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

Activity Report

1991/1992

Contents

1 Personnel

1.1 List of personnel

Professor (Professor)

Anders Lindquist, TeknD, docent

Docent, högskolelektor (Associate professor)

P. O. Lindberg, TeknD, docent

Högskolelektorer (Senior lecturers)

Tomas Björk, FD, Director of undergraduate studies
Krister Svanberg, TeknD

Forskarassistent (Research associate)

Anders Forsgren, TeknD

Postdoktorstipendiat (Postdoctoral fellow)

Alexandre Megretski, PhD

Gästforskare (Guest researchers)

Per-Olof Gutman, TeknD, docent
Xiaoming Hu, PhD

Intendent (Administrator)

Leena Druck

Sekreterare (Secretary)

Elise Hanning

Doktorander (Graduate students)

Torgil Abrahamsson, civing (graduated (TeknL) February 1992)
Patrik Alfredsson, civing
Erik Berglund, civing
Ulf Brännlund, civing, MS
Stefan Feltenmark, civing
Martin Hagström, civing
Robert Johansson, civing
Torbjörn Magnusson, civing (graduated (TeknL) December 1991)
Andreas Nöu, civing
Birgitta Olin, civing, TeknL
Anders Rantzer, civing, TeknL (graduated (TeknD) December 1991)
Jan-Åke Sand, civing, TeknL
Yishao Zhou, MS

Forskningsingenjör (Research engineer)

Omar Viera

1.2 Biographies

Torgil Abrahamsson was born in 1961 in Katarina, Stockholm. He received a civilingenjör degree in Engineering Physics at KTH in 1986. Between the summer of 1987 and the fall of 1991 he has been a PhD student at Optimization and Systems Theory at KTH. By the fall of 1991 he received a Licentiate of Engineering degree in Optimization and Systems Theory, KTH, and moved to continue his doctoral studies at the Department of Regional Planning at KTH. His main research interest is in traffic equilibria.

Patrik Alfredsson was born in Södertälje, Sweden, in 1967. He received a civilinjenjör degree in Engineering Physics from KTH in 1991. His main research interests are systems engineering and systems efficiency, concentrated on spare parts optimization problems.

At present, Alfredsson is the treasurer of the Swedish Operations Research Association.

Erik Berglund was born in Stockholm in 1961. He received a civilingenjör degree in Engineering Physics at KTH in 1985. Since 1984 he has been with the National Defense Research Establishment (FOA) where he works in guidance and control of missiles and evaluation of weapon systems. He is also a part-time PhD student of Optimization and Systems Theory at KTH, his main interests being in Systems and Control.

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. 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. During the period 1987-1990 he has also given several courses in Mathematical Economics at the Stockholm School of Economics. His main research interests include martingale theory, nonlinear filtering and mathematical economics.

Ulf Brännlund was born in 1961. He received a civilingenjör degree in Aeronautical Engineering from KTH in 1986 and an MS degree in Engineering-Economic Systems from Stanford University in 1988. His main research interests are dual optimization methods and production planning problems.

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

Stefan Feltenmark 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.

Anders Forsgren was born in Danderyd, Sweden, in 1961. He received a civilingenjör degree in Engineering Physics from KTH in 1985, an MS degree in Operations Research from Stanford University in 1987 and a TeknD degree in Optimization and Systems Theory from KTH in 1990. Since 1991, he is a research associate at the Division of Optimization and Systems Theory. His main research interest is nonlinear programming.

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.

Martin Hagström was born in Stockholm in 1963. He received a civilinjenjör degree in Aeronautical Engineering at KTH in 1988. He is presently a PhD student at the department. His main research interests are nonlinear dynamics of filtering algorithms and stochastic realization theory and its applications.

Elise Hanning has been the secretary at the Division of Optimization and Systems Theory between 1989 and 1992.

Xiaoming Hu was born in Chengdu, China, on April 19, 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.

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 Engineering.

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, and East China Normal University, Shanghai. 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).

Lindquist is a Communicating Editor of the *Journal of Mathematical Systems, Estimation, and Control* (published by Birkhäuser Boston) and 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).

Alexandre Megretski was born in Leningrad, USSR in 1963. He graduated from Leningrad University in 1985 and received a Ph.D. from there in 1988. Since then he is a research associate at the Laboratory of Theoretical Cybernetics, Leningrad (St. Petersburg) University. In 1990 he was awarded the Mittag-Leffler Institute Postdoctoral Fellowship, and in 1991 he was awarded a Göran Gustafsson Postdoctoral Fellowship to enable him to spend the academic year 1991/92 at the Division of Optimization and Systems Theory. His main research interests are robust control, Hankel operators, 2D optimal filtering, Riccati equations.

Andreas Nöu was born in Stockholm in 1967. 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.

Birgitta Olin was born in 1960 in Stockholm, Sweden. She received a civilingenjör degree in Engineering Physics from KTH in 1985 and a TeknL degree in Optimization and Systems Theory from KTH in 1990. At present, she is a PhD student at the Division of Optimization and Systems Theory at KTH.

Anders Rantzer was born in 1963. He has a civ.ing. (MSc) degree (1987) in Engineering Physics, a Tekn.Lic. (1989) in Mathematics, both from Lund University and a PhD (1991) in Optimization and Systems Theory from KTH. During the spring of 1992, he has served as a research associate at the Division of Optimization and Systems Theory at KTH. His research has mainly been focused on analysis and synthesis of robust control systems.

Jan-Åke Sand was born in 1964 in Stockholm. He received the civilingenjör degree in Engineering Physics from KTH in 1988 and the TeknL degree in Optimization and Systems Theory from KTH in 1992. He is now a PhD student at the Division of Optimization and Systems Theory at KTH. His main research interest is in Stochastic Systems.

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. Between 1976 and 1985 he held a position as Research Associate with the Contract Research Group of Applied Mathematics at the Royal Institute of Technology, and since 1985 he is a Senior Lecturer of Optimization and Systems Theory. His main area of research is structural optimization, in which area he has kept scientific contacts with such industrial companies as SAAB and VOLVO.

Omar Viera was born in 1953 in Montevideo, Uruguay. He will receive his degree in Engineering Physics at KTH in 1992. His main research interest is nonlinear programming, in particular energy applications.

Yishao Zhou, Ph.D student at KTH, was born in Shanghai in 1959. She received BS and MS degrees in mathematics from Fudan University, Shanghai, in 1982 and 1984 respectively. From 1984 to 1987 she worked for Department of Applied Mathematics of East China University of Chemical Technology, Shanghai. Her main research interests are the matrix Riccati equation, Kalman filtering, nonlinear dynamical systems and its applications in control and estimation, and stochastic realization theory.

1.3 Visiting and interacting scientists

Professor Christopher I. Byrnes
Department of Systems Science and Mathematics
Washington University
St. Louis, Missouri, USA

Dr. Anders E. Eriksson
Swedish Defense Research Establishment
Stockholm, Sweden

Professor Philip E. Gill
Department of Mathematics
University of California at San Diego
La Jolla, California, USA

Professor William B. Gragg
Department of Mathematics
Naval Postgraduate School
Monterey, California, USA

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 Lars Lundqvist
Department of Regional Planning
KTH
Stockholm, Sweden

Docent Lars-Göran Mattsson
Department of Regional Planning
KTH
Stockholm, Sweden

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

Professor Giorgio Picci
Department of Electronics and Informatics
University of Padova
Padova, Italy

Professor Alfredo Piria
Department of Mathematics
Facultad de Ingeneria
University Montevideo
Montevideo, Uruguay

Dr. Ulf Ringertz
The Aeronautical Research Institute of Sweden
Stockholm, Sweden

2 Research

2.1 List of projects

2.1.1 List of projects in Systems and Control

- Acausal realization theory.
- Adaptive prediction and control.
- Control of spinning missiles.
- Feedback stabilization and output regulation of nonlinear systems.
- Geometry of the discrete-time algebraic Riccati equation.
- Nonlinear control of uncertain systems with hard nonlinearities.
- On the nonlinear dynamics of Kalman filtering.
- Robust control of electrical drives.
- Robustness of linear systems with known uncertainty structure.
- Stochastic systems theory.
- The minimal rational covariance extension problem.
- Zeros of spectral factors and the geometry splitting subspaces.

2.1.2 List of projects in Mathematical Programming

- Advanced optimization methods for crew and vehicle scheduling problems.
- Component standardization.
- Dual methods for large scale optimization problems.
- Dual methods for the unit commitment problem.
- Dual methods for short term power planning problems.
- Experimental optimization with biotechnical applications.
- Inventory control, in particular stochastic leadtimes and back-order-time shortage penalties.
- Optimal water flow through a water power station.
- Optimization laboratory.
- Optimization of spare parts inventory systems.
- Random assignment problems.
- Random utility models.
- Second-derivative methods for nonlinear programming.
- Second-order decomposition methods for large-scale optimization problems, production planning problems in particular.
- Second order methods for structural optimization.
- Traffic equilibrium models and solution methods.

2.2 Description of projects

2.2.1 Description of projects in Systems and Control

Acausal realization theory

Researcher: Jan-Åke Sand (Anders Lindquist; advisor).

Stochastic models of random phenomena that are spatially distributed are useful in many areas of applications, such as image analysis and computer vision. As a prototype problem we study stochastic processes defined on a circle. The circle provides a parameter set that exhibits genuinely space-like properties, but still has the advantage of being one dimensional.

The goal is to realize a given stationary process as the output of a stochastic system of which the dynamics has a very detailed structure. The topological structure of the circle implies that the state process of an acausal realization cannot be a Markov process. The reason is, that since the past and future of a point on a circle coincide, Markov processes are trivial on a circle.

The suitable class of state processes on the circle are the class of reciprocal processes. A reciprocal process has the property that for a given interval, the values of the process in the interval are conditionally independent of the values outside the interval, given the values at the endpoints of the interval. It is a theorem that a Markov process is reciprocal, but the converse does not hold.

The analysis is carried out by adapting the geometric concepts of Lindquist and Picci's stochastic realization theory to this area. The results obtained sofar indicate that many structural results, such as the relation between minimality and observability, are valid in this setting as well.

Adaptive prediction and control

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

The goal of this project is to develop a systematic theory for prediction, filtering and control for stochastic processes where the probability law governing the process is not known. Using an extension of the classical theory of optimal parameter estimation we have been able to characterize optimal unbiased predictors for a fairly general class of semimartingales. For diffusion processes the theory leads to inverse parabolic boundary value problems and it is intimately connected with the theory of time reversal and reciprocal processes. At present we are trying to obtain an explicit representation of the so called extremal family connected with the Ornstein-Uhlenbeck process. We are also working on a theory of identifiability, based on the general results from the prediction theory above.

Control of spinning missiles

Researcher: Erik Berglund (Anders Lindquist; advisor).

Sponsor: National Defense Research Establishment (FOA).

The purpose of this project is to develop control laws suitable for spinning high velocity missiles. The problem of guidance and control of such missiles involves mainly the spin-induced coupling between motions in different directions and the

short amount of time available for corrections. The method of approach is disturbance decoupling with control variable constraints.

Feedback stabilization and output regulation of nonlinear systems

Researchers: Xiaoming Hu, in cooperation with C. I. Byrnes (Washington University, St. Louis).

Sponsors: The Swedish National Board for Technical Development (STUF) and the Swedish Research Council for Engineering Sciences (TFR).

The aim of this project is to solve the problems of feedback stabilization and output regulation for nonlinear control systems in any given compact region of initial data. Based on the results we reported last year, we have found new control laws which solve the problem of output tracking on compacta even for some globally nonminimum phase systems. Compared with the results previously reported, our new control scheme has the advantage that when the reference signal is set the be the equilibrium point, the closed loop system is asymptotically stable on compacta (instead of being only bounded and attractive as in the previous results). Some preliminary results have also been obtained for the case where the system contains some uncertainties. Another aspect of our research is exact tracking through singular points. By using mathematical tools such as convex analysis, viability theory, and semialgebraic sets, we have been able to give a fairly complete and satisfactory answer to a "rather difficult and potentially messy" problem. At the same time, we have generalized the zero dynamics algorithm to nonaffine nonlinear control systems.

Geometry of the discrete-time algebraic Riccati equation

Researcher: Yishao Zhou (Anders Lindquist; advisor).

The matrix Riccati equation plays an important role in a wide variety of applications, e.g. the theory of stochastic processes, optimal control and filtering, network theory, digital control and H^∞-control. It is also of independent mathematical interest, because the Riccati equation arises when the power iterates are considered in the canonical charts of the Grassmann manifold. There is therefore a considerable amount of control theory literature devoted to the study of Riccati equations. The purpose of this project is to generalize some of the known results for the continuous-time algebraic Riccati equation to its discrete-time counterpart. The discrete-time Riccati equation appears in applications both through sampling of continuous-time models and in discrete implementations. A good knowledge of this equation is therefore important especially since it may, in some cases, exhibit a completely different dynamical behavior than its continuous-time counterpart. As many researchers have noticed, it is not at all trivial to carry over results for the continuous-time Riccati equation to the discrete-time setting, since many such results only exist in a weaker form in the discrete-time case. A clear understanding of the structure of the solution set of the discrete-time algebraic Riccati equation will be important in the study of the phase portrait of the corresponding Riccati difference equation and in developing numerical methods. In the single input or single output case, we are able to describe the structure of this solution set for an algebraic Riccati equation of more general form, both at a set-theoretic and a topological level. As in the (continuous-time) work by Lindquist and Picci, the geometry of the solution set is connected to the results on zeros of spectral factors,

and, for example, the results on the "tightest local frame" can be generalized to the discrete-time case.

Nonlinear control of uncertain systems with hard nonlinearities

Researchers: P. O. Gutman and Anders Rantzer, in cooperation with C. G. Baril and S. Oldak (Technion, Haifa).

Sponsors: The Swedish Research Council for Engineering Sciences (TFR) and the Swedish National Board for Technical Development (STUF).

Electro-mechanical control systems in industry, such as motor drives or robots, can be modelled as uncertain linear dynamic systems, affected by nondifferentiable nonlinearities such as friction, backlash, limiters, etc. Current linear control design practice is unable to yield high precision for such systems without expensive high quality mechanical components. 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. The following results have been obtained. (1) A robust linear controller for a motion control system is complemented by an adaptive friction compensator such that the standard deviation of the unavoidable limit cycle is reduced to one fourth. (2) The limit cycle is exploited to identify the parameters of the linear plant model, thus enabling a more economical robust control. (3) An efficient way to compute transfer function value sets of uncertain systems is presented. All three contributions give the control designer theoretically justified tools to improve the design.

On the nonlinear dynamics of Kalman filtering

Researchers: Anders Lindquist, Yishou Zhou and Martin Hagström, in cooperation with C. I. Byrnes (Washington University, St Louis).

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

In this project we study the dynamical behavior of the Kalman filter when the given parameters are allowed to vary in a way which does not necessarily correspond to an underlying stochastic system. This may correspond to situations in which the basic parameters are chosen incorrectly through estimates. We show that, as has been suggested by Kalman, the filter equations converge to a limit (corresponding to a steady-state filter) for a subset of the parameter space which is much larger than that corresponding to *bona fide* stochastic systems. More surprisingly, in the complement of this subset the filtering equations behave in both a regular and an unpredictable manner, representative of some of the basic aspects present in chaotic dynamics. Using a "fast filtering" algorithm, which incorporates the statistics of the observation process as initial conditions, (rather than coefficient parameters) for a dynamical system, these results are analyzed in terms of the phase portrait of a "universal" nonlinear dynamical system. This point of view has additional advantages as well, since it enables one to use the theory of dynamical systems to study the sensitivity of the Kalman filter to (small) changes in initial conditions; e.g. to change in the statistics of the underlying process. This is especially important since these statistics are often either approximated or estimated. This interesting dynamical behavior occurs already for one-dimensional filters, and we give a complete

phase-portrait in this case. Most aspects of the general case is also studied in detail. Extensive simulations have been undertaken which show interesting dynamical behavior.

Robust control of electrical drives

Researchers: P. O. Gutman, Xiaoming Hu, Anders Rantzer, and Mattias Nordin (Master's Thesis), in cooperation with C. G. Baril and S. Oldak (Technion, Haifa), and Johann Galic (ABB Drives AB, Västerås).

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

This project is a continuation of the project: Nonlinear control of uncertain systems with hard non-linearities. The current program has been running since January 1992.

Electro-mechanical control systems in industry, such as motor drives or robots, can be modelled as uncertain linear dynamic systems, affected by nondifferentiable nonlinearities such as friction, backlash, limiters, etc. Current linear control design practice is unable to yield high precision for such systems without expensive high quality mechanical components. 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 will electrical drives with back-lash and uncertain loads and disturbances be studied.

The following results have been obtained. (1) A robust linear controller has been designed using the H_∞ method for a simulation model of an electric drive with backlash. (2) Extensive measurements have been performed on a 1400 kW electrical drive system in the laboratory of ABB Drives AB, and frequency domain and time domain models are being developed. (3) A systematic design method for uncertain linear systems that include a class of uncertain hard nonlinearities has been developed. It is assumed that the nonlinearity can be described as an uncertain linear operator, and a bounded disturbance. Common friction and backlash models are included in this description. The method is based on the Horowitz robust design methodology, and the describing function method (or alternatively the circle criterion). The method is believed to be one of the first systematic, performance related design methods for this class of systems.

Robustness of linear systems with known uncertainty structure

Researchers: Anders Rantzer and Alexandre Megretski.

A fundamental issue in control design is to limit the change in performance of the closed loop system that can be caused by changes in the system to be controlled or differences between the controlled system and its model. In the last decade, tremendous progress has been made in analysis and synthesis of robust controllers that achieve this objective. However, several problems remain to be solved. One of them is to reduce conservatism of design by taking into account the known structure of uncertainty. For example, one may use knowledge about the way uncertain physical parameters enter into the system equations, about the time constants of uncertain time varying parameters, or about passivity of uncertain nonlinear elements. Another problem is to identify fundamental limitations on what performance

is achievable for a given system configuration and controller structure. Several publications in this area have been made this year.

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. This work is presented within the framework of the geometric Hilbert space theory of Markovian splitting subspaces developed by Lindquist and Picci. We introduce a partial ordering of stochastic realizations and a noncausal estimation problem. Within this framework we clarify the relations between the structure of minimal splitting subspaces, the local structure of the matrix Riccati inequality and the zero structure of (not necessarily square) spectral factors. As a result we obtain direct systems theoretical interpretations of all solutions of the algebraic Riccati equation, and it is shown that the structure of each facet of the convex polyhedral set $\mathcal{P}$ of all solutions of the algebraic Riccati inequality is completely determined by the common zeros of the corresponding minimal spectral factors. 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. It is a fact that 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. The use of coordinates may sometimes only obscure the basic issues.

The minimal rational covariance extension problem

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

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 remain unsolved. As a step toward deeper understanding of these topics we study parametrizations of this problem. In addition to studying the Kimura-Georgiou parametrization in terms the zeros of the corresponding modelling filter, we have developed an algebraic-Riccati-type matrix equation of nonstandard type, the positive semidefinite solutions of which parametrize the solution set of the rational covariance extension problem. So far no computational procedure is available for this nonstandard algebraic Riccati equation, and we are studying this question.

Based on these results we have obtained important insights into the minimal partial stochastic realization problem. A clarification of these questions will provide us with a unification of methods of realization and identification of rational power spectra.

Zeros of spectral factors and the geometry splitting subspaces

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.

This project is concerned with the question how the zero dynamics of (not necessarily square) spectral factors relate to the splitting subspace geometry of stationary stochastic models and to the corresponding algebraic Riccati inequality. We introduce the notion of *output-induced subspace* of a minimal Markovian splitting subspace, which is the stochastic analogue of the *supremal output-nulling subspace* in geometric control theory. Through this concept the analysis can be made coordinate-free, and straightforward geometric methods can be applied. We show how the zero structure of the family of spectral factors relates to the geometric structure of 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. Finally, we generalize the well-known characterization of the the solutions of the algebraic Riccati equation in terms of Lagrangian subspaces invariant under the corresponding Hamiltonian to the larger solution set of the algebraic Riccati inequality.

2.2.2 Description of projects in Mathematical Programming

Advanced optimization methods for crew and vehicle scheduling problems

Researchers: P. O. Lindberg, Stefan Feltenmark and Andreas Nöu.

This project aims at using advanced dual methods on crew and vehicle scheduling problems.

Recently there has appeared optimizing methods for crew and vehicle scheduling problems. These methods solve time and capacity constrained path problems as subproblems and combine the subproblem solutions through Dantzig-Wolfe decomposition.

This framework fits very nicely into our metaproject on dual methods. We are looking at using more advanced dual methods in this framework, and have applied to TFB for funding.

Component standardization

Researcher: P. O. Lindberg.

This project aims at developing optimization methods for problems of component standardization. In general this problem is a nonlinear, nonconvex integer programming problem. For certain classes of this problem we have developed methods that are reducible to Wagner-Whitin type dynamic programming problems. They are hence solvable in polynomial time. During the year, results have been presented

at the 14th Math Programming Symposium and at Dept of Industrial and Systems Engineering, University of Florida, Gainesville.

Dual methods for large scale optimization problems

Researchers: P. O. Lindberg, Don Hearn, Ulf Brännlund, Torbjörn Magnusson, Stefan Feltenmark, Andreas Nöu, Torgil Abrahamsson, Birgitta Olin.

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK), ABB Network Control AB, Krångede Power Pool, Swedish State Power Board (Vattenfall), Swedish Transport Research Board (TFB).

Industrial contacts: ABB Network Control AB, Krångede Power Pool, Swedish State Power Board.

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

Central subprojects are the unit commitment project and the production planning project. 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.

We also have applied for money from TFB for a project on Crew and Vehicle Scheduling. This planned project is very close methodologically to the above projects.

The traffic equilibria project and the random assignment project share the ideas on a more methodological level, if not so far as to share codes. The common philosophy gives a strong backbone to our projects.

This project benefits strongly from the Optimization Laboratory.

Dual methods for the unit commitment problem

Researchers: P. O. Lindberg, Torbjörn Magnusson, Stefan Feltenmark and Andreas Nöu.

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK), ABB Network Control AB, Krångede Power Pool, Swedish State Power Board (Vattenfall).

Industrial contacts: ABB Network Control AB, Krångede Power Pool, Swedish State Power Board.

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 dual methods consist of several modules:

- finding initial primal solutions
- determination of dual search directions
- determination of dual steplengths
- perturbation of relaxed primal solutions to get feasibility, consisting of
  - determining which unit should be on for each time slot
  - determining the production for each unit and time slot (the so called EDP problem).

A system containing these parts has been programmed and tested on several test cases. For some of the modules mentioned above, extensive testing of several methods has been performed. In particular several direction finding and steplength methods have been tried out. The tests show that the approach is very viable.

During the year, Magnusson has received a Licentiate degree. His thesis is listed under reports. Feltenmark and Nöu have worked on testing and speeding up the commitment program, and have achieved a speedup by a factor of ten. This implies that a 200 unit, 168 h problem can be solved in under 10 minutes on a workstation.

Dual methods for short term power planning problems

Researchers: P. O. Lindberg, Stefan Feltenmark and Andreas Nöu.

Industrial contacts: ABB Network Control AB, Krångede Power Pool, Swedish State Power Board.

This is a project where we are applying for money.

We have done preliminary work at developing methods for the hydro part of the short term power planning problem. We are working at developing methods of different degrees of detail. From models with simple bilinear dependency of output on flows and water heights in the stations, to very complex models with detailed efficiency functions and commitments of the turbines in the stations.

Experimental optimization with biotechnical applications

Researchers: Robert Johansson and P. O. Lindberg.

Sponsors: The Swedish National Board for Industrial and Technical Development (NUTEK) and Kabi-Pharmacia AB.

This project concerns the optimization of incompletely known, typically biotechnical, processes. In these, function evaluation entails an experiment. However, there is some information on the structure of the process.

We have worked at understanding the local behavior of such processes, and have developed a scheme for their optimization, based on second order information.

As a test case, we have chosen a yeast process. This has shown to be very stiff, and we have had to use a special differential equation solver to be able to solve it.

Also, available optimization methods have shown insufficient to optimize this process. We therefore proceed to develop our own optimization methods.

Inventory control, in particular stochastic leadtimes and back-order-time shortage penalties

Researcher: P. O. Lindberg.

Industrial contact: Systecon AB.

This is a project aiming at clarifying basic concepts and results of inventory theory. We have studied important aspects of inventory control that have not been treated sufficiently in the literature: stochastic leadtimes and shortage penalties on back-order-time. Results have been presented for the Poisson demand case. Approximations of the METRIC type for multilevel systems have been derived, but not yet written up. These results have important applications for inventory systems of nonrepairable spare parts.

Optimal water flow through a water power station

Researchers: P. O. Lindberg and Omar Viera.

Sponsor: Swedish State Power Board (Vattenfall).

Industrial contact: Swedish State Power Board.

This project addresses the problem of, and has developed methods for, finding the optimal waterflow through the turbines and tunnels of a water power station. The problem is difficult due to the inherent nonconvexities of the problem. The problem is attacked through a form of dynamic programming over the tunnel tree of the station. Results have been presented at the 14th Mathematical Programming Symposium. In particular, we have for certain power stations established the existence of several local optima for most water flows, showing the inherent difficulties of the problem. Moreover, our method makes it possible to treat the combinatorial problem of choosing which turbines to run, without extra computations.

Optimization laboratory

Researchers: P. O. Lindberg, Torgil Abrahamsson, Patrik Alfredsson, Ulf Brännlund, Stefan Feltenmark, Anders Forsgren, Robert Johansson, Andreas Nöu, Birgitta Olin, Krister Svanberg.

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

Industrial contacts: ABB Network Control, Aeronautical Research Inst of Sweden, AlfGam Optimering AB, Avesta AB, Forest Operations Institute, Krångede Power Pool, Swedish State Power Board, Swedish Telecommunications Administration, Systecon AB.

This project aims at collecting state-of-the-art portable optimization routines as well as optimization problems. By making the routines and problems available to industry and government, we will enhance the spreading of optimization practice.

A partial list of routines include:

MINOS, QPSOL, LSSOL, NPSOL	(Gill et al, Stanford)
MMA	(Svanberg, KTH)
GRG2	(Lasdon, U Texas)
RELAX	(Bertsekas, MIT)
NETFLO, NETSIDE	(Kennington, S Methodist U)
NLPQL	(Schittkowski, U Bayreuth)
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 470 server with several work stations connected to it. During the year we have applied for (and received) funds (KSEK 450, excl. VAT) for upgrading our computer system.

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.

This project entails a broad study of spare parts inventory systems. We are, e.g., working with models for general multi-item, multi-echelon, multi-indenture systems for repairable spare parts. In particular we are studying optimization of spare parts inventories, location of repair facilities, and sensitivities of the optimal value with respect to the problem parameters. During the academic year we have derived suitable methods for computing these sensitivities efficiently using Danskin's theory of min-max.

Presently we are developing algorithms to determine the optimal inventory levels in a repairable item inventory system. This is in fact a hard non-convex non-linear integer problem, but a promising approach is to solve it by using a dynamic programming-type method.

Random assignment problems

Researchers: P. O. Lindberg and Birgitta Olin.

This project aims at deriving better upper and lower bounds for the optimal value of random assignment problems.

During the year several paper have been written and a doctoral thesis completed. In particular, almost sure lower and upper bounds for uniform and nonuniform distributions have been derived.

Random utility models

Researchers: P. O. Lindberg, Anders E Eriksson, Lars-Göran Mattsson.

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 worked at modifying the paper on the Robertsson-Strauss model.

Second-derivative methods for nonlinear programming

Researchers: Anders Forsgren, in cooperation with Philip E. Gill (UCSD), Walter Murray (Stanford University) and Ulf Ringertz (FFA).

Sponsor: The Swedish National Board for Technical Development (STUF).

The rapid development of computer hardware has made the use of optimization techniques viable for solving larger and larger problems. However, for solving large sparse problems efficiently, it is necessary to design algorithms that take advantage of matrix sparsity, when solving the systems of linear equations that arise.

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

Recent work include the development of modified Newton methods of the line-search type for linearly constrained optimization. The methods utilize both descent directions and directions of negative curvature. In particular, we have been focusing on suitable factorization methods for solving the systems of linear equations that arise, and an efficient way of combining the descent direction and the direction of negative curvature.

In cooperation with Dr. Ulf Ringertz at FFA, a modified Newton method has been applied to an energy minimization problem within nonlinear finite-element analysis. An interesting feature of this subproject is that on one of the test problems, it was essential to use directions of negative curvature in order to identify a local minimizer. Without directions of negative curvature, a non-optimal saddle-point was found.

Second-order decomposition methods for large-scale optimization problems, production planning problems in particular

Researchers: P. O. Lindberg, Ulf Brännlund, in cooperation with Donald W. Hearn (U. of Florida).

Sponsor: The Swedish National Board for Industrial and Technical Development (NUTEK) and the Swedish Research Council for Engineering Sciences (TFR).

The goal of this project is the development of second order decomposition methods for large scale optimization problems, and production planning problems in particular.

Studies of conjugate subgradients, least-squares approximation of the Hessian and exponential penalty methods for smoothing the dual objective function have been performed.

A new convergent subgradient algorithm based on the relaxation (Polyak) step, a step which uses an estimate of optimal value as a basis for the steplength calculation, has been suggested and studied. A generalization of the subgradient algorithm with relaxation step has been suggested. It has been shown that bundle methods are closely related to this generalization and that a popular modification of the ordinary subgradient algorithm may be viewed as an optimal choice of step length and direction in a restricted version of the generalization. The work on the generalization continues and especially its relation to bundle methods is being investigated.

A new method for handling constraints in subgradient optimization with known optimal value has been suggested. When the constraints are simple bounds or a unit simplex, the method has been proven to be superior to other relaxation step methods.

Large scale optimization problems from Hierarchical Production Planning and Capacitated Lotsizing have been used for testing.

Second order methods for structural optimization

Researcher: Krister Svanberg.

Structural optimization may be defined as "Computer-aided optimal design of stressed systems". An example of a structural optimization problem is to find the optimal cross section areas of the bars in a truss structure, so as to minimize the weight subject to constraints on structural stiffness and strength.

A method called MMA (developed by the author) for numerically solving structural optimization problems has been implemented in several large systems, e.g. at the Aircraft Division of SAAB-SCANIA. The method has shown to be very reliable, but sometimes rather slow. The purpose of the current project is to make MMA able to exploit second derivative information, in order to obtain superlinear convergence. The ultimate goal is a reliable and fast method for structural optimization.

Traffic equilibrium models and solution methods

Researchers: P. O. Lindberg, Lars Lundqvist, Torgil Abrahamsson.

Sponsor: Swedish Transport Research Board (TFB).

The project falls in two parts.

In the first, different models of the traffic equilibrium problem are developed and investigated. Here we written and tested programs on the computation of traffic equilibria.

The other part deals with solution techniques to the equivalent optimization formulation of the traffic equilibrium model. This problem is nonlinear and quite large, in terms of the number of variables. We have written several scientific reports on this subject. Abrahamsson received his licentiate thesis, based on these reports, in January 1992.

As a subproblem we have to solve a so called biproportional fit problem. For this we have improved the classical Cross-Fratar techniques, on the one hand through SOR-techniques, on the other through use of approximate conjugate gradient techniques. On the master problem an efficient orthogonalization method has been developed.

3 Education

3.1 Undergraduate courses

Number	Course name	Instructor	Credit
FA190	Optimization, General Course *(Optimeringslära, allmän kurs för D och F)*	T. Björk	3.5 p
FA191	Applications of Mathematics and Computer Science *(Matematikens och datateknikens tillämpningar)*	K. Svanberg	3 p
FA192	Optimization, General Course *(Optimeringslära, allmän kurs för T)*	K. Svanberg	4 p
FA195	Optimization *(Optimeringslära, grundkurs för M)*	K. Svanberg	4 p
FA196	Mathematical Programming *(Matematisk programmering)*	K. Svanberg	5 p
FA300	Systems Engineering *(Systemteknik)*	P. O. Lindberg	7 p
FA302	Methods of Systems Engineering *(Systemtekniska metoder)*	P. O. Lindberg	3.5 p
FA305	Production and Inventory Control *(Produktions- och lagerstyrning)*	P. O. Lindberg	3 p
FA310	Mathematical System Theory *(Matematisk systemteori)*	A. Lindquist	3.5 p
FA312	Calculus of Variations and Optimal Control *(Variationskalkyl och styrteori)*	T. Björk	3.5 p
FA320	Mathematical Economics *(Matematisk ekonomi)*	T. Björk	3 p

3.2 Graduate courses

Course name	Instructor	Credit	Participants KTH	Participants industry
Convexity, Optimality and Duality	P. O. Lindberg	5 p	5	1
Horowitz' method for synthesis of Robust Control Systems	P. O. Gutman	5 p	5	1
Numerical Nonlinear Programming	A. Forsgren	5 p	4	-

3.3 External courses

As part of a cooperative project between KTH and Facultad de Ingeneria of the University of Montevideo, we have delivered three mathematical programming based graduate courses at Facultad de Ingeneria during March-April 1992. This project was financed by BITS.

As an outgrowth of courses, we will continue to cooperate in the area of optimization of power systems.

Course name	Instructor	Appr. credit	Participants
Basic Optimization	P. O. Lindberg	3 p	14
Optimization Modelling	O. Viera	1 p	16
Advanced Optimization	P. O. Lindberg	3 p	5

3.4 Doctoral thesis

A. Rantzer, *Parametric uncertainty and feedback complexity in linear control systems*, TRITA-MAT-1991-35, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1991. Advisor: A. Lindquist.

3.5 Licentiate theses

T. Abrahamsson, *Combined models for traffic planning — improved solution techniques*, (Consists of five separate papers), Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1991. Advisor: P. O. Lindberg.

T. Magnusson, *The unit commitment problem: a dual approach*, TRITA-MAT-1991-44, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1991. Advisor: P. O. Lindberg.

J.-Å. Sand, *A geometric approach to the reciprocal realization problem on the circle*, TRITA-MAT-1992-1, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1992. Advisor: A. Lindquist.

3.6 Master theses (Examensarbeten)

P. Alfredsson (F), *Marginalkostnadsanalys och optimering av reservmateriellager*. Advisor: P. O. Lindberg. Performed at FMV.

R. Arrestam (D) and J. Holmlund (D), *A fuzzy-logic control language FLCL for embedded controllers*. Advisor: P. O. Lindberg. Performed at University of Florida.

M. Elf (T), *Kapacitetsberäkningar för järnväg med olika signalsystem*. Advisor: P. O. Lindberg. Performed at EB Signal.

S. Feltenmark (F), *Software for the unit commitment problem*. Advisor: P. O. Lindberg. Performed at ABB.

Ö. Flatebakken (T) and M. Johansson (T), *Simuleringsstudie för EB Teleproduksjon*. Advisor: P. O. Lindberg. Performed at EB Teleproduksjon.

A. Henriksson (T), *A study of methods for explosive detection in checked baggage*. Advisor: P. O. Lindberg. Performed at SAS.

S. Karlsson (T), *BULK-Ordering of mechanics, cables and domestic materials*. Advisor: P. O. Lindberg. Performed at Ericsson.

H. Kjellman (T), *Investigation of various objective functions for optimal short term production planning of hydro power*. Advisor: P. O. Lindberg. Performed at Vattenfall.

S. Kristofferson (T), *Möjligheter med NTM i förmedlingsnätet*. Advisor: P. O. Lindberg. Performed at Televerket.

G. Larsson (T), *Från linjeorganisation till processorganisation*. Advisor: P. O. Lindberg. Performed at Ericsson.

K. Liljefors (T), *Harmonized pricing.* Advisor: P. O. Lindberg. Performed at Gadelius Marine K.K.

K. Magnusson (T), *Optimering av artikelsortiment.* Advisor: P. O. Lindberg. Performed at Flakt.

H. Mattson (F), *Utvärdering av valutarisker och hedgingstrategier.* Advisor: T. Björk. Performed at J. P. Bank.

A. Myrenberg (F), *Optimering av transportnät inom telekommunikation.* Advisor: A. Forsgren. Performed at Ericsson.

F. Nordin (T), *Installation disturbances at Ericsson Telecommunications.* Advisor: P. O. Lindberg. Performed at Ericsson.

A. Nöu (F), *Congestion modelling in area evacuation networks.* Advisor: P. O. Lindberg. Performed at University of Florida.

S. Persson (F) and R. Johansson (F), *Algorithms and code for the optimization of component placement for assembly robots.* Advisor: P. O. Lindberg. Performed at University of Florida.

L. Sandström (T), *Optimal lokalisering av nytt försäljningskontor för Kinnarps S.A. i Frankrike.* Advisor: P. O. Lindberg. Performed at Kinnarps.

T. Schönbeck (T), *DfDP, Databas för driftsäkerhetsprediktering.* Advisor: P. O. Lindberg. Performed at Bofors Aerotronics.

U. Sivesson (F), *Option pricing with arbitrage hedges.* Advisor: T. Björk.

K. Sjöberg (T), *Utveckling av prognoshantering i standardsystemet R2.* Advisor: P. O. Lindberg. Performed at Ericsson.

K. Söderberg (T) and T. Hörnfeldt (F), *A two dimensional cutting stock algorithm applied in the metal cutting industry.* Advisor: P. O. Lindberg. Performed at University of Florida.

4 Publications

4.1 Published (and accepted) papers

4.1.1 Published (and accepted) papers in Systems and Control

T. Björk and B. Johansson, *Adaptive prediction and reverse martingales*, To appear in Stochastic Processes.

C.I. Byrnes and X. Hu, *The zero dynamics algorithm for general nonlinear systems and its application in exact output tracking*, To appear in J. of Math. Systems, Estim., and Control, Vol. 3, Number 1.

C. I. Byrnes, A. Lindquist and Y. Zhou, *Stable, unstable and center manifolds for fast filtering algorithms*, in Modeling, Estimation and Control of Systems with Uncertainty, Birkhäuser's series Progress in Systems & Control, Vol. 10, 1991.

C. I. Byrnes, A. Lindquist and Y. Zhou, *On the nonlinear dynamics of fast filtering algorithms*, Accepted for SIAM J. Control and Optimization.

X. Hu, *On state observers for nonlinear systems*, Systems and Control Letters vol-17 (1991), 465–473.

X. Hu, *Output tracking through singularities for nonlinear systems*, "Recent Advances in Mathematical Theory of Systems, Control, Networks and Signal Processing II" (eds H. Kimura and S. Kodama), Mita Press, Tokyo, 1992, 339–344.

X. Hu, *Robust dynamic state feedback regulators for nonlinear plants*, In the proceedings of the 1992 American Control Conference, Chicago.

A. Lindquist and G. Picci, *A geometric approach to modelling and estimation of linear stochastic systems*, Journal of Mathematical Systems, Estimation, and Control, 1(1991), 241-333.

A. V. Megretsky, *A quasinilpotent Hankel operator*, Leningrad Math. J. 2(1991), 879–889.

A. Megretski, *Sensitivity optimization problem for uncertain discrete SISO systems*, Journal of Optimization Theory and Applications (to appear).

A. Megretski, *Necessary and sufficient conditions of stability: a multiloop generalization of the circle criterion*, IEEE Transactions on Automatic Control (to appear).

A. Megretski and S. Treil, *Power Distribution Inequalities in Optimization and Robustness of Uncertain Systems*, Journal of Mathematical Systems, Estimation, and Control (to appear).

A. Rantzer and B. Bernhardsson, *Structured stability margin and the finite argument principle*, Proc. of IFAC Symposium on Design Methods of Control Systems, ETH Zurich, September 1991.

A. Rantzer and P. O. Gutman, *Addition and multiplication of value set of uncertain transfer functions*, Proc. of CDC, Brighton, December 1991.

A. Rantzer, *A weak Kharitonov theorem holds if and only if the stability region and its reciprocal are convex*, Int. Jour. of Robust and Nonlinear Control, to appear.

A. Rantzer, *Convex robustness specifications for real parametric uncertainty in linear systems*, Proc. of ACC, 1992.

A. Rantzer, *Continuity properties of the parametric stability margin*, Proc. of ACC, 1992.

Y. F. Zheng and X. Hu, *Local disturbance decoupling with asymptotic stability for nonlinear systems*, To appear in J. of Control Theory and Application.

4.1.2 Published (and accepted) papers in Mathematical Programming

A. Forsgren, P. E. Gill and W. Murray, *On the identification of local minimizers in inertia-controlling methods for quadratic programming*, SIAM Journal on Matrix Analysis and Applications 12(1991), 730-746.

A. Forsgren and W. Murray, *Newton methods for large-scale linear equality-constrained minimization*, Accepted for publication in SIAM Journal on Matrix Analysis and Applications.

K. Svanberg, *A new approximation of the constraints in truss sizing problems: an explicit second order approximation which is exact for statically determinate truss structures*, Accepted for publication in Structural Optimization.

4.2 Technical reports and preprints

4.2.1 Technical reports and preprints in Systems and Control

T. Björk and B. Johansson, *On asymptotically sufficient statistics for some stochastic processes in continuous time*, Report No 162, Institute of Actuarial Mathematics and Mathematical Statistics, Stockholm University, Submitted for publication.

P. O. Gutman, P. O. Lindberg and I. Seginer, *A non-linear optimal greenhouse control problem solved by linear programming*, Preprint.

X. Hu, *Some results in nonlinear output regulation and feedback stabilization*, Submitted for publication.

X. Hu, *Stabilization of planar real analytic systems*, Preprint.

A. Lindquist, Gy. Michaletzky and G. Picci, *Zeros of spectral factors, the geometry of splitting subspaces, and the algebraic Riccati inequality*, Preprint.

A. Megretski, *S-Procedure in optimal non-stochastic filtering*, Report TRITA-MAT-1992-15, Department of Mathematics, KTH, 1992, Submitted for publication.

A. Megretski, *Discrete-time realizations in inverse spectral problem for self-adjoint Hankel operators*, Report TRITA-MAT-1992-20, Department of Mathematics, KTH, 1992.

A. Megretski, *Power distribution approach in robust control*, Report TRITA-MAT-1992-27, Department of Mathematics, KTH, 1992, Submitted for publication.

S. Oldak, C. Baril and P. O. Gutman, *Quantitative design of a class of nonlinear systems with parameter uncertainty*, Preprint, Submitted for publication.

A. Rantzer and A. Megretski, *A convex parametrization of robustly stabilizing controllers*, TRITA-MAT-1992-24, Dept. of Mathematics, KTH, 1992, Submitted for publication.

4.2.2 Technical reports and preprints in Mathematical Programming

T. Abrahamsson and P. O. Lindberg, *A note on network related optimization*, Report TRITA-MAT-1991-28, Department of Mathematics, KTH, 1991.

T. Abrahamsson and P. O. Lindberg, *Some experiments on different direction finding methods for combined trip distribution and assignment*, Report TRITA-MAT-1991-29, Department of Mathematics, KTH, 1991.

P. Alfredsson, *Sensitivity analysis of a repairable item inventory system*, Preprint.

U. Brännlund, *An "optimal" subgradient method*, Working paper.

U. Brännlund, *A note on subgradient optimization with constraints*, Working paper.

A. Forsgren and U. Ringertz, *On the use of a modified Newton method for nonlinear finite element analysis*, Report TRITA-MAT-1992-22, Department of Mathematics, KTH, 1992. Submitted for publication.

B. Olin, *Aspects of random assignment problems — an experimental study*, Preprint.

B. Olin, *A note on random assignment problems for arbitrary cost distributions*, Preprint.

B. Olin, *Almost sure bounds on the optimal value in a random assignment problem*, Preprint.

K. Svanberg, *Convex approximation methods for structural optimization*, Lecture notes for the COMETT-Seminar on Computer aided optimal structural design, Castle of Thurnau, Germany, May 18-22, 1992.

K. Svanberg, *The MMA-91 package*, Description of a subroutine-package for structural optimization.

5 Seminars at the division

5.1 Formal seminars

Aug. 9, 1991	Professor Alberto Isidori, University of Rome. *Disturbance attenuation in nonlinear systems.*
Sep. 13, 1991	Docent Per-Olof Gutman, Technion. *Performance related friction compensation for uncertain systems.*
Sep. 25, 1991	Docent Per-Olof Gutman, Technion. *On line estimation of transfer function value sets.*
Oct. 18, 1991	Dr. Chuang Min Hwei, Nanyang Technological Institute, Singapore. *Use of linear programming in a feedmill company.*
Nov. 1, 1991	Professor Michiel Hazewinkel, Centre for Mathematics and Computer Science (CWI), Amsterdam, The Netherlands. *Symmetry and extremality.*
Nov. 22, 1991	Tekn.Lic. Anders Rantzer, KTH. *Parametric uncertainty and feedback complexity in linear control systems.*
Nov. 26, 1991	Professor Jan Willems, Mathematical Institute, University of Groningen, The Netherlands. *Dynamical systems: The behavior, manifest, and latent variables.*
Nov. 26, 1991	Professor Jan Willems, Mathematical Institute, University of Groningen, The Netherlands. *Controllability and observability in a new perspective.*
Nov. 28, 1991	Professor Jan Willems, Mathematical Institute, University of Groningen, The Netherlands. *Continuous parameterization of linear dynamical systems.*
Nov. 29, 1991	Professor Jan Willems, Mathematical Institute, University of Groningen, The Netherlands. *Symmetries in dynamical systems.*
Dec. 18, 1991	Torbjörn Magnusson, KTH. *The unit commitment problem – a dual approach.*
Dec. 19, 1991	Professor Keith Glover, University of Cambridge, UK. *Generalized relative error model approximation.*
Jan. 14, 1992	Torgil Abrahamsson, KTH. *Combined models for traffic planning – improved solution techniques.*
Jan. 31, 1992	Professor Hoang Tuy, Linköpings Tekniska Högskola. *Convexity in nonconvex optimization.*
Feb. 7, 1992	Jan-Åke Sand, KTH. *A geometric approach to the reciprocal realization problem on the circle.*
Mar. 27, 1992	Tekn.Dr. Ulf Ringertz, Flygtekniska Försöksanstalten, Bromma. *Optimal design of shell structures and higher order optimality conditions.*

Apr. 10, 1992 Dr. Krister Forsman, Department of Electrical Engineering, Linköping University. *Constructive algebraic geometry – a tool for nonlinear control systems.*

Apr. 14, 1992 Professor Leon A. Petrosjan, St. Petersburg State University. *Differential games: recent advancements and problems.*

Apr. 24, 1992 Professor Björn Ottersten, KTH. *Sensor array signal processing – Theoretical and experimental results.*

May 15, 1992 Dr. Kjell Gustafsson, Lunds Tekniska Högskola. *Control of error and convergence in ODE solvers.*

May 22, 1992 Professor William B. Gragg, Naval Postgraduate School Monterey, and Interdisciplinary Project Center for Supercomputing Swiss Federal Institute of Technology, Zürich. *Divide and Conquer Algorithms for Structured Eigenvalue Problems.*

Jun. 5, 1992 Tekn.Dr. Anders Rantzer, KTH. *Robust control by convex optimization.*

5.2 Informal seminars in Systems and Control

Sep. 2, 1991 Alexandre Megretski, Division of Optimization and Systems Theory. *S-procedure and optimization of uncertain systems.*

Sep. 17, 1991 Professor Per-Olof Gutman, Faculty of Agricultural Engineering, Technion, Haifa, Israel. *Practical Filter Design.*

Nov. 4, 1991 Yishao Zhou, Division of Optimization and Systems Theory. *The Discrete-time Algebraic Matrix Riccati equation.*

Nov. 18, 1991 Yishao Zhou, Division of Optimization and Systems Theory. *The Discrete-time Algebraic Matrix Riccati equation cont..*

Dec. 2, 1991 Alexandre Megretski, Division of Optimization and Systems Theory. *Something about Riccati-equations.*

Dec. 16, 1991 Janne Sand, Division of Optimization and Systems Theory. *Reciprocal processes and realizations I.*

Jan. 13, 1992 Janne Sand, Division of Optimization and Systems Theory. *Reciprocal processes and realizations II.*

Jan. 20, 1992 Alexandre Megretski, Division of Optimization and Systems Theory. *Non-stochastic optimal filtering I.*

Feb. 3, 1992 Docent Torbjörn Kolsrud, Department of Mathematics. *Riccatiekvationen och Gaussiska reciproka diffusioner.*

Apr. 13, 1992 Anders Lindquist, Division of Optimization and Systems Theory. *Zeros of spectral factors and the geometry of splitting subspaces.*

Apr. 27, 1992 Alexandre Megretski, Division of Optimization and Systems Theory. *Non-stochastic optimal filtering II.*

May 4, 1992 Alexandre Megretski, Division of Optimization and Systems Theory. *Non-stochastic optimal filtering III.*

May. 11, 1992 Xiaoming Hu, Division of Optimization and Systems Theory. *Basics about non-linear control theory I.*

May. 18, 1992 Professor Bill Gragg, Naval Postgraduate School, Monterey, California, USA. *Jacobi matrices and their unitary analogs.*

May. 25, 1992 Xiaoming Hu, Division of Optimization and Systems Theory. *Zero-dynamics.*

5.3 Informal seminars in Mathematical Programming

Aug. 22, 1991 Professor Walter Murray, Stanford University. *Barrier methods for linear and nonlinear programming.*

Sep. 12, 1991 Anders Forsgren, Division of Optimization and Systems Theory. *Modified Newton methods.*

Sep. 26, 1991 Ulf Brännlund, Division of Optimization and Systems Theory. *Non-differentiable optimization.*

Oct. 3, 1991 Robert Johansson, Division of Optimization and Systems Theory. *City-shop travelling salesman problem.*

Oct. 10, 1991 Andreas Nöu, Division of Optimization and Systems Theory. *Network formulation of area evacuation problem.*

Oct. 17, 1991 Patrik Alfredsson, Division of Optimization and Systems Theory. *Spare parts optimization and marginal cost analysis.*

Oct. 24, 1991 P. O. Lindberg, Division of Optimization and Systems Theory. *Reduced gradients and Pontryagin's maximum principle.*

Oct. 31, 1991 Anders Forsgren, Division of Optimization and Systems Theory. *Quadratic programming.*

Nov. 7, 1991 Stefan Feltenmark, Division of Optimization and Systems Theory. *The unit commitment problem.*

Nov. 21, 1991 Ulf Brännlund, Division of Optimization and Systems Theory. *An LP-model for resource balancing.*

Dec. 5, 1991 Birgitta Olin, Division of Optimization and Systems Theory. *An auction algorithm for the assignment problem.*

Dec. 12, 1991 Krister Svanberg, Division of Optimization and Systems Theory. *Optimization of truss structures.*

Jan. 30, 1991 Ulf Brännlund, Division of Optimization and Systems Theory. *Subgradient optimization and an extension.*

Apr. 2, 1992 Anders Forsgren, Division of Optimization and Systems Theory. *Lanzcos' method and its relation to the conjugate gradient method.*

Apr. 9, 1992 Gunnar Sjödin, SICS. *Neuron nets.*

Jun. 4, 1992 Krister Svanberg, Division of Optimization and Systems Theory. *Convex approximation methods.*

Jun. 11, 1992 P. O. Lindberg, Division of Optimization and Systems Theory. *The simple single station dynamic height dependent hydra optimization problem.*

Jun. 18, 1992 Professor Alfredo Piria, University Montevideo, Montevideo, Uruguay. *A modification of the Polyak subgradient method for structured optimization problems.*

6 Presentations by staff

T. Abrahamsson and P. O. Lindberg, *Matrix balancing by successive overrelaxation with applications to traffic assignment*, 14th International Symposium on Mathematical Programming, Amsterdam, The Netherlands, August 5–9, 1991.

T. Abrahamsson and P. O. Lindberg, *Some experiments on matrix balancing by a conjugate direction method with applications to traffic assignment*, 2nd Stockholm Optimization Days, Stockholm, Sweden, August 12–13, 1991.

P. Alfredsson, *Sensitivity analysis of a repairable item inventory system*, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, April 30, 1992.

P. Alfredsson, *Demonstration of spare parts optimization package OPUS9*, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, April 30, 1992.

T. Björk, *Adaptive prediction and reversed martingales*, Lund University, May, 1992.

U. Brännlund, *A subgradient algorithm based on Polyak step*, 14th International Symposium on Mathematical Programming, Amsterdam, Netherlands, August 5-9, 1991.

U. Brännlund, *A generalized subgradient method based based on the Polyak step*, 2nd Stockholm Optimization Days, Stockholm, August 12-13, 1991.

U. Brännlund, *A generalized subgradient method based based on the Polyak step*, INRIA, Le Chesnay, France, December 19, 1991.

U. Brännlund, *An "optimal" subgradient method*, University of Florida, Gainesville, USA, April 24, 1992.

U. Brännlund, *Bundle methods applied to production planning problems*, TIMS/-ORSA Joint National Meeting, Orlando, Florida, April 26-29, 1992.

U. Brännlund, *On subgradient optimization with constraints*, 3rd Stockholm Optimization Days, Stockholm, June 25-26, 1992.

A. Forsgren, *Newton methods for large-scale linear equality constrained minimization*, 14th International Symposium on Mathematical Programming, Amsterdam, The Netherlands, August 5–9, 1991.

A. Forsgren, *Newton methods for large-scale linear equality constrained minimization*, 2nd Stockholm Optimization Days, Stockholm, Sweden, August 12–13, 1991.

A. Forsgren, *Optimization – use of external routines for optimization via the MEX interface*, Conference "Scientific computation and simulation in a powerful engineering environment with Matlab/Simulab and Matlab v4.0", Stockholm, October 15, 1991.

A. Forsgren, *Newton methods for optimization*, Facultés Universitaires Notre-Dame de la Paix, Namur, Belgium, November 12, 1991.

A. Forsgren, *Large-scale issues in Newton methods for linearly constrained optimization*, 4th SIAM Conference on Optimization, Chicago, Illinois, USA, May 11–13, 1992.

A. Forsgren, *Newton methods for optimization*, Boeing Computer Services, Seattle, Washington, USA, May 21, 1992.

A. Forsgren, *Linesearch issues in modified Newton methods*, 3rd Stockholm Opti-

mization Days, Stockholm, Sweden, June 25-26, 1992.

X. Hu, *Asymptotic tracking with internal stability in the large for nonlinear systems (invited)*, 1st European Control Conference, Grenoble, France, July, 1991.

X. Hu, *Nonlinear control theory and its application in spacecraft attitude control*, Department of Mechanics, Royal Institute of Technology, April 9, 1992.

P. O. Lindberg, *A component/product line standardization problem*, 14th International Symposium on Mathematical Programming, Amsterdam, August 5-9, 1991.

P. O. Lindberg, *Finding all local minima in polynomial mathematical programming problems with Groebner bases*, 2nd Stockholm Optimization Days, August 12-13, 1991.

P. O. Lindberg, *Developments in airline crew scheduling and vehicle planning with potential effects for railway companies*, Presentation for the management of the Swedish State Railways, September 2, 1991.

P. O. Lindberg, *Distribution systems and network analysis*, Course "Produktion av Transporttjänster", Borlänge, September 24, 1991.

P. O. Lindberg, *Network flow methods*, Dept Math, Facultad de Ingeneria, University of Montevideo, Uruguay, March 1992.

P. O. Lindberg, *Unit commitment problems*, Dept Math, Facultad de Ingeneria, University of Montevideo, Uruguay, March 1992.

P. O. Lindberg, *Reduced gradient and the Pontryagin maximum principles*, Dept Math, Facultad de Ingeneria, University of Montevideo, Uruguay, March 1992.

P. O. Lindberg, *Optimal* (s, S) *policies for inventories with random lead times*, Dept Math, Facultad de Ingeneria, University of Montevideo, Uruguay, March 1992.

P. O. Lindberg, *Spare parts optimization and availability of technical systems*, Dept Math, Facultad de Ingeneria, University of Montevideo, Uruguay, March 1992.

P. O. Lindberg, *Dual methods and decomposition*, Dept Math, Facultad de Ingeneria, University of Montevideo, Uruguay, March 1992.

P. O. Lindberg, *A component/product line standardization problem*, Dept of Industrial and Systems Engineering, University of Florida, Gainesville, April 23, 1992.

P. O. Lindberg, *Repair facility location in a repairable item inventory system*, TIMS/-ORSA joint national meeting, Orlando, Florida, April 26-29, 1992.

P. O. Lindberg and P. Alfredsson, *Repair facility location and parameter sensitivities in a repairable item inventory system*, Dept. of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, May 1, 1992.

P. O. Lindberg, *A nonlinear optimal control problem solved by linear programming*, International Conference on Agricultural Engineering 1992, Uppsala, June 1-4, 1992.

P. O. Lindberg, *Almost sure asymptotic bounds in random assignment problems*, 3rd Stockholm Optimization Days, KTH, June 25-26, 1992.

P. O. Lindberg, *Second order information in reduced gradients and the Pontryagin maximum principle*, 3rd Stockholm Optimization Days, KTH, June 25-26, 1992.

P. O. Lindberg, T. Magnusson, S. Feltenmark and A. Nöu, *Application of Lagrangian relaxation to short term power planning problems*, EURO XII/TIMS XXXI Joint International Conference, Helsinki, June 29-July 1, 1992.

A. Lindquist, *A geometric state space theory for modeling of stationary time series*, TIMS–SOBRAPO Congress, Rio de Janeiro, July 15–17, 1991. Invited speaker.

A. Lindquist, *On the nonlinear dynamics of fast filtering algorithms*, Centro de Calculo Cientifico, Comision Nacional de Energia Atomica, Buenos Aires, Argentina, July 22, 1991.

A. Lindquist, *Zeros of spectral factors and the geometry of splitting subspaces*, Workshop on Stochastic Theory and Adaptive Control, University of Kansas, September 26–28, 1991. Invited speaker.

A. Lindquist, *Zeros of spectral factors and the geometry of splitting subspaces*, Washington Univ. St Louis, September 30, 1991.

A. Lindquist, *Chaos in Kalman filtering?*, Mathematical Statistics Colloquium, Eötvös Lorand University, Budapest, Hungary, March 25, 1992.

A. Lindquist, *Fast filtering algorithms for Kalman filtering*, Mathematics Seminar, Eötvös Lorand University, Budapest, Hungary, March 27, 1992.

A. Lindquist, *Zeros of spectral factors and the geometry of splitting subspaces*, Computer and Automation Institute, Budapest, Hungary, March 31, 1992.

A. Lindquist, *Determining zeros of spectral factors from the geometry of splitting subspaces*, Washington Univ. St Louis, February 28, 1992.

A. Lindquist, *Zeros of spectral factors, the geometry of splitting subspaces and the algebraic Riccati inequality*, Systems, Models and Feedback: Theory and Applications. Workshop in honor of Professor Antonio Ruberti, Capri, June 15–17, 1992.

A. Megretski, *Scattering and control theory in inverse spectral problem for self-adjoint Hankel operators*, Univ. of Bordeaux I, June 1-2, 1992.

A. Megretski, *Inverse spectral problem for self-adjoint Hankel operators*, Univ. of Paris 6, June 4, 1992.

A. Megretski, *A class of compact Hankel operators with easily computable spectrum, singular values and Jordan structure*, Univ. of Paris 6, June 5, 1992.

A. Megretski, *Power distribution inequalities in optimization and robustness of uncertain systems*, INRIA, Paris, June 9, 1992.

A. Rantzer and B. Bernhardsson, *Structured stability margin and the finite argument principle*, IFAC Symposium on Design Methods of Control Systems, ETH Zurich, September 1991.

A. Rantzer, *Convex robusteness specifications for real parametric uncertainty in linear systems*, IFAC Workshop on Robust Control, Kappel am Albis, Switzerland, 1991.

A. Rantzer and P. O. Gutman, *Addition and multiplication of value set of uncertain transfer functions*, Conference of Decision and Control, Brighton, December 1991.

A. Rantzer, *Parametric uncertainty in linear systems*, ETH, Zürich, Switzerland, January, 1992.

A. Rantzer, *On computation of value sets of uncertain transfer functions*, DLR, Oberpfaffenhofen, Germany, January 1992.

A. Rantzer, *Parametric uncertainty in linear systems*, Linköping University, February, 1992.

A. Rantzer, *A convex parametrization of robustly stabilizing controllers*, Int. Workshop on Robust Control, Ascona, Switzerland, April, 1992.

A. Rantzer, *Convex robustness specifications for real parametric uncertainty in linear systems*, American Control Conference, Chicago, June 1992.

A. Rantzer, *Continuity properties of the parametric stability margin*, American Control Conference, Chicago, June 1992.

K. Svanberg, *Mathematical programming methods for structural optimization*, 2nd Stockholm Optimization Days, August 12-13, 1991.

K. Svanberg, *The method of moving asymptotes with some extensions*, NATO/DFG ASI on Optimization of large structural systems, Berchtesgaden, Germany, September 23-October 4, 1991, (invited lecturer).

K. Svanberg, *Local and global optima in structural optimization*, NATO/DFG ASI on Optimization of large structural systems, Berchtesgaden, Germany, September 23-October 4, 1991, (invited lecturer).

K. Svanberg, *Some second order methods for structural optimization*, NATO/DFG ASI on Optimization of large structural systems, Berchtesgaden, Germany, September 23-October 4, 1991, (invited lecturer).

K. Svanberg, *Convex approximation methods for structural optimization*, COMETT-Seminar on Computer aided optimal structural design, Castle of Thurnau, Germany, May 18-22, 1992, (invited lecturer).

K. Svanberg, *Topological optimization of structures*, 3rd Stockholm Optimization Days, June 25-26, 1992.

O. Viera, *Optimal water usage in a power station*, 14th International Symposium on Mathematical Programming, Amsterdam, August 5-9, 1991.

7 2nd Stockholm Optimization Days

The 2nd Stockholm Optimization Days, a two-day workshop on optimization, was held at KTH in Stockholm, August 12-13, 1991. It attracted a small but qualified audience and an impressive list of speakers. The number of participants was close to 50, coming from 4 continents and 15 countries. The conference was sponsored by the Göran Gustafsson Foundation and the Swedish National Board for Technical Development. Head of the organizing committee was P. O. Lindberg.

Invited presentations

Philip E. Gill, University of California at San Diego, La Jolla, California, USA, Walter Murray and Michael A. Saunders, Stanford University, Stanford, California, USA. *Phase 1 Algorithms for Linear Programming.*

Jean-Louis Goffin, McGill University, Montreal, Quebec, Canada. *Decomposition with the Projective Algorithm.*

William W. Hager and **Donald W. Hearn**, University of Florida, Gainesville, Florida, USA. *The Dual Active Set Algorithm with Application to Quadratic Networks.*

Krzysztof Kiwiel, Polish Academy of Sciences, Warsaw, Poland. *Partial Subgradient Aggregation in Decomposition of Large-Scale Convex Programs via Bundle Methods.*

Siriphong Lawphongpanich, Naval Postgraduate School, Monterey, California, USA. *Accelerating the Cutting Plane Algorithm for Maximin Problems.*

Claude Lemarechal, INRIA, Domaine de Voluceau, Rocquencourt, France. *Lagrangian Decomposition and Nonsmooth Optimization: Bundle Algorithm, Prox Iteration, Augmented Lagrangian.*

Philip E. Gill, University of California at San Diego, La Jolla, California, USA, **Walter Murray**, Dulce Ponceleon and Michael A. Saunders, Stanford University, Stanford, California, USA. *Primal-Dual Methods for Linear Programming.*

Arkadii Nemirovski, Central Econ. & Math. Institute, USSR Acad. Sci., Moscow, USSR. *Conic Duality and Its Applications in Convex Programming.*

Panos M. Pardalos, University of Florida, Gainesville, Florida, USA. *Computational Techniques for Solving Global Optimization Problems.*

Andrew R. Conn, IBM T. J. Watson Research Center, Yorktown Heights, New York, USA, Nicholas I. M. Gould, Rutherford Appleton Laboratory, Oxfordshire, England and **Philippe Toint**, Facultés Universitaires ND de la Paix, Namur, Belgium. *Early Experience Using the LANCELOT Optimization Package.*

Other presentations

Torgil Abrahamsson and Per Olov Lindberg, Royal Institute of Technology, Stockholm, Sweden. *Matrix Balancing by a Conjugate Direction Method with Applications to Traffic Assignment.*

Ulf Brännlund, Royal Institute of Technology, Stockholm, Sweden. *A Generalized Subgradient Method with Polyak Step.*

Anders Forsgren, Royal Institute of Technology, Stockholm, Sweden and Walter

Murray, Stanford University, Stanford, California, USA. *Newton Methods for Large-Scale Linearly Constrained Optimization.*

Ubaldo M. Garcia-Palomares, Universidad Simon Bolivar, Caracas, Venezuela. *Iterative Algorithm for Solving LARGE Least Squares Problems.*

Clovis C. Gonzaga, COPPE – Federal University of Rio de Janeiro, Rio de Janeiro, Brazil. *An Interior Trust Region Method for Linearly Constrained Optimization.*

Per Olov Lindberg and **Lars Svensson**, Royal Institute of Technology, Stockholm, Sweden. *Finding All Local Optima to Polynomial (and Rational) Optimization Problems with the Help of Groebner Bases.*

Birgitta Olin, Royal Institute of Technology, Stockholm, Sweden. *Asymptotic Properties of Random Assignment Problems.*

Ulf Ringertz, The Aeronautical Research Institute of Sweden, Stockholm, Sweden. *On Maximizing the Buckling Load of Stiffened Shell Structures.*

Stephen Nash and **Ariela Sofer**, George Mason University, Fairfax, Virginia, USA. *Using Truncated-Newton Methods for Constrained Nonlinear Optimization.*

Krister Svanberg, Royal Institute of Technology, Stockholm, Sweden. *Mathematical Programming Methods for Structural Optimization.*

Jørgen Tind, University of Aarhus, Aarhus, Denmark. *Decomposition in Mathematical Programming.*

Sami Viitanen, Åbo Akademi, Åbo, Finland. *Parallel Topographic Algorithm for Global Optimization.*

Dag Wedelin, Chalmers Institute of Technology, Gothenburg, Sweden. *Probabilistic Networks and Combinatorial Optimization.*

8 3rd Stockholm Optimization Days

The 3rd Stockholm Optimization Days, a two-day workshop on optimization, was held at KTH in Stockholm, June 25-26, 1992. It attracted a small but qualified audience and an impressive list of speakers. The number of participants was close to 50, coming from many different countries. The conference was sponsored by the Göran Gustafsson Foundation and the Swedish National Board for Industrial and Technical Development. Head of the organizing committee was P. O. Lindberg.

Invited presentations

Jonathan F. Bard, University of Texas at Austin, Austin, Texas, USA. *Using Decomposition to Solve the Tour Scheduling Problem.*

Jacques Desrosiers and Yvan Dumas, GERAD and Ecole des HEC, Montreal, Canada, Marius M. Solomon, Northeastern University, Boston, Massachusetts, USA and François Soumis, GERAD and Ecole Polytechnique, Montreal, Canada. *A Unified Approach to Airline Fleet Planning, Crew Pairing and Crew Rostering Problems.*

Philip E. Gill, University of California at San Diego, La Jolla, California, USA. *An Algorithm for Large-Scale Quadratic Programming.*

Hsin-Der Chen, **Donald W. Hearn** and Chung-Yee Lee, University of Florida, Gainesville, Florida, USA. *A New DP Algorithm for the Capacitated Dynamic Lot Size Model.*

James K. Ho, University of Illinois at Chicago, Chicago, Illinois, USA. *Recent Results in Using Distributed Computation for Linear Programming.*

Walter Murray, Stanford University, Stanford, California, USA. *The Choice of Merit Function for SQP Algorithms.*

Other presentations

G. Anandalingam, University of Pennsylvania, Philadelphia, Pennsylvania, USA and Douglas J. White, University of Manchester, Manchester, New Hampshire, USA. *A Penalty Function Approach for Solving Bi-level Linear Programs.*

Ulf Brännlund, Royal Institute of Technology, Stockholm, Sweden. *On Subgradient Optimization with Constraints.*

Antonio Conejo, **Fernando de Cuadra** and Ignacio J. Pérez-Arriaga, Universidad Pontifica Comillas, Madrid, Spain. *Structured Multi-Attribute Optimization: Concepts and Applications.*

Bob Entriken, Shell Research, Amsterdam, Netherlands. *Object-Oriented Modeling with GAMS.*

Anders Forsgren, Royal Institute of Technology, Stockholm, Sweden. *Linesearch Issues in Modified Newton Methods .*

Per Olov Lindberg and Birgitta Olin, Royal Institute of Technology, Stockholm, Sweden. *Almost Sure Asymptotic Bounds in Random Assignment Problems.*

Per Olov Lindberg, Royal Institute of Technology, Stockholm, Sweden. *Second Order Information in Reduced Gradients and the Pontryagin Maximum Principle.*

Saied Ghannadan, **Athanasios Migdalas**, Hoang Tuy and Peter Värbrand, Linköping Institute of Technology, Linköping, Sweden. *Strongly Polynomial Algorithm for a Production-Transportation Problem with Concave Production Costs.*

Udatta S. Palekar, University of Illinois at Urbana-Champaign, Urbana, Illinois, USA, Nikolaos V. Sahinidis, Carnegie Mellon University, Pittsburg, Pennsylvania, USA, B. A. Kijowski and M. I. Dessouky. *Tardiness Issues in Cyclic Scheduling Problems.*

Dulce Ponceleon, Apple Computer, Inc., Cupertino, California, USA. *A Comparison of Barrier Methods for LP with those for NLP.*

Mauricio G.C. Resende, AT&T Bell Laboratories, Murray Hill, New Jersey, USA and Geraldo Veiga, University of California at Berkeley, Berkeley, California, USA. *An Efficient Implementation of a Network Interior Point Method.*

Ulf Ringertz, The Aeronautical Research Institute of Sweden, Stockholm, Sweden. *On Finding the Optimal Distribution of Material Properties .*

Anders Klarbring, Torbjörn Larsson and **Mikael Rönnqvist**, Linköping Institute of Technology, Linköping, Sweden. *A Second Order Method for Frictionless Contact Problems.*

Carl-Louis Sandblom, Technical University of Nova Scotia, Halifax, Canada. *How to Measure the Deformity of a Polyhedron.*

Annick Sartenaer, FUNDP, Namur, Belgium. *A Class of Trust Region Methods for Nonlinear Network Optimization Problems, Including Some Numerical Experiments.*

Jacques Desrosiers and Yvan Dumas, GERAD and Ecole des HEC, Montreal, Canada, **Marius M. Solomon**, Northeastern University, Boston, Massachusetts, USA and François Soumis, GERAD and Ecole Polytechnique and Montreal, Canada. *Sensitivity Analyses for Airline Crew Scheduling Problems.*

Krister Svanberg, Royal Institute of Technology, Stockholm, Sweden. *Topological Optimization of Structures.*

9 Other activities

Patrik Alfredsson

- Participated in the 14th International Symposium on Mathematical Programming, Amsterdam, The Netherlands, August 5–9, 1991.
- Visited the Department of Industrial and Systems Engineering, University of Florida, Gainesville, Florida, USA, April 22–24, 1992.
- Participated in the 33rd TIMS/ORSA Joint National Meeting, Orlando, Florida, USA, April 26–29, 1992.
- Visited the Department of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, April 30–May 1, 1992.
- Participated in EURO XII/TIMS XXXI Joint International Conference, Helsinki, Finland, June 29–July 1, 1992.
- Member of Board of the Swedish Operations Research Association.

Tomas Björk

- Director of Undergraduate Studies (studierektor) in Optimization and Systems Theory.

Ulf Brännlund

- Gave with P. O. Lindberg a 1 day course in "Modelling and Optimization" at Swedish Defense Research Establishment (FOA), November 29, 1991.
- Constructed an LP-model for resource balancing in a forestry company in cooperation with The Forest Operations Institute.
- Visited INRIA, Le Chesnay, France, December 14-20, 1991.
- Opponent on Licenciat-thesis at Linköping University, January 22, 1992.
- Visited University of Florida, Gainesville, USA, April 22-25, 1992.

Stefan Feltenmark

- Participated in EURO XII/TIMS XXXI Joint International Conference, Helsinki, Finland, June 29–July 1, 1992.

Anders Forsgren

- Referee for Mathematical Programming and SIAM Journal on Optimization.
- Visited the Department of Mathematics at Facultés Universitaires Notre-Dame de la Paix, Namur, Belgium, November 11-15, 1991.
- Visited the Department of Operations Research at Stanford University, Stanford, California, USA, May 14-18, 1992.

Martin Hagström

- Visited Narvik Institute of Technology, Narvik, Norway, June 15-16, 1992.

Xiaoming Hu

- Referee for Systems and Control Letters.
- Participated in the 30th IEEE Conference on Decision and Control, Brighton, England, December, 1991.

P. O. Lindberg

- Adjunct Professor in Industrial and Systems Engineering, University of Florida at Gainesville, USA.
- Member of Board of Undergraduate Education in the Schools of Vehicle Engineering (linjenämnden T) and Industrial Engineering (linjenämnden I).
- Head of organizing committee of the 2nd Stockholm Optimization Days, Au-

gust 12-13, 1992.
- Head of organizing committee of the 3rd Stockholm Optimization Days, June 25-26, 1992.
- On editorial board of Computational Optimization and Applications.
- Gave basic and advanced course in Optimization at Facultad de Ingeneria, University of Montevideo, Uruguay, February 24-March 19, 1992.

Anders Lindquist

- Communicating Editor, *Mathematical Systems, Estimation and Control*, journal published by Birkhäuser Boston.
- Associate Editor, *Systems and Control Letters*, journal published by North-Holland.
- 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 five other journals.
- Affiliate Professor, Washington University, St Louis, USA.
- Vice Chairman of Board of Academic Appointments for the School of Engineering Physics (tjänsteförslagsnämnden för teknisk fysik).
- Steering Committee, International Symposium on the Mathematical Theory of Networks and Systems (MTNS).
- Member, International IFAC Committee for Mathematics in Control.
- Program Committee of MTNS-93 to be held in Regensburg, Germany, August 2- 6, 1993.
- Organizing Committee of the 24th ISCIE Symposium on Stochastic Systems Theory and its Applications to be held in Kyoto, Japan, November 11-13, 1992.

Alexandre Megretski

- Refereed three papers for Systems and Control Letters.
- Refereed one paper for Journal of Mathematical Systems, Estimation, and Control.

Andreas Nöu

- Participated in EURO XII/TIMS XXXI Joint International Conference, Helsinki, Finland, June 29–July 1, 1992.

Anders Rantzer

- Refereed several papers for Systems and Control Letters, Automatica, IEEE Transactions on Automatic Control and Journal of Mathematical Systems Estimation and Control.

Krister Svanberg

- Refereed two papers for Structural Optimization.
- Distributed the MMA-91 package for structural optimization to the following researchers: Professor Ernest Hilton, University College of Swansea, Professor Jochem Zowe, University of Bayreuth, and Dr Karoly Jarmai, University of Miskolc.

Omar Viera

- Gave course in modelling with GAMS and acted as teaching assistant at basic and advanced course in Optimization at Facultad de Ingeneria, University of Montevideo, Uruguay, February 24-March 19, 1992.

Yishao Zhou

- Refereed four papers for "System & Control Letters", "J. of Mathematical Systems, Estimation, and Control", "Mathematics of Control, Signals and Systems".
- Visited Narvik Institute of Technology, June 15-16, 1992.