Division of Optimization and Systems Theory
Department of Mathematics
Royal Institute of Technology
S–100 44 Stockholm, Sweden

Activity Report

1994/1995

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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 1994/1995 (July 1994 – June 1995).

Optimization and Systems Theory is a discipline in Applied Mathematics primarily devoted to mathematical programming, optimal control theory, and systems theoretic aspects of control and signal processing. In addition, attention is also given to mathematical economics and more 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, matrix Riccati equations, and robust and nonlinear control; dual optimization methods, with applications to crew and vehicle scheduling, large scale optimization and power planning; structural optimization; and nonlinear programming. The division also has an Optimization Laboratory devoted to collecting state-of-the-art optimization routines, making them available to research institutions and industry. For ease of reference, in this activity report research projects as well as publications are reported either under the heading of *Systems and Control* or under the heading of *Mathematical Programming*.

The Division of Optimization and Systems Theory offers undergraduate courses in mathematical programming, mathematical systems theory, optimal control and calculus of variations, mathematical economics, as well as various topics in operations research and modeling. There is an active graduate program. During the academic year of 1994/1995 two licentiate degrees in Optimization and Systems Theory were awarded. Two persons have been appointed to the position of Docent.

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.

Contents

1 Personnel

1.1 List of personnel

Professor (Professor)

Anders Lindquist, TeknD

Docenter, högskolelektorer (Associate professors)

Tomas Björk, FD, docent
P. O. Lindberg, TeknD, docent
Krister Svanberg, TeknD, docent Director of undergraduate studies

Forskarassistent (Research associate)

Anders Forsgren, TeknD, docent

Förste forskningsingenjörer (Researchers)

Ulf Brännlund, TeknD
Xiaoming Hu, PhD, docent

Gästforskare (Guest researchers)

Leonid Faybusovich, associate professor
Per-Olof Gutman, docent
Vladimir Yakubovich, professor

Intendent (Administrator)

Leena Druck

Doktorander (Graduate students)

Patrik Alfredsson, civing
Anders Dahlén, FK
Per Enqvist, civing
Stefan Feltenmark, civing
Kristoffer Hägglöf, civing
Camilla Landén, civing
Jorge Marí, MS, TeknL
Mattias Nordin, civing, TeknL
Andreas Nöu, civing
Andreas Wolf, MS

1.2 Biographies

[0,l,[width=30mm]was born in Södertälje, Sweden, in 1967. He received a civilingenjör degree in Engineering Physics from KTH in 1991. 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.,] **Patrik Alfredsson**

Tomas Björk was born in Fagersta, Sweden, in 1947. He received his B.A. from the University of Stockholm in 1971, and his PhD in Optimization and Systems Theory from the Royal Institute of Technology in 1981. In 1994 he was appointed Docent. Between 1971 and 1974 he worked as a Researcher at the National Defense Research Establishment (FOA). In 1981 he became a Research Associate and in 1987 a Senior Lecturer of Optimization and Systems Theory at the Royal Institute of Technology. He has also given several courses in Mathematical Finance at the Stockholm School of Economics. His main research interests include martingale theory, nonlinear filtering and mathematical economics.

[0,l,[width=30mm]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 and production planning problems.,] **Ulf Brännlund**

[0,l,[width=30mm]was born in Karlskrona, Sweden, in 1969. He did his undergraduate work in Mathematics of Science in Växjö. He is presently a PhD student at the Division of Optimization and Systems Theory. His main interest is Mathematical Systems Theory, and especially Stochastic Systems.,] **Anders Dahlén**

[0,l,[width=30mm]is the administrator at the Division of Optimization and Systems Theory since 1992.,] **Leena Druck**

[0,l,[width=30mm]was born in Upplands Väsby, Sweden, in 1971. He received a civilingenjörs degree in Engineering Physics from KTH in 1994. He is presently a PhD student at the Division of Optimization and Systems Theory. His main research interest is mathematical systems theory, and especially stochastic realization.,] **Per Enqvist**

[0,l,[width=30mm]received his M.Sc. from the Polytechnic Institute, Leningrad in 1977 and his Ph.D. from Harvard University in 1991. Since 1991 he has held positions at the University of Notre Dame, Assistant Professor 1991–1994 and Associate Professor since 1994. He spent most of the academic year 1994/1995 at the Division of Optimization and Systems Theory while on sabbatical leave from University of Notre Dame.,] **Leonid Faybusovich**

[0,l,[width=30mm]was born in Boden in 1968. He received a civilingenjör degree in Engineering Physics from KTH in 1991. He is presently a PhD student at the Division of Optimization and Systems Theory. Main research interests are

dual methods for large-scaled problems, particularly applied to short-term power production planning problems.,] **Stefan Feltenmark**

[0,l,[width=30mm]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. Since 1991, he is a research associate at the Division of Optimization and Systems Theory, where in 1995 he was appointed Docent. His main research interest is nonlinear programming.,] **Anders Forsgren**

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.

His research interest include robust and adaptive control, control of non-linear systems, computer aided design and control of agricultural systems.

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.

[0,l,[width=30mm]was born in Umeå, Sweden, in 1969. He received a civilingenjör degree in Computer Science from KTH in 1994. His main research interests are optimal expansion strategies for telecommunication networks with focus on uncertainty in technology development and future demand.,] **Kristoffer Hägglöf**

[0,l,[width=30mm]was born in Upplands Väsby, Sweden, in 1970. She received a civilingenjör degree in Engineering Physics from KTH in 1994. She is presently a PhD student at the Division of Optimization and Systems Theory. Her main research interests are stochastic differential equations and financial mathematics.,] **Camilla Landén**

Per Olov Lindberg was born in Stockholm on February 20, 1942. He received a civilingenjörs examen in Engineering Physics at KTH in 1967 and a PhD in Optimization Theory at KTH in 1975.

He served as a Systems Analyst at Datema in 1967–68. From 1968 to 1974 he served as a Research Assistant at the Department of Mathematics at KTH, on Transportation Research Grants. From 1975 to 1979 he was Assistant Professor of Optimization and Systems Theory at KTH. From 1980 he has been Associate Professor at KTH. He also has served as Acting Professor on several instances, including the three year period Fall 1980–Spring 1983.

Lindberg was a board member of the Swedish OR Association 1974–1980. He has served on the board of the School of Computer Science at KTH and is presently serving at the boards of the Schools of Vehicle Engineering and Industrial Engineer-

ing.

Lindberg was visiting professor at Sloan School of Management, MIT, during the Spring Semester 1988. He has also been Visiting Scholar at Stanford University and University of Washington. He has recently been appointed Adjunct Professor at University of Florida.

Lindberg is on the editorial board of Computational Optimization and Applications.

Lindberg's research interests include most areas of Mathematical Programming and its applications, including Linear, Nonlinear, Dynamic and Integer Programming, Convexity and Duality, Inventory Control and Random Utility Models. He has guided six students to a PhD and four for a Licentiate Degree. Furthermore he has guided well over 100 students for an Engineering Master's Thesis (examensarbete).

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. Since 1989 he is a Fellow of the IEEE (Institute of Electrical and Electronics Engineers), and since 1994 an honorary member the Hungarian Operations Research Society.

Lindquist 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 two book series *Systems and Control: Foundations and Applications* and *Progress in Systems and Control* (Birkhäuser Boston). Since 1983 he has been a member, and between 1985 and 1987 the chairman, of the steering committee for the biannual international symposia on the Mathematical Theory of Networks and Systems (MTNS).

Jorge Marí received the Electrical Engineer degree from Facultad de Ingeniería in Montevideo year 1992, studied Mathematics at the Facultad de Ciencias, worked initially for the Mathematics Department at the first mentioned place from 1988 to 1992 and later as project designer in power supply systems for the telephone company ANTEL. Late 1992 he moved to Stockholm and was engaged until 1994 in a KTH-industry project 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. Since February 1995 he has been working as visiting researcher at the Institute for Robotics and System Dynamics at the German Aerospace Research Establishment in Oberpfaffenhofen. The tasks here shifted to control applications for surface vehicles and aircraft. His main interests include electrical systems, computer aided engineering, optimization, dynamical systems and control theory and applications.

[0,l,[width=30mm]was born in Lund, Sweden, in 1967. He received a civilingenjör degree in Engineering Physics from KTH in 1992. He is presently a PhD student at the Division of Optimization and Systems Theory. His main research interests are robust control, especially QFT and systems with backlash. At the moment he is working on control of systems with backlash. Also new methods for value set computations are being developed.,] **Mattias Nordin**

[0,l,[width=30mm]was born in Stockholm in 1967. He recieved a civilingenjör degree in Engineering Physics from KTH in 1991. He is presently a PhD student at the Division of Optimization and Systems Theory. His main research interests are optimization methods for applications in the transportation sector.,] **Andreas Nöu**

Krister Svanberg was born in Stockholm in 1950. He received his civilingenjör degree in Engineering Physics from KTH in 1975, and his TeknD degree in Optimization Theory from KTH in 1982. In 1993 he was appointed Docent. Between 1976 and 1985 he held a position as Research Associate with the Contract Research Group of Applied Mathematics at KTH, and since 1985 he is a Senior Lecturer of Optimization and Systems Theory. His main area of research is structural optimization.

[0,l,[width=30mm]was born in Hamburg, Germany, in 1956. He received his MS in hydrology from Freiburg university (Germany) in 1985. Since 1986 he has been working at Vattenfall Utveckling AB with hydromechanics related to hydropower. In spring 1994 he began PhD-studies financed by TFR and Vattenfall. His main research interest is nonlinear programming, in particular energy applications.,] **Andreas Wolf**

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
- Dr. Bertil Berggren, Dept Electric Power Systems, KTH, Stockholm, Sweden
- 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
- Dr. E. Anders Eriksson, Swedish Defense Research Establishment, Stockholm, Sweden
- Professor A. L. Fradkov, Department of Mathematics and Mechanics, St. Petersburg University, Russia
- Professor Philip E. Gill, Department of Mathematics, University of California at San Diego, La Jolla, California, USA
- Dr. S. V. Gusev, Department of Mathematics, St. Petersburg University, St. Petersburg, Russia
- Professor Donald W. Hearn, Department of Industrial and Systems Engineering, University of Florida, Gainesville, Florida, USA
- Dr. Björn Johansson, Department of Mathematical Statistics, University of Stockholm, Stockholm, Sweden
- Professor Yuri Kabanov, CEMI, Moscow, Russia
- Professor Krzysztof C. Kiwiel, Systems Research Institute, Warsaw, Poland
- Docent Lars-Göran Mattsson, Department of Regional Planning, KTH, Stockholm, Sweden
- Professor A. S. Matveev, Department of Mathematics, St. Petersburg University, St. Petersburg, Russia
- Professor György Michaletzky, Department of Probability Theory and Statistics, Eötvös Lorand University, Budapest, Hungary
- Professor Walter Murray, Department of Operations Research, Stanford University, Stanford, California, USA
- Jan-Eric Nilsson, Centre for Research in Transportation and Society, Borlänge, Sweden
- Dr. Birgitta Olin, Ericsson Telecom AB, Stockholm, Sweden
- Professor Giorgio Picci, Department of Electronics and Informatics, University of Padova, Padova, Italy
- Professor Wofgang Runggaldier, University of Padova, Padova, Italy
- Professor Tony Smith, Regional Science Department, University of Pennsylvania, Philadelphia, Pennsylvania, USA
- Professor Francois Soumis, GERAD and École Polytechnique de Montréal, Montréal, Québec, Canada
- Dr. Daniel Tasende, Dept of Mathematics, Facultad Ingeneria, Montevideo, Uruguay

1.4 Networks

- European Research Network for Systems Identification (ERNSI)
- INTAS Network on Robust Control

2 Research

2.1 List of projects

2.1.1 List of projects in Systems and Control

- Adaptive prediction and parameter identification
- Control of land and air vehicles
- Estimation of lost state information in linear stochastic systems
- Financial economics
- Linear stochastic systems theory
- Optimal damping of forced oscillations in discrete-time systems
- Robust control of electrical drives
- Robust feedback control of nonlinear and uncertain systems
- Stochastic realizations and geometric control theory—a synthesis
- Stochastic realization theory and identification
- The minimal rational covariance extension problem

2.1.2 List of projects in Mathematical Programming

- Allocation of scarce track capacity
- Computation of global optima to polynomial optimization problems
- Dual methods for large scale optimization problems
- Dual methods for short term power planning problems
- Dual methods for the unit commitment problem
- Infinite-dimensional quadratic optimization: Interior-point methods and control applications
- KTH Optimization Laboratory
- Large scale decomposition and nonsmooth optimization
- Locomotive scheduling
- Methods for structured dual problems
- Optimal expansion strategies for telecom networks
- Optimal short term operation of a cascade of hydropower stations
- Optimization of spare parts inventory systems
- Random utility models
- Second-derivative methods for nonlinear programming
- Structural optimization

2.2 Description of projects

2.2.1 Description of projects in Systems and Control

Adaptive prediction and parameter identification

Researchers: Tomas Björk, in cooperation with Björn Johansson (University of Stockholm).

The goal of this project is to build a theory of parameter identification for a fairly general class of semimartingales, but up to now we have confined ourselves to diffusions and point processes. We have studied the existence of unbiased parameter estimators (and their asymptotic properties), as well as the existence of asymptotically consistent parameter estimators. Based on earlier work on adaptive prediction, we have shown that unbiased parameter estimation can be seen as a limiting case of adaptive prediction, a fact which leads to interesting connections between unbiased estimators and reverse martingales. We have also shown that the existence of an unbiased parameter estimate is equivalent to the existence of a solution to an inverse (ill posed) parabolic boundary value problem. We obtain non standard representation formulaes of Feynman-Kac type for the optimal estimators, and we can also give error bounds extending the standard Cramer-Rao results. Presently we are working on finite dimensional representations of asymptotically sufficient tail-σ-algebras and on the existence of so called sufficient generating martingales.

Control of land and air vehicles

Researchers: Jorge Marí in cooperation with J. Ackermann, German Aerospace Research Establishment in Oberpfaffenhofen (Anders Lindquist; advisor).

Sponsors: The Swedish Research Council for Engineering Sciences (TFR) and the Swedish Institute.

The dynamics of vehicles considered as rigid bodies and different control strategies for their "safe" movement are being studied. We have shown that under ideally satisfied assumptions the use of transversal accelerometers attached to a vehicle is the key to guarantee the generic rejection of disturbances. We have also derived computable criteria for a system to be robustly decoupable, and have shown that aircraft with tailerons and canards can have their longitudinal movements decoupled against uncertainties in load and position of center of gravity, while insuring stability. We are currently participating in the High Incidence Research Model benchmark, which deals with the design of controllers to satisfy a set of requirements for a military aircraft.

Estimation of lost state information in linear 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.

The geometric theory of stochastic realization described in the project *Linear stochastic systems* with its symmetry under reversal of time is a very natural tool for the analysis of noncausal estimation problems. A case in point is the smoothing problem, earlier studied by Badawi, Lindquist and Pavon, which is very naturally

cast in this framework, and also the noncausal estimation problem used as mathematical devise by Lindquist and Picci.

Now, 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 [R12] is to reconstruct the lost state information from the remaining observations. This is precisely a problem of the type described above. It corresponds to the smoothing problem or the noncausal estimation problem with the important difference that the estimate becomes a linear combination of noninternal states rather than internal states. 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".

Financial economics

Researcher: Tomas Björk and Camilla Landén, in cooperation with Y. Kabanov (CEMI, Moscow), and W. Runggaldier (University of Padova).

The goal of this project is to study the mathematical theory of financial derivatives. In particular we have studied the term structure of interest rates, when the dynamics of the short rate (or the forward rate curve) is driven by a general marked point process as well as by a diffusion term. For hedging purposes this leads to a new theory of infinite-dimensional portfolios and in particular to the study of integral equations of the first kind.

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 noncausal 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.

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 the Gustaf Sigurd Magnuson Foundation.

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 [R15] 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 [A16] we consider the case of complete state feedback, in which case an OUR always exists. The problem of optimal tracking is also considered.

Robust control of electrical drives

Researchers: P. O. Gutman, Xiaoming Hu, Mattias Nordin and Anders Lindquist, in cooperation with Johann Galic (ABB Drives AB, Västerås).

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK) and ABB Drives AB.

The aim of this project is to combine robust linear control with nonlinear control elements, implemented in a microprocessor, that alleviate the effects of the process nonlinearities. In particular are electrical drives with friction, back-lash and uncertain loads and disturbances be studied.

The project has been running since January 1992, and has received continued funding until June 1996.

During the past year the activities have been concentrated mainly in the following areas: robust identification and robust frequency analysis [A8][A9][A7][R9], robust control of systems with friction [A21][A22][A12][R3][R4], robust control of systems with backlash [A21][A19][A17][A20], and control of elastic systems, and systems with oscillative disturbances [A16][A18][R16].

Robust feedback control of nonlinear and uncertain systems

Researcher: Xiaoming Hu.

Sponsor: TFR.

This project is devoted to several important issues in feedback design for the control of nonlinear systems affected by disturbances.

In the past year we have concentrated our efforts on the problem of feedback stabilization on compacta for nonlinear control systems. Some new results of feedback stabilization on compacta are obtained by using an invariant manifold approach. In particular, a class of globally nonminimum phase systems are treated. Issues such

as high gain feedback stabilization on compacta vs. peaking phenomenon, and globally exponentially minimum phase vs. globally asymptotically (critically) minimum phase are also studied.

In order to solve the problem of stabilization on compacta, a natural way is to use high gain feedback controls, where the gain is tunable according to the size of the initial data set. In order to obtain a high gain regulator as the result of an optimal control problem, the cost of the control should be "cheap". In the past year, The cheap control regulator for time-invariant nonlinear systems has also been studied with respect to uniform L^2-boundedness of the state trajectories in the case where the small parameter "ϵ" tends to zero. We have obtained some preliminary results on the state-space conditions for L^2-boundedness.

Stochastic realizations and geometric control theory—a synthesis

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

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

In this project we show that there is an important connection between the geometric theory of splitting subspaces and geometric control theory in the style of Wonham and Basile and Marro. We introduce the notion of *output-induced subspace* of a minimal Markovian splitting subspace, and show that it is the analogue of *supremal output nulling subspace* in geometric control theory. Then we show how the zero structure of the family of (not necessarily square) spectral factors relates to the family of minimal Markovian splitting subspaces in the sense that the relationship between the zeros of different spectral factors is reflected in the partial ordering of minimal splitting subspaces and the corresponding solutions of the algebraic Riccati inequality. In [A15] we considered the continuous-time systems with nonsingular noise. This is the simplest case in which the *supremal reachability space* becomes trivial under our correspondence. In general this is not the case, and consequently more structure is introduced, especially in the discrete-time case [R12], [A25]. This corresponds to singular control.

What makes the discrete-time case more complicated is the possibility of the occurrence of invariant directions. Now we also need to introduce the stronger concept of *strictly output-induced subspace*. In [R12] we discuss the role of invariant directions, zeros of spectral factors and output-induced subspaces in determining the systems-theoretical properties of the 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 Y^* now plays the role of maximal output-induced subspace in the regular case. We also show that Y^* can be determined by algorithms akin to that used in geometric control theory for determining the maximal output-modeling subspace Y^*. 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, a remarkable fact that enables us actually

to compute these spaces.

Stochastic realization theory and identification

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

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

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

In [R14] we demonstrate that there is no guarantee that several popular identification procedures based on the same principle will not fail to produce a positive extension, unless some rather stringent assumptions are made which, in general, are not explicitly reported. This brings in the issue of stochastic model reduction. The statistical problem of stochastic modeling from estimated covariances is phrased in the geometric language of stochastic realization theory. We discuss the concept of stochastic balancing and of stochastic model reduction by principal subsystem truncation. The model reduction method of Desai and Pal, based on truncated balanced stochastic realizations, is partially justified, showing that the reduced system structure is has a positive covariance sequence but is in general not balanced. As a byproduct of this analysis we obtain a theorem prescribing conditions under which the "subspace identification" methods produce *bona fide* stochastic systems.

The minimal rational covariance extension problem

Researchers: Anders Lindquist and Per Enqvist, in cooperation with C. I. Byrnes (Washington University, St Louis) and S. V. Gusev and A. S. Matveev (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. This problem of finding all positive real rational functions interpolating the given covariance sequence is a version the Carathéodory extension problem with the added requirement of rationality.

In [A5] we formalize 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 are 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 are 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 enables us to analyze the robustness of this parameterization with respect to variations in the problem data.

In [R8] 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.

2.2.2 Description of projects in Mathematical Programming

Allocation of scarce track capacity

Researchers: Ulf Brännlund, P. O. Lindberg and Andreas Nöu in cooperation with 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.

Preliminary computational testing shows that the method works and it gives close to optimal solutions within two hours in a rather slow computation environment (Matlab).

Results have been reported in [P23].

Computation of global optima to polynomial optimization problems

Researchers: P. O. Lindberg, Lars Svensson, and Kristoffer Hägglöf.

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK).

This is a miniproject that applies Gröbner base theory to the computation of global optima to polynomial optimization problems.

Results have been presented in [P26] and will appear in [A36].

Dual methods for large scale optimization problems

Researchers: P. O. Lindberg, Ulf Brännlund, Stefan Feltenmark, Andreas Nöu, in cooperation with Don Hearn (University of Florida) and Krzysztof Kiwiel (Polish Academy of Sciences).

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK), Swedish Research Council for Engineerig Sciences (TFR), Swedish Transport Research Board (TFB), Vattenfall AB, Swedish National Rail Administration (Banverket).

Industrial contacts: ABB Network Control AB, Krångede Power Pool, Swedish National Rail Administration (Banverket) .

This is a meta project aiming at obtaining efficient dual methods for large scale optimization problems.

Central subprojects are the projects on short term power planning, structured duals and large scale decomposition. These projects share a common structure. Therefore it has been possible to exchange program modules between the projects (as planned). A similar project lead by Don Hearn in Florida is part of this program exchange.

The project on scarce track capacity also shares the same methodology. So does the project on crew and vehicle scheduling.

The common philosophy gives a strong backbone to our projects.

Finally, this meta project benefits strongly from the Optimization Laboratory.

Dual methods for short term power planning problems

Researchers: P. O. Lindberg and Stefan Feltenmark.

Sponsor: The Ernst Johnson Foundation.

Industrial contacts: ABB Network Control AB, Krångede Power Pool, Vattenfall AB.

This project comprises a host of related, but diverse, problems. The Economic Dispatch Problem (EDC) concerns the optimal distribution of an electric load among power generating units, while keeping reserves. For this problem, we have developed an efficient method based on the special structure of the constraints. A generalization of EDC includes the transmission network, so called Optimal Power Flow (OPF). We have done preliminary studies on OPF, which is a non-convex, large-scale, sparse programming problem.

When applying Lagrangian decomposition to short term planning of a system that includes thermal- and hydrounits, one get independent subproblems, the solutions of which must be coordinated. We have previously treated the variable-head

hydroelectric planning problem, showing how to compute local optima to this non-convex, network flow problem by modifying algorithms for the linear case. The thermal subproblem is described in another project. We have also initiated work on the hydro-thermal coordination, which suffers from severe instability due to the extreme point solutions of the hydro subproblem.

Dual methods for the unit commitment problem

Researchers: Stefan Feltenmark and P. O. Lindberg.

Sponsor: The Ernst Johnson Foundation.

Industrial contacts: ABB Network Control AB, Krångede Power Pool, Vattenfall AB.

This project aims at developing efficient dual methods for large scale unit commitment problems (i.e. short term production planning for thermal power stations). The work has evolved along the following lines:

- We have developed algorithms for the static EDC problem, which is solved each time one constructs a primal feasible solution [P13].
- We have experimentally shown that there are *few* commitment plans optimal to the subproblems in the neighbourhood of the dual optimum.
- Based on the previous observation, we have developed an algorithm for the exact solution of the dual problem.
- We have started to look at different ways of closing the duality gap, including branch-&-bound and Benders decomposition, which may benefit from the results above. (I.e. good lower bounds, and efficient subproblem solutions (EDC)).

Infinite-dimensional quadratic optimization: Interior-point methods and control applications

Researcher: Leonid Faybusovich.

An infinite-dimensional version of the interior-point technique of Nesterov-Nemirovsky has been developed. Complexity estimates which coincide with the best known for the finite-dimensional case have been obtained. Control applications include: linear-quadratic control pro blem with quadratic constraints, linear-quadratic stochastic control problem with partial observations, various versions of the separation theorem with constraints.

KTH Optimization Laboratory

Researchers: P. O. Lindberg, Patrik Alfredsson, Ulf Brännlund, Stefan Feltenmark, Anders Forsgren, Jorge Marí, Andreas Nöu, 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, Aeronautical Research Inst of Sweden, AlfGam Optimering AB, Avesta AB, Ericsson Telecom, Forest Operations Institute, Krångede Power Pool, Swedish Defense Material Administration (FMV), Swedish National Rail Administration (Banverket), Swedish State Power Board, Swedish Telecommunications Administration, Stockholm Transport (SL), Systecon 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, QPSOL, LSSOL, NPSOL	(Gill et al, Stanford)
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 Adademy of Sciences)
RSDNET, RSDTA	(Hearn, U Florida)
NAG	(NAG)
GAMS	(GAMS)
ELSUNC, ENLSIP	(Umeå University)

During the year we have continued working at collecting optimization routines and facilitating easy use of these routines. For several routines, we have written an interface to MATLAB, thereby making them easy to use. These interfaced routines have been used extensively, both in our own research and for educational purposes.

The lab has a SUN 670MP server with several work stations connected to it.

Large scale decomposition and nonsmooth optimization

Researchers: Ulf Brännlund and P. O. Lindberg.

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

Many important optimization problems are inherentely nonsmooth, i.e. the objective function does not have continuous derivatives. A typical source of nondifferentiability is when the objective function is the maximum of other functions. One such very important class of nonsmooth problems arise in decomposition in the framework of Lagrangian relaxation.

In this project we try to extend and improve a new bundle method for nonsmooth optimization, which was developed in Brännlund's thesis. We believe this bundle method, is more stable than other bundle methods at least when a good estimate of the optimal value is known. This is the case in decomposition and many other nonsmooth optimization problems. In [A28] we present a new bundle method for, possibly, constrained convex optimization. It does not use linesearches and it is proven to be globally convergent. This work continues. In particular, we plan to perform extensive numerical testing on real problems, arising from large scale decomposition, and also difficult academic testproblems.

Locomotive scheduling

Researchers: Andreas Nöu (P. O. Lindberg; advisor), 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 have, after preprocessing, more than 2400 locomotive requests. We consider two types of locomotives. Our preliminary computational results are encouraging.

Methods for structured dual problems

Researchers: P. O. Lindberg and Stefan Feltenmark, in cooperation with Alfredo Piria (University of Montevideo).

Sponsor: The Swedish National Board for Industrial and Technical Development (NUTEK).

Large decomposable problems often have a separable structure. The duals of such problems also have a separable structure. This can be utilized in developing solution techniques.

We have generalized the subgradient technique with Polyak steps to this setting. Then one updates the multipliers after each subproblem solution.

We have also utilized the detailed structure of unit commitment problems to attack the bidual [P21].

Optimal expansion strategies for telecom networks

Researchers: P. O. Lindberg and Kristoffer Hägglöf, in cooperation with Per Lindberg (Telia Research) and Anders Rudberg (Ericsson Telecom).

Sponsor: The Swedish National Board for Industrial and Technical Development (NUTEK).

Industrial contacts: Ericsson Telecom and Telia Research.

This project is concerned with optimal expansion strategies for telecom networks in the face of large uncertainties concerning demand and technical developement.

We aim to model the problem as a multistage stochastic programming problem. The underlying network structure implies that we could utilize the structure to devise efficient methods.

We have applied for and received a research grant for studying the area under the "complex systems" program at NUTEK.

Optimal short term operation of a cascade of hydropower stations

Researchers: P. O. Lindberg and Andreas Wolf.

Sponsors: Swedish Research Council for Engineerig Sciences (TFR) and Vattenfall AB.

Industrial contact: Vattenfall AB.

In a cascade of hydropower stations considerable head losses can occur between stations. This is typically the case in river-like reservoirs. Head losses are high when

the flow is high relative to the depth and width of the river. Furtheron head losses are varying due to changes in flow and water levels.

Varying head losses cause varying travel times of the water between stations. Up to now models for a cascade of hydropower stations either use a constant travel time or neglect the travel time at all. In river-like reservoirs this approximation is poor.

A new type of model, the dynamic production model DYNPRO, has been developed at Vattenfall. The new feature is that a hydrodynamic model is used for the river to obtain the head as a function of time at each station. After having simulated the head the production and its value are calculated.

The aim of the ongoing project is to develop DYNPRO from being a simulation model to become an optimization model. We have designed a scheme to compute gradient information efficiently and will test it using the Matlab environment.

Optimization of spare parts inventory systems

Researchers: P. O. Lindberg and Patrik Alfredsson.

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 are devoloping algorithms for solving this difficult, nonconvex, nonlinear integer problem. We have 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 are influencing 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 also studied robustness issues and are developing techniques to obtain more robust solutions (spare parts allocations).

During the academic year results have been presented at the MPS symposium in Ann Arbor[P1] and the European Summer Institute at Chester, UK[P3].

Random utility models

Researchers: P. O. Lindberg, in cooperation with Anders E. Eriksson (Swedish Defense Research Establishment), Lars-Göran Mattsson (KTH) and Tony Smith (University of Pennsylvania).

Industrial contact: Stockholm County Council.

This is a long running project aiming at developing the theoretical foundations of random-utility-models. During the year we have continued our work on the Robertsson-Strauss model [A37] and on applications of a previous paper to congestion tolls [A29] as well as on the existence of stochastic equilibria in very generel serttings [R20].

Second-derivative methods for nonlinear programming

Researchers: Anders Forsgren, in cooperation with Philip E. Gill (UCSD), Walter Murray (Stanford University) and Joseph R. Shinnerl (UCSD).

Sponsors: The Swedish Natural Science Research Council (NFR) and the Royal Swedish Academy of Sciences (Magnusons fond, KVA).

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.

A paper describing joint work with Philip E. Gill and Walter Murray on the computation of modified Newton directions using a partial Cholesky factorization has been published during the year [A34].

Recent joint work with Walter Murray has been focused 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 report, dealing with strategies suitable for large-scale problems has been written [R25].

Together with Philip E. Gill and Joseph R. Shinnerl, the stability of barrier equations has been investigated. In particular, the focus has been on the stability of the symmetric indefinite systems of equations that arise in barrier methods for constrained optimization [A35].

One subproject has been directed to weighted linear least-squares problems. Such problems arise when using interior methods, and good understanding of these problems is of vital importance for extending the stability analysis further. A report dealing with extensions of results for diagonal matrices to more general matrices such as diagonally dominant matrices has been written [R24].

Structural optimization

Researcher: Krister Svanberg.

The goal of this project is a reliable and efficient method for solving structural optimization problems, i.e. problems dealing with the optimal design of load-carrying structures.

During the year, some new results concerning the convergence of a classical method for structural sizing have been published in [A38]. Further, a new version of the Method of Moving Asymptotes (MMA), which is a mathematical programming method for structural optimization, has been developed and proven to be globally convergent, see [A39].

3 Education

3.1 Undergraduate courses

5B1710 Optimeringslära, allmän kurs för D och F, Optimization, General Course

A. Forsgren 3.5 p

5B1720 Optimeringslära, allmän kurs för T, Optimization, General Course

U. Brännlund 4 p

5B1740 Matematisk systemteori, Mathematical System Theory

T. Björk 3.5 p

5B1750 Optimeringslära, grundkurs för E, Optimization

K. Svanberg 4 p

5B1780 Matematikens och datateknikens tillämpningar, Applications of Mathematics and Computer Science

T. Björk 3 p

5B1810 Matematisk programmering, Mathematical Programming

K. Svanberg 5 p

5B1820 Matematisk systemteori, fortsättningskurs, Advanced Course in Mathematical Systems Theory

A. Lindquist 4 p

5B1830 Systemteknik, Systems Engineering

P. O. Lindberg 7 p

5B1840 Systemtekniska metoder, Methods of Systems Engineering

U. Brännlund 3.5 p

5B1850 Matematisk ekonomi, Mathematical Economics

T. Björk 3 p

5B1862 Stokastisk kalkyl och kapitalmarknadsteori, Stochastic calculus and the theory of capital markets

T. Björk 5 p

5B1870 Optimal styrteori, Optimal Control Theory

T. Björk 3.5 p

5B1880 Produktions- och lagerstyrning, Production and Inventory Control

P. O. Lindberg 3 p

3.2 Graduate courses

Course name	Instructor	Credit	Participants KTH	Participants industry
Combinatorial Optimization	A. Forsgren	5 p	5	-
Nonlinear Control System Analysis	X. Hu	5 p	9	2

3.3 Licentiate theses

[T1] J. Marí, *Mathematical Methods Applied to Biotechnical Processes*, TRITA-MAT-94-43, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1994. Advisor: P. O. Lindberg.

[T2] M. Nordin, *Uncertain systems with backlash: Modeling, Identification and Synthesis*, (Consists of five separate papers), Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1995. Advisors: P.-O. Gutman and A. Lindquist.

3.4 Master theses (Examensarbeten)

4 Publications

4.1 Published (and accepted) papers

4.1.1 Published (and accepted) papers in Systems and Control

[A1] J. Ackermann and X. Hu, *Acceleration and braking effects on robustly decoupled car steering (short version)*, To appear in Proc. 3rd European Control Conference, Rome, September, 1995.

[A2] J. P. Axelsson, P. O. Lindberg, and J. Marí, *Design of optimal feed profiles for fedbatch production of human growth factors using yeast*, Proceedings 1st Asean Control Conference, Tokyo, July 27-30, 1994, 315-318.

[A3] V. Blondel, M. Gevers, and A. Lindquist, *Major open problems and challenges in control systems theory*, European Journal of Control, to be published.

[A4] C. I. Byrnes and A. Lindquist, *Toward a solution of the minimal partial stochastic realization problem*, Comptes Rendus Acad. Sci. Paris, t. 319, Série I, p. 1231–1236, 1994.

[A5] C. I. Byrnes, A. Lindquist, S. V. Gusev and A. S. Matveev, *A complete parameterization of all positive rational extensions of a covariance sequence*, IEEE Transactions on Automatic Control, to be published.

[A6] C. I. Byrnes, A. Lindquist, S. V. Gusev and A. S. Matveev, *The geometry of positive real functions with applications to the rational covariance extension problem*, Proc. 33rd Conf. on Decision and Control, 3883–3888.

[A7] B. Cohen, M. Nordin and P.-O. Gutman, *Recursive grid methods to compute value sets for transfer functions with parametric uncertainty*, Proc. American Control Conference, June 21-23, San Francisco, 1995.

[A8] P.-O. Gutman, *On-line parameter interval estimation using recursive least squares*, International J. Adaptive Control & Signal Processing 8 (1994), 61–72.

[A9] P.-O. Gutman, C. Baril and L. Neumann, *An algorithm for computing value sets of uncertain transfer functions in factored real form*, IEEE Trans. Aut. Contr. 39 (1994), 1268–1273.

[A10] P.-O. Gutman, K. Peleg and U. Ben-Hanan, *Classification by varying features with an erring sensor*, Automatica 30 (1994), 1943–1948.

[A11] X. Hu, *An invariant manifold approach to nonlinear feedback stabilization on compacta*, To appear in J. Math. Systems, Estimation, Control.

[A12] X. Hu, *Nonlinear control of servo systems affected by friction forces*, Proc. 33rd IEEE Conference on Decision and Control, Orlando, Florida, December 14–16, 1994.

[A13] I. Ioslovich, P.-O. Gutman and I. Seginer, *A non-linear optimal greenhouse control problem with heating and ventilation*, Tentatively accepted in Optimal Control, Appl. & Methods, 1995.

[A14] I. Ioslovich, I. Seginer, P.-O. Gutman and M. Borshchesvsky, *Suboptimal CO2-enrichment in greenhouses*, J. Agr. Eng. Research 60 (1995), 117–136.

[A15] A. Lindquist, Gy. Michaletzky, and G. Picci, *Zeros of spectral factors, the geometry of splitting subspaces, and the algebraic Riccati inequality*, SIAM J. Control and Optimization 33 (1995), 365–401.

[A16] A. Lindquist and V. A. Yakubovich, *Optimal damping of forced oscillations in discrete-time systems*, IEEE Transactions on Automatic Control, to be published.

[A17] M. Nordin, J. Galić and P.-O. Gutman, *New models for backlash and gear play*, Int. J. of Adaptive Control and Signal Processing, 1995 (accepted).

[A18] M. Nordin and P.-O. Gutman, *Digital QFT design for the flexible transmission benchmark problem*, Invited paper to 1995 European Control Conference.

[A19] M. Nordin and P.-O. Gutman, *A robust linear design of an uncertain two-mass system with backlash*, Proc. First IFAC Workshop on Advances in Automotive Control, Ascona, Switzerland, March 13–17, 1995.

[A20] M. Nordin and P. Bodin, *A backlash gap estimation method*, Accepted to 1995 European Control Conference.

[A21] S. Oldak, C. Baril and P.-O. Gutman, *Quantitative design of a class of nonlinear systems with parameter uncertainty*, Int. J. Robust & Nonlinear Control 4 (1994), 101–117.

[A22] S. Oldak and P.-O. Gutman, *Self oscillating adaptive design of systems with dry friction and significant parameter uncertainty*, Int. J. Adaptive Control & Signal Processing, 1995 (accepted).

[A23] J.-Å. Sand, *Reciprocal realizations on the circle*, To appear in SIAM Journal on Control and Optimization.

[A24] J.-Å. Sand, *Two-sided linear prediction and reconstruction of a stationary time series*, To appear in IEEE Transactions on Signal Processing.

[A25] J.-Å. Sand, *Zeros of discrete-time spectral factors, and the internal part of a Markovian splitting subspace*, Journal of Mathematical Systems, Estimation, and Control (to appear).

4.1.2 Published (and accepted) papers in Mathematical Programming

[A26] U. Brännlund, *A generalized subgradient method with relaxation step*, Mathematical Programming, To appear.

[A27] U. Brännlund, K. C. Kiwiel and P. O. Lindberg, *A descent level bundle method for convex nondifferentiable optimization*, In U. Derigs editor, *Operations Research Proceedings 1994*. Springer Verlag. Berlin 1995.

[A28] U. Brännlund, K.C. Kiwiel, and P. O. Lindberg, *A descent proximal bundle method for convex nondifferentiable optimization*, Operation Research Letters 17 (1995), 121–126.

[A29] E. A. Eriksson, P. O. Lindberg, and T. Smith, *Existence of optimal tolls under conditions of stochastic user equilibria*, In Johansson-Mattsson (Eds), Road Pricing: Theory, Empirics, Assessment and Policy, Kluwer, 1994, 65-87.

[A30] L. Faybusovich, *On a matrix generalization of affine-scaling vector fields*, SIAM Journal of Matrix Analysis and Applications 16 (1995), 886–897.

[A31] L. Faybusovich, *A Hamiltonian structure for generalized affine-scaling vector fields*, Journal of Nonlinear Science 5 (1995), 11–28.

[A32] L. Faybusovich, *A Hamiltonian formalism for optimization problems*, Journal of Mathematical Systems, Estimation and Control 5 (1995), 367–370.

[A33] L. Faybusovich, *Semi-definite programming: a path-following algorithm for a linear-quadratic functional*, To appear in SIAM Journal on Optimization.

[A34] A. Forsgren, P. E. Gill and W. Murray, *Computing modified Newton directions using a partial Cholesky factorization*, SIAM Journal on Scientific Computing 16 (1995), 139–150.

[A35] A. Forsgren, P. E. Gill and J. R. Shinnerl, *Stability of symmetric ill-conditioned systems arising in interior methods for constrained optimization*, To appear in SIAM Journal on Matrix Analysis and Applications.

[A36] K. Hägglöf, P. O. Lindberg, and L. Svensson, *Computing global optima to polynomial optimization problems using Gröbner bases*, To appear in J. Global Optimization.

[A37] P. O. Lindberg, E. A. Eriksson and L.-G. Mattsson, *Invariance of achieved utility in random utility models*, Environment and Planning A 27 (1995), 121-142.

[A38] K. Svanberg, *Global convergence of the stress ratio method for truss sizing*, Structural Optimization 8 (1994), 60–68.

[A39] K. Svanberg, *A globally convergent version of MMA without linesearch*, To appear in Proceedings of the First World Congress of Structural and Multidisciplinary Optimization, Goslar, Germany, May 28-June 2, 1995.

4.2 Technical reports and preprints

4.2.1 Technical reports and preprints in Systems and Control

[R1] J. Ackermann and X. Hu, *Acceleration and braking effects on robustly decoupled car steering (long version)*, Preprint.

[R2] C. Baril and J. Galić, *Speed control of an elastic two-mass system*, Report TRITA-MAT-94-29, Department of Mathematics, KTH, 1994.

[R3] C. Baril and P.-O. Gutman, *Performance enhancing adaptive friction compensation for uncertain systems*, Submitted to IEEE Trans. Control Systems Technology.

[R4] C. Baril and P.-O. Gutman, *Adaptive friction compensation for uncertain systems: the servo case*, Preprint.

[R5] T. Björk, *Barrier options, lookbacks and ladders*, Preprint.

[R6] T. Björk, *On the term structure of discontinuous interest rates*, Preprint.

[R7] T. Björk, Y. Kabanov and W. Runggaldier, *Bond markets where prices are driven by a general marked point process*, Preprint.

[R8] C. I. Byrnes and A. Lindquist, *On the partial stochastic realization problem*, Preprint.

[R9] N. Galperin and P.-O. Gutman, *On-line identification of transfer function value sets using Lissajou figures*, Preprint.

[R10] P.-O. Gutman and B. Nilsson, *Modelling and prediction of bending stiffness for paper board manufacturing*, submitted to 13th IFAC World Congress, San Francisco, June 30 - July 5, 1996.

[R11] X. Hu and C. Larsson, *On bounded peaking in the cheap control regulator*, Preprint.

[R12] A. Lindquist and Gy. Michaletzky, *Output-induced subspaces, invariant directions and interpolation in linear discrete-time stochastic systems*, Submitted for publication in SIAM J. Control and Optimization.

[R13] A. Lindquist and G. Picci, *On "subspace methods" identification and stochastic model reduction*, Proc IFAC Workshop on Systems Identification, Copenhagen, July, 1994, pp. 397–403.

[R14] A. Lindquist and G. Picci, *Canonical correlation analysis, approximate covariance extension, and identification of stationary time series*, Submitted for publication in Automatica.

[R15] A. Lindquist and V. A. Yakubovich, *Optimal damping of forced oscillations by output feedback*, Submitted for publication in Automatica.

[R16] M. Nordin and P.-O. Gutman, *A robust QFT design for a multivariable paper machine benchmark*, Submitted to 34th IEEE Conference on Decision and Control, New Orleans, Dec 13-15, 1995.

4.2.2 Technical reports and preprints in Mathematical Programming

[R17] P. Alfredsson, *Optimization of a multi-echelon repairable item inventory system with simultaneous repair facility localization*, Preprint, 1995, Submitted for publication.

[R18] G. Andersson, B. Berggren and P. O. Lindberg, *A strongly polynomial algorithm for a nonconvex binary optimization problem in power system dynamics*, Submitted for publication.

[R19] U. Brännlund, *A simplex method for semi-definite programming*, Report TRITA-MAT-1994-47, Department of Mathematics, KTH, 1994.

[R20] E. A. Eriksson, P. O.Lindberg and T. Smith, *Stochastic equilibria in general additive random utility models*, Submitted for publication.

[R21] L. Faybusovich and J. Moore, *Infinite-dimensional optimization: Interior-point methods and control applications*, Preprint.

[R22] L. Faybusovich and J. Moore, *A long-step path-following algorithm in a Hilbert space*, Preprint.

[R23] L. Faybusovich and Y. Nakamura, *On explicitly solvable gradient systems of Moser-Karmarkar type*, Preprint.

[R24] A. Forsgren, *On linear least-squares problems with diagonally dominant weight matrices*, Report TRITA-MAT-1995-OS2, Department of Mathematics, KTH, 1995. (Submitted to SIAM Journal on Matrix Analysis and Applications.).

[R25] A. Forsgren and W. Murray, *Newton methods for large-scale linear inequality-constrained minimization*, Report TRITA-MAT-1994-44, Department of Mathematics, KTH, 1994. (Submitted to SIAM Journal on Optimization.).

[R26] K. Hägglöf, P. O. Lindberg and L. Svensson, *Computing global minima to polynomial optimization problems using Gröbner bases*, Department of Mathematics, KTH, 1995.

[R27] K. C. Kiwiel, A. Nöu, and P. O. Lindberg, *Dual Bregman proximal methods for large-scale 0-1 problems*, Preprint, Department of Mathematics, KTH, 1995.

5 Seminars at the division

- Professor Leonid Faybusovich, University of Notre Dame, USA, *Interior-point methods as a tool for solving control problems*, Sep. 30, 1994.
- Professor Krzysztof C. Kiwiel, Systems Research Institute, Polish Academy of Sciences, *Free-steering relaxation methods for problems with strictly convex costs and linear constraints*, Oct. 7, 1994.
- Professor Christopher I. Byrnes, Washington University, St Louis, USA, *Feedback stabilization about attractors and inertial manifolds*, Oct. 14, 1994.
- Professor Jørgen Aase Nielsen, Department of Operations Research, University of Aarhus, Denmark, *Equity-linked life insurance—a model with stochastic interest rates*, Oct. 17, 1994.
- Dr. Andrea Gombani, LADSEB-CNR, Padova, Italy, *On the differential structure of matrix valued rational inner functions*, Oct. 28, 1994.
- Professor Sjur Didrik Flåm, Economics Department, Bergen University, Norway, *Equilibrium programming*, Nov. 25, 1994.
- Professor Jürgen Ackermann, German Aerospace Research Establishment, Germany, *Robust control for car steering*, Nov. 28, 1994.
- Dr. Ruggero Frezza, University of Padova, Italy, *Autonomous navigation and environment reconstruction based on splines*, Dec. 2, 1994.
- Jorge Marí, Optimization and Systems Theory, KTH, *Mathematical methods applied to biotechnical processes* (Licentiate seminar), Jan. 20, 1995.
- Professor Arthur J. Krener, Dept of Mathematics, University of California, Davis, USA, *Necessary and sufficient conditions for nonlinear worst H^∞-control and estimation*, Mar. 15, 1995.
- Professor Alexander L. Fradkov, Inst. for Problems of Mechanical Eng., Academy of Sciences of Russia, St. Petersburg, *Adaptive control of periodic and chaotic nonlinear oscillations*, Mar. 31, 1995.
- Professor Vladimir A. Yakubovich, St Petersburg University, Russia, *Nonconvex optimal control problems*, Apr. 4, 1995.
- Xiaoming Hu, Optimization and Systems Theory, KTH, *Feedback stabilization of nonlinear control systems* (Docent seminar), Apr. 6, 1995.
- Anders Forsgren, Optimization and Systems Theory, KTH, *Second-derivate methods for optimization* (Docent seminar), Apr. 7, 1995.
- Professor Philip E. Gill, University of California, San Diego, USA, *SQP methods for large-scale constrained optimization*, Apr. 21, 1995.
- Dr. Alexander Stotsky, Inst. for Problems of Mechanical Eng., Academy of Sciences of Russia, St. Petersburg, *Combined variable structure and adaptive control with application to vehicle following control*, Apr. 26, 1995.
- Dr. Riho Lepp, Institute of Cybernetics, Estonian Academy of Sciences, *On approximations in stochastic programming*, Apr. 28, 1995.
- Professor Jonathan Bard, Dept of Mechanical Engineering, University of Texas, USA, *The vehicle routing problem with time windows: combining heuristics with a branch and cut algorithm*, Jun. 1, 1995.

- Professor Jonathan Bard, Dept of Mechanical Engineering, University of Texas, USA, *Designing long-distance telecommunications networks for the reseller market*, Jun. 1, 1995.
- Mattias Nordin, Optimization and Systems Theory, KTH, *Uncertain systems with backlash: modeling, identification and synthesis* (Licentiate seminar), Jun. 2, 1995.
- Professor Aharon Ben-Tal, Faculty of Industrial Eng. and Management, Technion, Haifa, Israel and University of Copenhagen, Denmark, *Penalty/barrier multiplier methods for convex programming problems with application to structural optimization*, Jun. 14, 1995.
- Professor Aharon Ben-Tal, Faculty of Industrial Eng. and Management, Technion, Haifa, Israel and University of Copenhagen, Denmark, *Stable truss topology design via semidefinite programming*, Jun. 15, 1995.
- Dr. Boris Mordukhovich, Department of Mathematics, Wayne State University, Detroit, USA, *Discrete approximation and optimal control of differential inclusions*, Jun. 16, 1995.
- Professor Donald W. Hearn, Center for Applied Optimization, ISE Department, University of Florida, USA, *Continuous state dynamic programming for dynamic lot size models*, Jun. 28, 1995.

6 Awards and appointments

Anders Forsgren was appointed Docent of Optimization and Systems Theory.

Xiaoming Hu was appointed Docent of Optimization and Systems Theory.

7 Presentations by staff

[P1] P. Alfredsson, *Calculating parameter sensitivities in repairable item inventory systems*, 15th International Symposium on Mathematical Programming, Ann Arbor, Michigan, USA, August 19, 1994.

[P2] P. Alfredsson, *Quantitative methods for system optimization*, Advanced Course in Reliability and LCC arranged by FMV, Stockholm, Sweden, January 15, 1995.

[P3] P. Alfredsson, *Optimal allocation of spares and test equipment with simultaneous level of repair determination*, European Summer Institute XI, Chester, UK, April 23, 1995.

[P4] P. Alfredsson, *Optimal allocation of spares and test equipment with simultaneous level of repair determination*, 6th Stockholm Optimization Days, KTH, Stockholm, Sweden, June 26, 1995.

[P5] T. Björk, *On the term structure of discontinuous interest rates*, ETH Zurich, February, 1995.

[P6] T. Björk, *Parameter estimation*, Lund University, September, 1994.

[P7] T. Björk, *On the term structure of discontinuous interest rates*, Helsiniki University, January, 1995.

[P8] T. Björk, *On the term structure of discontinuous interest rates*, University of Cambridge, February, 1995.

[P9] T. Björk, *Bond markets where prices are driven by a general marked point process*, University of Aarhus, April, 1995.

[P10] U. Brännlund, *A descent proximal level bundle method for convex nondifferentiable optimization*, Mathematical Programming Symposium, Ann Arbor, August 14–19, 1994.

[P11] U. Brännlund, *Level methods for convex optimization*, *Nonsmooth and discontinuous optimization and applications*, IIASA, Laxenburg, Austria, June 12-16, 1995.

[P12] U. Brännlund, *Positive definite programming and the simplex method*, 6th Stockholm Optimization Days, Stockholm, Sweden, June 26-27, 1995.

[P13] S. Feltenmark, *A continuous convex knapsack problem with one convex complicating constraint: The economic dispatch problem*, 15th International Symposium on Mathematical Programming, The University of Michigan, Ann Arbor, Michigan, U. S. A., August 15-19, 1994.

[P14] S. Feltenmark, *Economic dispatch calculation*, Dept of Electric Power System Engineering, KTH, January 24, 1995.

[P15] S. Feltenmark, *Head-dependent hydro power scheduling*, The 6th Stockholm Optimization Days, Stockholm, Sweden, June 26–27, 1995.

[P16] A. Forsgren, *Stability of symmetric ill-conditioned systems arising in interior methods for constrained optimization*, The 15th International Symposium on Mathematical Programming, Ann Arbor, Michigan, August 14–19, 1994.

[P17] A. Forsgren, *On linear least-squares problems with diagonally dominant weight matrices*, Conference on Least Squares Methods: Theory, Algorithms and Applications, Linköping, Sweden, January 9–10, 1995.

[P18] A. Forsgren, *Stability of symmetric ill-conditioned systems arising in interior methods for constrained optimization*, Conference on Numerical Analysis in honor of Germund Dahlquist's 70th birthday, Stockholm, Sweden, January 11–13, 1995.

[P19] A. Forsgren, *On linear least-squares problems with diagonally dominant weight matrices*, The 6th Stockholm Optimization Days, Stockholm, Sweden, June 26–27, 1995.

[P20] X. Hu, *Nonlinear control of servo systems affected by friction forces*, The 33rd IEEE Conference on Decision and Control, Orlando, Florida, December, 1994.

[P21] P. O. Lindberg, *Solving large structured duals of unit commitment problems*, 15th Math Programming Symposium, Ann Arbor, Michigan, August 14–19, 1994.

[P22] P. O. Lindberg, *What has optimization to do with systems engineering? Quantitative methods for systems engineering* (in Swedish), Reference group meeting for Systems Engineering, Oct 10, 1994.

[P23] P. O. Lindberg, *Allocation of scarce track capacity through Lagrangean relaxation*, Workshop on Optimization in Production and Transportation, Scheveningen, Nov 9–11, 1994.

[P24] P. O. Lindberg, *Potential of model based optimization vs neural networks and other recent methods*, Pharmacia Peptide Hormones, Jan 25, 1995.

[P25] P. O. Lindberg, *Computing the best solution without testing all alternatives* (in Swedish), The Math Gym (a series of lectures for undergraduates and high school teachers), Feb 10, 1995.

[P26] P. O. Lindberg and B. Berggren, *A strongly polynomial algorithm for a nonconvex binary optimization problem in power system dynamics*, Dept of Electric Power Systems, KTH, April 19, 1995.

[P27] P. O. Lindberg, *Computing global optima to polynomial optimization problems using Gröbner bases*, Conf. State of the art in global Optimization, Princeton, April 27-29.

[P28] P. O. Lindberg, *A differentiable dual approach to large scale 0-1 problems*, Dept. Industrial and Systems Engineering, University of Florida, Gainesville, May 4, 1995.

[P29] P. O. Lindberg, *Neighbourhood structures in nonlinear integer programming*, KTH-Yale Workshop, KTH, May 23, 1995.

[P30] P. O. Lindberg, *A strongly polynomial algorithm for a nonconvex binary optimization problem in power system dynamics*, 6th Stockholm Optimization Days, June 26–27, 1995.

[P31] A. Lindquist, *Some recent results on the rational covariance extension problem*, Invited plenary lecture, IEEE European Workshop on Computer Intensive Methods in Control and Signal Processing, Prague, September 7–9, 1994.

[P32] A. Lindquist, *Optimal damping of forced oscillations*, KTH–ABB minisymposium, Prague, September 7–9, 1994.

[P33] A. Lindquist, *Subspace identification and positivity. What are the hidden assumptions?*, Plenary lecture, ERNSI Workshop, Amsterdam, October 10, 1994.

[P34] A. Lindquist, *Some recent results on the rational covariance extension problem*, Minisymposium organized by the Hungarian Operations Research Society in honor of Anders Lindquist at the occation of his appointment as an Honorary Member of the society, Budapest, October 31, 1994.

[P35] A. Lindquist, *A complete parametrization of all positive rational extensions of a covariance sequence*, University of Padova, Italy, November 18, 1994.

[P36] A. Lindquist, *The geometry of positive real functions with applications to the rational covariance extension problem*, 33rd IEEE Conference on Decision and Control, Lake Buena Vista, Florida, December 14–16, 1994.

[P37] A. Lindquist, *On the rational covariance extension problem – a mathematical problem important in signal processing*, Key note speaker, Annual Meeting of the Finnish Mathematical Society, January 9–10, 1995.

[P38] A. Lindquist, *Some recent results on the rational covariance extension problem*, University of Uppsala, Sweden, January 25, 1995.

[P39] A. Lindquist, *Some recent results on the rational covariance extension problem*, Washington University, St. Louis, February 15, 1995.

[P40] A. Lindquist, *Optimal damping of forced oscillations*, Washington University, St. Louis, March 2, 1995.

[P41] A. Lindquist, *The geometry of positive real functions with applications to the rational covariance extension problem*, Invited plenary lecture, Euler Mathematical Institute, St Petersburg, Russia, March 17, 1995.

[P42] A. Lindquist, *Some recent results on the rational covariance extension problem*, Workshop on the Dynamics and Control of Physical Systems, Cortona, Italy, May 22–25, 1995.

[P43] A. Lindquist, *On subspace identification*, Chairman and discussion leader, ERNSI Workshop, Padova, Italy, June 7–9, 1995.

[P44] J. Marí, *Local structure of equality constrained NLP and optimal control problems*, University of Michigan, Aug. 16, 1994.

[P45] J. Marí, *Optimization of input flows for fedbatch production of pharmaceuticals using recombinant yeast*, Västerås, Sweden, October 25, 1994.

[P46] J. Marí, *Optimization in the biotechnical industry*, KABI PHARMACIA Biotech., January 25, 1995.

[P47] J. Marí, *Mathematical methods applied to biotechnical processes*, University of Lund, January 27, 1995.

[P48] M. Nordin, *A robust linear design of an uncertain two-mass system with backlash*, First IFAC Workshop on Advances in Automotive Control, Ascona, Switzerland, March 13–17, 1995.

[P49] M. Nordin, *Recursive grid methods to compute value sets for transfer functions with parametric uncertainty*, American Control Conference, June 21-23, San Francisco, 1995.

[P50] A. Nöu, *A differentiable dual approach to large scale 0-1 problems*, 15th International Symposium on Mathematical Programming, August 14-19, 1994.

[P51] A. Nöu, *A differentiable dual approach to large scale 0-1 problems*, GERAD, Montréal, Canada, December 6, 1994.

[P52] A. Nöu, *A differentiable dual approach to large scale 0-1 problems*, Workshop on Integer Programming, Yale/KTH meeting, KTH, May 22-28, 1995.

[P53] A. Nöu, *Weekly locomotive scheduling*, The 6th Stockholm Optimization Days, Stockholm, Sweden, June 26–27, 1995.

[P54] K. Svanberg, *A globally convergent version of MMA without linesearch*, First World Congress of Structural and Multidisciplinary Optimization, Goslar, Germany, May 28-June 2, 1995.

[P55] K. Svanberg, *A globally convergent method for structural optimization*, The 6th Stockholm Optimization Days, Stockholm, Sweden, June 26–27, 1995.

8 6th Stockholm Optimization Days

The 6th Stockholm Optimization Days were held at KTH in Stockholm, June 26–27, 1995. The format was similar to the previous years with approximately 50 participants, coming from many different countries. The conference was financially supported by the Göran Gustafsson Foundation and the Swedish National Board for Industrial and Technical Development (NUTEK). The organizing committee consisted of U. Brännlund (head), A. Forsgren, P. O. Lindberg, and K. Svanberg.

In total 30 talks were given, among them 15 invited presentations. The following is a list of presentations, where the speakers' names are given in boldface:

Patrik Alfredsson, Royal Institute of Technology, Stockholm, Sweden, *Optimal allocation of spares and test equipment with simultaneous level of repair determination.*

M. C. Bartholomew-Biggs, University of Hertfordshire, Hatfield, England, *Implementing and using a nonlinear least squares method in Fortran 90.*

Aharon Ben-Tal*, Technion, Haifa, Israel, *Optimal design of engineering structures by mathematical programming methods.*

Ulf Brännlund, Royal Institute of Technology, Stockholm, Sweden, *Positive definite programming and the simplex method.*

Jacques Desrosiers*, Eric Gelinas, GERAD and Ecole des HEC, Montreal, Canada, Michel Gamache, Francois Soumis, Daniel Villenueuve, GERAD and Ecole Polytechnique, Montreal, Canada , *A new algorithm for preferential bidding problems.*

Leonid Faybusovich*, University of Notre Dame, Indiana, USA, *Infinite-dimensional quadratic optimization: Interior-point methods and control applications.*

Stefan Feltenmark and P. O. Lindberg, Royal Institute of Technology, Stockholm, Sweden, Daniel Tasende UTE, Uruguay, *Head-dependent hydro power scheduling.*

Sjur Flåm, Bergen University, Norway, *Coordinate subgradient methods and network games.*

Anders Forsgren, Royal Institute of Technology, Stockholm, Sweden, *On linear least-squares problems with diagonally dominant weight matrices.*

Paul Armand, URA, Limoges, France and **Jean-Charles Gilbert**, INRIA, Rocquencourt, France, *A piecewise line-search technique for maintaining the positive definiteness of the matrices in the SQP method.*

Philip E. Gill*, University of California at San Diego, La Jolla, California, USA, *Limited-storage quasi-Newton methods.*

Clovis Gonzaga*, Federal University of Santa Catarina, Brazil, *The complexity of path following algorithms for LCP's using large neighborhoods of the central path.*

Donald W. Hearn* University of Florida, Gainesville, Florida, USA and Alexander L. Hipolito, University of the Philippines, Diliman, Philippines , *An interior point based bundle method for decomposition.*

Claude Lemaréchal* and Claudia Sagastizàbal*, INRIA, Rocquencourt, France, *Toward a definition of favourable convex functions .*

Riho Lepp, Institute of Cybernetics, Tallinn, Estonia, *Approximation of nonlinear control problems.*

*Invited speaker.

G. Andersson, B. Berggren and **P. O. Lindberg**, Royal Institute of Technology, Stockholm, Sweden, *A strongly polynomial algorithm for a nonconvex binary optimization problem in power system dynamics .*

Marko M. Mäkelä and Kaisa Miettinen, University of Jyväskylä, Finland, *Nimbus – Versatile optimization tool for nonlinear programming.*

Robert Mifflin*, Washington State University, Pullman, Washington, USA, *Space decomposition preconditioning in convex minimization.*

Walter Murray*, Stanford University, Stanford, California, USA, *Primal-dual methods for nonconvex optimization problems.*

Yuri Nesterov*, CORE, Catholic University of Louvain, Louvain-la-Neuve, Belgium and Michael Todd, Cornell University, New York, USA, *Self-scaled cones and interior-point methods in nonlinear programming .*

Andreas Nöu, Royal Institute of Technology, Stockholm, Sweden, *Weekly locomotive scheduling.*

Michael L. Overton*, Courant Institute, New York University, New York, USA, *Conditioning of linear systems arising in primal-dual interior-point methods for linear, nonlinear and semidefinite programming.*

Jean-Francois Pusztaszeri and Paul Rensing, European Laboratory for Particle Physics (CERN), Geneva, Switzerland, *Tracking elementary particles in colliding beam experiments: A combinatorial approach.*

Sheu Ruey-Lin and Soon-Yi Wu, National Cheng-Kung University, Tainan, Taiwan, *On smooth convex programming with infinitely many linear constraints.*

Claude Lemaréchal* and Claudia Sagastizàbal*, INRIA, Rocquencourt, France, *Using the Moreau-Yosida regularization for minimizing non-smooth functions.*

Annick Sartenaer*, Facultés Universitaires ND de la Paix, Namur, Belgium, *On the shape and the size of trust regions in trust region methods for nonlinear optimization.*

Abul K. M. S. Hossein and **Trond Steihaug***, University of Bergen, Bergen, Norway, *A graph coloring approach to the estimation of sparse Jacobian matrix and row and column computation.*

Torbjörn Larsson, Linköping Institute of Technology, Linköping, Sweden, Michael Patriksson, University of Washington, Seattle, USA, and **Ann-Brith Strömberg**, Linköping Institute of Technology, Linköping, Sweden, *Ergodic results in subgradient optimization.*

Krister Svanberg, Royal Institute of Technology, Stockholm, Sweden, *A globally convergent method for structural optimization.*

Robert J. Vanderbei*, Princeton University, New Jersey, USA, *Interior point methods for large scale convex optimization.*

9 Other activities

Patrik Alfredsson

- Participated in the 4th International Symposium on Advances in Logistics, Exeter, UK, December 12–15, 1994.

Tomas Björk

- Referee for Systems and Control Letters.
- Referee for Mathematical Finance.
- On the editorial board of Finance and Stochastics.
- Member of the IFAC technical committee on stochastic systems.

Ulf Brännlund

- Referee for Mathematical Programming.
- Visited the PROMATH group at INRIA, Rocquencourt, France, from April 9-29, 1995.

Anders Dahlén

- Participated in the conference "Reglermöte 94" in Västerås, Sweden, October 25–26, 1994.
- Participated in the 4th ERNSI Workshop on System Identification in Padova, Italy, June 7–9, 1995.

Per Enqvist

- Participated in the conference "Reglermöte 94" in Västerås, Sweden, October 25–26, 1994.
- Participated in the 4th ERNSI Workshop on System Identification in Padova, Italy, June 7–9, 1995.

Anders Forsgren

- Referee for International Journal of Technology Management, Linear Algebra and its Applications, Mathematical Programming, SIAM Journal on Optimization, and SIAM Journal on Matrix Analysis and Applications.
- Visited the Department of Operations Research at Stanford University, California, USA, December 6–10, 1994.
- Visited the Department of Mathematics at the University of California at San Diego, La Jolla, California, USA, December 10–17, 1994.

Xiaoming Hu

- Referee for J. of Math. Systems, Estimation and Control.
- Referee for J. of Dynamic Systems, Measurement, and Control.
- Referee for 1995 American Control Conference.
- Referee for the 3rd European Control Conference.

P. O. Lindberg

- Adjunct Professor in Industrial and Systems Engineering, University of Florida at Gainesville, USA.
- On editorial board of Computational Optimization and Applications.
- Initiator and administrator of student exchange program with dept of Industrial and Systems Engineering at U Florida, Gainesville.

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, *Progress in Systems and Control Theory*, book series published by Birkhäuser, Boston.
- Associate Editor, *Systems and Control: Foundations and Applications*, book series published by Birkhäuser, Boston.
- Referee for six other journals.
- Affiliate Professor, Washington University, St Louis, USA.
- Member of Swedish Committee for Systems Analysis and IIASA (International Institute for Applied System Analysis in Vienna, Austria).
- Steering Committee, International Symposium on the Mathematical Theory of Networks and Systems (MTNS).
- Vice-Chairman, International IFAC Committee on Stochastic Systems.
- Member, International IFAC Committee for Mathematics in Control.
- Organizing committee of the 26th ISCIE Symposium on Stochastic Systems Theory and its Applications in Kyoto, Japan, October 26-28, 1994.
- International Advisory Board for the 27th ISCIE Symposium on Stochastic Systems Theory and its Applications in Oita, Japan, October 31 – November 2, 1995.
- Organizing committee of ERCIM Workshop on Systems and Control, Budapest, Hungary, November 6–8, 1995.
- PhD Committes (Betygsnämnd), Universities of Linköping and Uppsala, Sweden.

Jorge Marí

- Visited the the Robust Control group of the Institute for Robotics and System Dynamics at the German Aerospace Research Establishment, January–August 1995.

Mattias Nordin

- Referee for IEEE Transactions on Automatic Control.
- Referee for Int. J. of Adaptive Control and Signal Processing
- Referee for American Control Conference.

Andreas Nöu

- Visited GERAD, Montréal, Canada, September 1994 - January 1995.

Krister Svanberg

- Refereed three papers for Numerical Methods in Engineering, and one paper for Structural Optimization.