School of Economics. *Some system theoretic aspects of interest rate theory.*

Mar. 21, 1997 Professor Jürgen Ackermann, German Aerospace Research Establishment, Germany. *A robust car driver support system.*

Apr. 4, 1997 Patrik Alfredsson, Optimization and Systems Theory, KTH. *Optimization of support systems.*

Apr. 25, 1997 Dr. Mikael Rönnqvist, Department of Mathematics, University of Linköping. *Production systems in forestry using operations research techniques.*

Apr. 25, 1997 Dr. Andrey Barabanov, St. Petersburg State University, Russia. *Design of minimax regulators.*

Apr. 28, 1997 Professor Alexander Fradkov, Inst for Problems of Mechanical Engineering, Russian Academy of Sciences, St. Petersburg. *Discrete and continuos adaptive control of nonlinear oscillations and chaos.*

May 30, 1997 Professor Bijoy Ghosh, dept of Systems Science and Mathematics, Washington University, St Louis, USA. *A perspective view of control and visionics.*

Jun.10, 1997 Dr. George Meyer, NASA Ames Research Center, USA. *Guidance of nonlinear systems, part 1.*

Jun. 12, 1997 Professor Shankar Sastry, University of California, Berkeley, USA. *Algorithms for the design of distributed, multi-agent control systems.*

Jun. 13, 1997 Professor Michal Pioro, Teletrafiksystem, LTH, Lund. *Robust design problems in telecommunication networks.*

Jun. 16, 1997 Professor Shankar Sastry, University of California, Berkeley, USA. *Hybrid control issues in air trafficmanagement systems.*

Jun. 17, 1997 Dr. George Meyer, NASA Ames Research Center, USA. *Guidance of nonlinear systems, part 2.*

Jun. 19, 1997 Professor Dan C. Sorensen, Rice University, Houston, Texas, USA. *New approaches to large scale eigenanalysis.*

6 Awards and appointments

Anders Lindquist was elected Member of the *Royal Swedish Academy of Engineering Sciences* and its Division VII for *Basic and Interdisciplinary Engineering Sciences*.

Vladimir A. Yakubovich was awarded the *1996 IEEE Control Systems Award* for "pioneering and fundamental contributions to stability analysis and optimal control".

7 Presentations by staff

[P1] P. Alfredsson, *Quantitative methods for system optimization*, Advanced Course in Reliability and LCC arranged by FMV, Stockholm, Sweden, January 30, 1997.

[P2] U. Brännlund, *An implementation of an interior point method for truss topology design*, NorFa Network on Structural Optimization, Skørping, Denmark, May 2-4, 1997.

[P3] S. Feltenmark, *Solving unit commitment problems in power production planning*, Symposium of Operations Research, Braunschweig, September 4-6, 1996.

[P4] A. Forsgren, *Interior methods for optimization*, University of Oslo, Oslo, Norway, May 6, 1997.

[P5] X. Hu, *Global nonlinear feedback stabilization and nonpeaking conditions*, Second Chinese World Congress on Intelligent Control and Intelligent Automation, Xi'an, China, June, 1997.

[P6] A. Lindquist, *The geometry of positive real functions with applications to filtering and rational covariance extension*, Plenary lecture at Conference on Stochastic Differential and Difference Equations, Györ, Hungary, August 21–24, 1996.

[P7] J. Marí, *Output shaping for robust decoupling*, 13th IFAC World Congress, San Francisco, July 1996.

[P8] A. Nagurney, *Projected dynamical systems and variational inequalities with applications*, University of Copenhagen, Copenhagen, Denmark, November, 1996.

[P9] K. Svanberg, *Activities in Structural Optimization at the Division of Optimization and Systems Theory, KTH*, NorFa Network Workshop on Structural Optimization, Denmark, May 2-4, 1997.

8 Other activities

Claudio Altafini

- Participated in the Advanced Research Workshop on Autonomous Robotic Systems, Coimbra, Portugal, June 19–21, 1997.

Ulf Brännlund

- Referee for Mathematical Programming, Computational Optimization and Applications, and Annals of Operations Research.
- Participated in seminar on train scheduling at CTS in Borlänge, January 1997.
- Visited the University of Florida, Gainesville, May 1997.

Magnus Egerstedt

- Participated in the "Advanced Research Workshop on Autonomous Robotic Systems" in Coimbra, Portugal, June 19-21, 1997.

Per Enqvist

- Referee for IEEE Transactions on Automatic Control.
- Development of exercises in Mathematical Systems Theory, advanced course.

Stefan Feltenmark

- Refereed a paper for ITOR.

Anders Forsgren

- Member of PhD committee (betygsnämnd), Department of Building Technology and Structural Engineering, Aalborg University, Aalborg, Denmark, August 16, 1996.
- Visited the Department of Mathematics at the University of California, San Diego, California, USA, December 4–11, 1996.
- Member of PhD committee (betygsnämnd), Department of Mathematics, Linköping University, Linköping, Sweden, February 21, 1997.
- Referee for BIT, International Journal of Technology Management and SIAM Journal on Optimization.

Per-Olof Gutman

- Member of the Ph.D.-examination committee of Mr. Karim Hamiti, Laboratoire d'Instrumentation Micro-informatique et Electronique de Grenoble, ENSIEG, Grenoble, France, September 1996.
- Associate Editor of Automatica, beginning 1997.

Camilla Landén

- Participated in C.I.M.E.'s session on financial mathematics, Bressanone, Italy, July 8-13, 1996.
- Participated in the International Workshop on the Interplay between Insurance, Finance and Control, Aarhus, Denmark, February 25 - March 1, 1997.
- Visited Humbolt Universität, Berlin, Germany, May 8-9, 1997.
- Participated in the 19th Finnish summer school on probability theory, Lahti, Finland, June 2-6, 1997.

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 NATO, and for Stichting Matematisch Centrum.
- Vice Chairman, Appointment Committee for School of Engineering Physics (Tjänsteförslagsnämnden), KTH.
- Board Member, Strategic Center for Autonomous Systems, KTH.
- PhD Committee (betygsnämnd), Lund University.
- 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.
- Organizing committee of 2nd ERCIM Workshop on Systems and Control, Prague, Czech Republic, August 25–27, 1996.
- Program Committee for the 1996 IEEE Conference on Decision and Control, Kobe, Japan, December 11-13, 1996.
- International Advisory Committee of the 28th ISCIE International Symposium on Stochastic Systems Theory and its Applications, Kyoto, Japan, November 14–16, 1996.
- Scientific Committee, Workshop on Open Problems in Mathematical Systems Theory and Control, Liege, Belgum, June 30, 1997.
- Chairman, ERNSI Workshop (European Research Network for System Identification), Stockholm, Sweden September 8–10, 1997.

Jorge Marí

- Referee for IEEE Transactions on Automatic Control.

Henrik Rehbinder

- Participated in the "Advanced Research Workshop on Autonomous Robotic Systems" in Coimbra, Portugal, June 19-21, 1997.

Krister Svanberg

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