Activity Report

1990/1991

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

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

Vikarierande högskolelektor (Acting senior lecturer)

Anders Forsgren, TeknD

Forskarassistent (Research associate)

Xiaoming Hu, PhD

Sekreterare (Secretary)

Elise Hanning

Doktorander (Graduate students)

Torgil Abrahamsson, civing
Erik Berglund, civing
Ulf Brännlund, civing, MS
Martin Hagström, civing
Torbjörn Magnusson, civing (Employed by Skandia International, 1990)
Birgitta Olin, civing, TeknL
Anders Rantzer, civing, TeknL
Jan-Åke Sand, civing
Henrik Winkler, diploming. (Visiting)
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. Since the summer of 1987 he is a PhD student at Optimization and Systems Theory at KTH. His main research interest is in traffic equilibria.

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.

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. His main research interest is nonlinear programming.

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

Elise Hanning is the secretary at the Division of Optimization and Systems Theory since 1989.

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 50 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 some fifty publications 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).

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 and a Tekn.Lic. (1989) in Mathematics, both from Lund University. At present, he is a PhD student at the Division of Optimization and Systems Theory at KTH. In 1990, he won the SIAM Student Paper Competition in Chicago. Main research interests are stabilization and robustness of linear control systems.

Jan-Åke Sand was born in 1964 in Stockholm. He received a civilingenjör degree in Engineering Physics at KTH in 1988 and is now a PhD student 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 continuous scientific contacts with such industrial companies as SAAB-SCANIA, VOLVO, and ALFA-LAVAL.

Omar Viera was born in 1953 in Montevideo, Uruguay. He will receive his degree in Engineering Physics at KTH in 1991. 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 at 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

Dr. Ruggero Frezza
Department of Electronics and Informatics
University of Padova
Padova, Italy

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

Dr. Andrea Gombani
LADSEB-CNR
Padova, Italy

Professor P. O. Gutman
Faculty of Agricultural Engineering
Technion
Haifa, Israel

Professor Donald W. Hearn
Department of Industrial and Systems Engineering
University of Florida
Gainesville, Florida, USA

Professor Alberto Isidori
Department of Informatics and Systems Sciences
University of Rome
Rome, Italy

Dr. Björn Johansson
Department of Mathematical Statistics
University of Stockholm
Stockholm, Sweden

Professor John Lund
Montana State University
Bozeman, Montana, USA

Professor Lars Lundqvist
Department of Regional Planning
KTH
Stockholm, Sweden

Dr. Lars-Göran Mattsson
Office of Regional Planning and Urban Transportation
Stockholm County Council
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

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

Professor Yu-Fan Zheng
Applied Math. Research Division
East China Normal University
Shanghai, China

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.
- Disturbance decoupling with stability for nonlinear systems.
- Feedback stabilization and output regulation of nonlinear systems.
- Generalized semimartingale representations.
- Geometry of the discrete-time algebraic Riccati equation.
- Nonlinear control of uncertain systems with hard nonlinearities.
- On the nonlinear dynamics of Kalman filtering.
- Optimal greenhouse control.
- 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

- Component standardization.
- Dual methods for large scale optimization problems.
- Dual methods for the unit commitment problem.
- Higher order methods for structural optimization.
- Inventory control, in particular stochastic leadtimes and back-order-time shortage penalties.
- Optimal waterflow 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.
- 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.

Disturbance decoupling with stability for nonlinear systems

Researchers: Xiaoming Hu and Y. F. Zheng.

Sponsors: STU and STUF.

The disturbance decoupling problem with stability (DDPS for short) has been paid a considerable amount of attention in recent years, due to its practical significance and theoretical attraction. Typically, the disturbance decoupling problem with exponential stability (DDPES for short) can be solved if the system has a so-called maximal stable distribution. However, the existence of the maximal stable distribution strongly depends on the conditions that the linearized counterpart of the nonlinear system is controllable and the zero dynamics of the nonlinear system has a hyperbolic equilibrium. And moreover, in many cases, the DDPS can be considered solved if the DDP is solved and the state trajectories of the system are bounded when the disturbance is sufficiently small. By the theory on total stability, we can replace the requirement of exponential stability by that of asymptotic stability for this purpose. We have studied the disturbance decoupling problem with asymptotic stability (DDPAS for short) and DDPAS is solved by using the smallest locally controlled invariant and involutive distribution which contains the disturbance channel. We have also applied the results to cascading nonlinear systems and a procedure is given of how to design DDPAS controllers for such systems.

Feedback stabilization and output regulation of nonlinear systems

Researchers: Xiaoming Hu, in cooperation with C. I. Byrnes (Washington University, St. Louis) and A. Isidori (University of Rome).

Sponsors: STU and STUF.

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 shown that the problem of output regulation in the large can be solved for a class of globally nonminimum phase nonlinear systems by using a control law which only requires the knowledge of the output of the system and the reference signal. If the measurement of all state variables of the system is available, then an improved adaptive control law can be used for the same purpose, which gives faster system response time. As has been noted by some control theorists, when we use estimated state variables to solve the output regulation problem (even locally), in many situations only nonexponential error decay observers are possible to construct. Since this kind observers had not been discussed much in the literature, we studied the very basic problems regarding the existence of such observers. We have found some very interesting properties of nonexponential observers. In particular, we have proposed the concept of uniform observer which would make easy the design of a nonexponential observer to some extent and a necessary condition and some sufficient conditions have been given for the construction of a uniform observer for nonlinear systems.

Generalized semimartingale representations

Researcher: Henrik Winkler (Anders Lindquist; advisor).

Sponsor: STU.

The project is concerned with the generalization of certain results regarding representation and time reversal of semimartingales due to Lindquist and Picci to vector processes with higher order stationary increments.

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).

Sponsor: STU.

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: STU, FOA 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.

Optimal greenhouse control

Researchers: P. O. Gutman and P. O. Lindberg.

It is believed that current greenhouse control practice can be made more economical by including dynamical models for the growing plant, weather forecasts, and economic criteria functions. An optimal control problem is formulated for a simple nonlinear constrained growth model. It is found that the problem can be transformed into a constrained linear problem and thus solved by linear programming. The resulting control trajectory is interesting since it is seemingly "counterintuitive" but yields an energy saving of about 10%.

Robustness of linear systems with known uncertainty structure

Researcher: Anders Rantzer (Anders Lindquist; advisor).

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. Perhaps the most important of them is to reduce conservativeness of the design by taking into account the known structure of uncertainty.

Two major approaches have been proposed for robustness analysis with respect to uncertainty with known structure, the 'value set' approach and the 'μ synthesis' approach. The present project concentrates on three unsolved problems regarding structured uncertainty, which are central for the treatment of more realistic models of plant uncertainty.

- *Optimal control design with respect to uncertain parameters that appear linearly in the characteristic polynomial.* This is the kind of uncertainty structure that is typically produced by modern identification algorithms.
- *Efficient robustness analysis with respect to uncertain parameters that appear multilinearly in the characteristic polynomial.* Uncertainty in physical parameters often comes in this way.
- *Unification of value set approach and μ-appraoch.* Despite the fact that these two approaches treat the same problem, the connections between them still remain unexplored. There are several issues that seem very likely to gain from an interaction.

Stochastic systems theory

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

Sponsors: STU 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: STU, FOA 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 Georgiou's 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).

Sponsor: The Göran Gustafsson Foundation.

This project is concerned with the question how the zero structure of (not necessarily square) spectral factors is reflected in the geometry of minimal splitting subspaces and stochastic realizations. Among other things the zeros are completely characterized in term of splitting subspace geometry.

2.2.2 Description of projects in Mathematical Programming

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.

Dual methods for large scale optimization problems

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

Sponsors: Swedish Board for Technical Development, ABB Network Control AB, Krångede Power Pool, Swedish State Power Board, Swedish Transport Research Board.

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.

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 and Torbjörn Magnusson.

Sponsors: Swedish Board for Technical Development, ABB Network Control AB, Krångede Power Pool, Swedish State Power Board.

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 fo 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.

Higher 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 the "Truss sizing problem" in which the optimal cross section areas of the different elements (bars) in a truss structure should be calculated. With "optimal" is (in this case) meant that the structural weight is minimized subject to given constraints on structural stiffness and strength.

In this project, we develop and investigate different higher order optimization methods for truss sizing problem. During 1990/91, we developed and implemented some new explicit approximations of the implicit constraint functions. These approximations turned out to be of such high quality, that the overall optimization process converged to an optimal solution after less than 6 iterations on each of a large number of considered truss sizing problems.

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 waterflow through a water power station

Researchers: P. O. Lindberg and Omar Viera.

Sponsor: Swedish State Power Board.

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. Preliminary results have been presented. 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, Ulf Brännlund, Anders Forsgren, Krister Svanberg, Torgil Abrahamsson, Yvonne Strömdahl (Master's Thesis).

Sponsor: The Swedish National Board for Technical Development.

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 worked at collecting optimization routines and facilitate 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. Some software has been distributed to companies (GAMS and NETSIDE).

Optimization of spare parts inventory systems

Researchers: P. O. Lindberg and Patrik Alfredsson (Master's Thesis).

Sponsors: Swedish Board for Technical Development and Swedish Defense Material Administration.

Industrial contact: Swedish Defense Material Administration.

This project entails a broad study of spare parts inventory systems. In particular we are studying optimization of spare part inventories, location of repair facilities, and sensitivities of the optimal value with respect to the problem parameters. We have started the programming of the computation of sensitivities as part of an Engineering Master's Thesis.

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, proofs of the previously announced lower bounds have been written up as a Licentiate Thesis. Moreover we have performed extensive testing by simulation of the distributions of several interesting entities for the problem.

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, which got positive referee response. Several other ideas are in the pipeline.

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 associated system of equations.

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

On the theoretical side, recent work include the development of modified Newton methods for linearly constrained optimization, for which theoretical results have been established.

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.

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: STU.

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 Polyak step has been suggested and studied. A generalization of the subgradient algorithm with Polyak 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.

Large scale optimization problems from Hierarchical Production Planning has been used for testing.

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. A first combined model containing trip distribution, modal split and traffic assignment with an application to the Stockholm region was presented at the RSA conference in Istanbul, 1990. 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. 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 master problem a second order method is being developed and applied.

3 Education

3.1 Undergraduate courses

Number	Course name	Instructor	Credit
FA190	Optimization, General Course *(Optimeringslära, allmän kurs för D och F)*	A. Forsgren	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)*	T. Björk	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
FA314	Filtering and Stochastic Control *(Filtrering och stokastisk 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
Stochastic Differential Equations and Applications	T. Björk	10 p	8	2
Global Optimization	P. O. Lindberg	2 p	8	-

3.3 Licentiate thesis

B. Olin, *An improved lower bound on the optimal value in a random assignment problem*, TRITA-MAT-1990-31, Division of Optimization and Systems Theory, Department of Mathematics, KTH, 1990. Advisor: P. O. Lindberg.

3.4 Master theses (Examensarbeten)

P. Appelgren (F), *Om optimal styrning av robotar*. Advisor: T. Björk. Performed at FOA.

T. Herulf (T), *Optimala transportsätt och depåstrukturer vid transporter av farligt gods.* Advisor: P. O. Lindberg. Performed at Statens Räddningsverk.

H. Håkansson och A. Wahlgren (M), *Utvärdering av optimeringsprogram för råvaruhantering.* Advisor: P. O. Lindberg.

C. Lundell (T), *Reservdelsdimensionering för AXE-stationer.* Advisor: P. O. Lindberg. Performed at Televerket.

P.-E. Magnusson (T), *Utveckling av optimerande resursallokeringsprogram för projektstyrningsapplikationer.* Advisor: K. Svanberg. Performed at Cepro Information Engineering.

A. Mårtensson (F), *Informationssystem för orderoptimering hos Pictura Graphica AB.* Advisor: P. O. Lindberg. Performed at Pictura Graphica AB.

C. Nilsson (T), *Global optimering i elektroniska kretsar.* Advisor: K. Svanberg. Performed at Ericsson Telecom.

B. Pellbäck (T), *Underhållsanalys av skjutsimulator BT41.* Advisor: P. O. Lindberg. Performed at FMV.

M. Raab (F), *Dynamisk optimering av telenät.* Advisor: K. Svanberg. Performed at Televerket.

Y. Strömdahl (F), *Optimering av produktionsplan i pumpkraftverk.* Advisor: P. O. Lindberg. Performed at ABB Network Control.

F. Voldmo (T), *LCC-optimerat val av underhållsfilosofi för havsbaserade vindkraftverk.* Advisor: P. O. Lindberg. Performed at Vattenfall.

4 Publications

4.1 Published (and accepted) papers

4.1.1 Published (and accepted) papers in Systems and Control

Cladio G. Baril and Per-Olof Gutman, *Performance related adaptive friction compensation for uncertain systems*, To appear in Proc. European Control Conference, Grenoble, France, 2-5 July 1991.

C. I. Byrnes, A. Lindquist and T. McGregor, *Predictability and unpredictability in Kalman filtering*, IEEE Transactions on Automatic Control AC-36 (1991), 563–579.

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

X. Hu, *Asymptotic tracking with stability in the large for a planar system*, New Trends in Systems Theory (eds. G. Conte, A. Perdon and B. Wyman), Progress in Systems and Control, vol. 7, Birkhäuser, Boston, 1991, 417-424.

X. Hu, *On state observers for nonlinear systems*, To appear in Systems and Control Letters, No. 1, vol. 18.

X. Hu, *Output tracking through singularities for nonlinear systems*, To appear in the proceedings of the MTNS Conference, Kobe, Japan, 1991.

X. Hu, *A note on nonlinear state observers*, Proceedings of the 10th American Control Conference, Boston, 1991.

X. Hu, *Asymptotic tracking with internal stability in the large for nonlinear systems*, Proceedings of the First European Control Conference, Grenoble, France (1991), 2058-2063.

A. Lindquist and G. Picci, *A geometric approach to modelling and estimation of linear stochastic systems*, To appear in Journal of Mathematical Systems, Estimation and Control I (1991), No. 3.

A. Rantzer, *Minimal testing sets: A generalization of Kharitonov's theorem*, New Trends in Systems Theory, (G. Conte, A.M. Perdon, B. Wyman, eds.), Birkhäuser (1991), pp. 614-621.

A. Rantzer, *Hurwitz testing sets for parallel polytopes of polynomials*, Systems & Control Letters 15(1990), 99–104.

A. Rantzer, *Stability conditions for polytopes of polynomials*, To appear in IEEE Trans. Automatic Control.

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*, Accepted for publication in SIAM Journal on Matrix Analysis and Applications.

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, subject to amendments.

K. Svanberg, *Optimal truss sizing based on explicit Taylor series expansions*, Structural Optimization 2(1990), 153-162.

4.2 Technical reports and preprints

4.2.1 Technical reports and preprints in Systems and Control

T. Björk and B. Johansson, *Adaptive prediction and reverse martingales*, Report TRITA-MAT-1991-9, Department of Mathematics, KTH, 1991, Submitted for publication.

C. I. Byrnes, A. Lindquist and Y. Zhou, *On the nonlinear dynamics of fast filtering algorithms*, Report TRITA-MAT-1991-25, Department of Mathematics, KTH, 1991, Submitted for publication.

P. O. Gutman, P. O. Lindberg, and I. Seginer, *A nonlinear optimal greenhouse control problem solved by linear programming*, Submitted to the 5th Internation Conference on Agricultural Engineering, Uppsala, Sweden 1-4 June, 1992.

X. Hu, *Output feedback stabilization of nonlinear systems in the large*, Submitted to SIAM J. Control and Optimization.

X. Hu, *Output regulation in the large for a class of nonlinear systems*, Preprint.

X. Hu, *The zero dynamics algorithm for general nonlinear systems and its application in exact output tracking*, Preprint.

A. Megretsky, *Sensitivity optimization problem for uncertain discrete SISO systems*, Report TRITA-MAT-1990-40, Department of Mathematics, KTH, 1990, Submitted for publication.

A. Megretsky, *Necessary and sufficient conditions of stability: A multiloop generalization of the circle criterion*, Report TRITA-MAT-1990-41, Department of Mathematics, KTH, 1990, Submitted for publication.

I. Petersen and A. Rantzer, *On holes in the value set of an uncertain transfer function*, To appear.

A. Rantzer and B. Bernhardsson, *Structured stability margin and the finite argument principle*, Submitted for publication.

A. Rantzer and P. O. Gutman, *An algorithm for addition and multiplication of value sets of uncertain transfer functions*, Submitted for publication.

A. Rantzer, *Kharitonov regions and their reciprocals are convex*, Submitted for publication.

Y-F. Zheng and X. Hu, *Local disturbance decoupling with asymptotic stability for nonlinear systems*, Submitted to Dynamics and Control.

4.2.2 Technical reports and preprints in Mathematical Programming

T. Abrahamsson and P. O. Lindberg, *Matrix balancing by successive overrelaxation with applications to traffic assignment*, Report TRITA-MAT-1991-22, Department of Mathematics, KTH, 1991. (Presented at the 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*, Report TRITA-

MAT-1991-21, Department of Mathematics, KTH, 1991. (Presented at the Second Stockholm Optimization Days, Stockholm, August 12-13, 1991.).

U. Brännlund, *A convergent subgradient algorithm based on the Polyak step*, Working Paper presented at 14th Intl. Symp. on Math. Prog., Amsterdam 1991.

U. Brännlund, *A generalized subgradient algorithm with Polyak step*, Working Paper presented at Stockholm Optimization Days, Stockholm 1991.

A. Eriksson and P. O. Lindberg, *Equilibria in additive random utility models*, Under revision for Regional Science and Urban Economics, TRITA-MAT-1987-10.

A. Forsgren and U. Ringertz, *On the use of a modified Newton method for nonlinear finite element analysis*, Preprint.

P. O. Lindberg, A. Eriksson and L.-G. Mattsson, *Generalized extreme value choice models and the invariance property*, Under revision for Environment and Planning.

K. Svanberg, *Approximation of the constraints in truss sizing problems*, Submitted for publication.

K. Svanberg, *The method of moving asymptotes (MMA) with some extensions*, Lecture notes for the NATO/DFG ASI Optimization of Large Structural Systems.

K. Svanberg, *Local and global optima*, Lecture notes for the NATO/DFG ASI Optimization of Large Structural Systems.

K. Svanberg, *Some second order methods for structural optimization*, Lecture notes for the NATO/DFG ASI Optimization of Large Structural Systems.

5 Awards

Division of Optimization and Systems Theory was nominated Center of Excellence (for Nordic Universities) by the President's Office.

Alexander Megretsky was awarded one of two *Göran Gustafsson Postdoctoral Fellowships* to enable him to spend academic year 1991/92 at the Division of Optimization and Systems Theory.

Anders Rantzer was winner of the SIAM Student Paper Competition, Chicago 1990.

Omar Viera received an energy research award from the Swedish State Power Board in June 1991.

6 Presentations by staff

T. Abrahamsson and L. Lundqvist, *A combined trip distribution modal split and assignment model applied to Stockholm*, 30th RSA European Congress, Istanbul, Turkey, August 28-31, 1990.

T. Björk, *Adaptive prediction*, LADSEB-Institute, Padova, Italy, August 1990.

T. Björk, *Adaptive prediction and reverse martingales*, CEMI-Institute, Moscow, June 1991.

A. Forsgren, *Newton methods for optimization*, Uppsala University, April 17, 1991.

M. Hagström, *On the convergence of fast filtering algorithms for Kalman filtering and the geometry of the global Kimura-Georgiou parameterization of positive real functions*, Mathematical Theory of Networks and Systems (MTNS'91), Kobe, Japan, June 17–21, 1991, (invited speaker).

X. Hu, *Set point control of a planar nonlinear system*, Conference on New Trends in Systems Theory, Genoa, Italy, July, 1990.

X. Hu, *Output tracking through singularities for nonlinear systems*, MTNS Conference, June 21, 1991, Kobe, Japan.

P. O. Lindberg, *Optimeringsmodeller för nätverksanalys*, Kursen "Transporter, logistik och den nya rörligheten", Borlänge, September 24, 1990.

P. O. Lindberg, *Optimeringsmodeller från modelleringssynpunkt*, FOA-kursen "Operationsanalytiska metoder", Stockholm, November 30, 1990.

P. O. Lindberg, *Genomgång av optimeringsprogrammen LP88, MILP88 och TSA88*, Svenska Operationsanalysföreningens temadag "Beslutsstöd på persondator", KTH, January 8, 1991.

P. O. Lindberg, *Genomgång av GIS- och transportoptimeringspaketet TransCAD*, Svenska Operationsanalysföreningens temadag "Beslutsstöd på persondator", KTH, January 8, 1991.

P. O. Lindberg, *Heldags introduktion till optimeringsmetoder och -modellering*, Kursen "Optimeringsmodellering och problemlösning med GAMS", KTH, January 8, 1991.

A. Lindquist, *On the nonlinear dynamics of Kalman filtering*, The SIAM 1990 Annual Meeting, Chicago July 16-20 1990. Invited speaker.

A. Lindquist, *A review of fast algorithms for Kalman filtering*, Washington Univ. St Louis, July 19 1990.

A. Lindquist, *On the nonlinear dynamics of fast filtering algorithms*, Washington Univ. St Louis, July 20 1990.

A. Lindquist, *A geometric state space theory for modeling of stationary time series*, International Interdisciplinary Workshop on Modern Directions in Time Series Analysis (sponsored by the Institute of Mathematics and its Applications), University of Minnesota, July 1990. Invited Plenary Speaker.

A. Lindquist, *On the nonlinear dynamics of Kalman filtering*, Second Conference on Computation and Control, Bozeman, Montana, August 1–11, 1990. Invited plenary speaker.

A. Lindquist, *Geometric theory of linear stochastic systems*, The 11th World Congress of IFAC, Tallinn, Estonia, August 13–17, 1990. Invited speaker.

A. Lindquist, *On the partial realization problem*, LADSEB-CNR, Padova, Italy, November, 1990.

A. Lindquist, *On the nonlinear dynamics of fast filtering algorithms*, University of Linköping, May 24, 1991.

A. Lindquist, *On the nonlinear dynamics of Kalman filtering*, Institute of Control Sciences, Academia Sinica, Beijing, Kina, June 10, 1991.

A. Lindquist, *On the nonlinear dynamics of fast filtering algorithms*, Preconference to the MTNS, Hangzhou, Kina, June 13, 1991, Invited plenary speaker.

A. Lindquist, *Zeros of spectral factors and the structure of the solution set of the algebraic Riccati inequality*, International Symposium on the Mathematical Theory of Networks and Systems, Kobe, Japan, June 19, 1991.

A. Lindquist, *On the nonlinear dynamics of Kalman filtering*, International Symposium on the Mathematical Theory of Networks and Systems, Kobe, Japan, June 21, 1991.

A. Rantzer, *Maximizing singular values over frequency*, Conference on New Trends in Systems Theory, Genoa, July 1990.

A. Rantzer, *Zero locations of polytopes of polynomials*, Conference on New Trends in Systems Theory, Genoa, July 1990.

A. Rantzer, *Zero locations of polytopes of polynomials*, SIAM Annual Meeting, Chicago, July 1990.

A. Rantzer, *A finite argument principle*, California Institute of Technology, December 1990.

A. Rantzer, *Stability conditions for polytopes of polynomials*, Conference of Decision and Control, Honolulu, December 1990.

A. Rantzer, *What about polytopes of polynomials?*, Lund University, April 1991.

K. Svanberg, *Structural optimization — methods and applications*, Uppsala University, February 6, 1991.

K. Svanberg, *Structural optimization — methods and applications*, Konferens ITM-91, June 11-13, 1991.

Y. Zhou, *Predictable and unpredictable dynamical behavior of Kalman filtering algorithms*, Second SIAM Conference on Linear Algebra in Signals, Systems and Control, San Francisco, USA, November 5–8, 1990, (invited speaker).

Y. Zhou, *On the nonlinear dynamics of the fast filtering algorithms*, Texas Tech University, Lubbock, USA, November 1990.

Y. Zhou, *On the convergence of fast filtering algorithms for Kalman filtering*, Mathematical Theory of Networks and Systems (MTNS'91), Kobe, Japan, June 17–21, 1991, (invited speaker).

7 Seminars at the division

7.1 Formal seminars

Aug. 20, 1990	Professor Y. C. Ho, Harvard University. *On discrete-event systems.*
Aug. 24, 1990	Professor Youri Kabanov, TSEMI, Moskva. *Optimal control of singularly perturbed stochastic differential equation.*
Sep. 14, 1990	Professor Alain Bensoussan, President of INRIA, Paris, France. *Exact controllability for linear dynamic systems with skew symmetric operators.*
Sep. 21, 1990	Civ.ing. Bo Bernhardsson, Lund University. *The game theory approach to* H^∞.
Oct. 5, 1990	Professor Tu Xu-Yan, University of Science and Technology, Beijing. *Most economical control.*
Oct. 12, 1990	Dr. Ruggero Frezza, Universita di Padova, Italy. *Models of gaussian reciprocal processes with application to the smoothing problem.*
Oct. 19, 1990	Högskolelektor Tomas Björk, Optimization and Systems Theory, KTH. *Adaptive prediction.*
Nov. 9, 1990	Jerry Eriksson, Umeå University. *Global optimization.*
Nov. 16, 1990	Dr. Alexander Megretsky, Leningrad University, Dept Math & Mech.,NIIMM. *S-procedure and power distribution inequalities: A new method in optimization and robustness of uncertain systems.*
Nov. 20, 1990	Professor Aimo Törn, Dept of Computer Science, Åbo Akademi. *Two approaches to global optimization.*
Nov. 23, 1990	Civ.ing. Birgitta Olin, Optimization and Systems Theory, KTH. *En undre gräns för förväntade optimalvärdet till ett stokastiskt tilldelningsproblem.*
Dec. 14, 1990	Professor S. Treil, Leningrad University, USSR. *Decentralized control. A criterion for the existence of stabilizing decentralized feedback.*
Dec. 18, 1990	Professor Stanislaw Walukiewics, Systems Research Institute, Polish Academy of Sciences, Poland. *PC-oriented algorithms for the knapsack problem.*
Jan. 4, 1991	Professor Michele Pavon, Dipartemento di Elettronica e Informatica Universita di Padova and LADSEB-CNR, Italy. *Reverse-time stochastic control, Schrodinger processes and statistical mechanics.*
Mar. 1, 1991	Docent Per-Olof Gutman, Technion, Haifa, Israel. *Optimal reglering av växthus.*
Mar. 7, 1991	Professor Svante Wold, Umeå University. *Experimentell optimering av kemiska system.*

Mar. 12, 1991	Tekn.Dr. Henrik Jönsson, Gothenburg University. *Optimization within a spreadsheet environment on a personal computer.*
Mar. 15, 1991	Dr. Virginija Simonytė, Institute of Mathematics and Informatics of the Lithuanian Academy of Sciences. *Minimal realization and formant analysis of dunamic systems and signals.*
Mar. 22, 1991	Dr. Andrea Gombani, LADSEB-CNR, Padova, Italy. *Approximate modelling and Hankel operators.*
Apr. 5, 1991	Professor György Michaletzky, Eötvös Loránd University, Budapest, Hungary. *A representation of inner products and stochastic realization.*
May 2, 1991	Professor Mark H. Davis, Imperial College, London. *Value of information in stochastic control.*
May 3, 1991	Professor Mark H. Davis, Imperial College, London. *Optimal stopping, free boundary problems and singular stochastic control.*
May 17, 1991	Professor John Lund, Montana State University, Bozeman, Montana, USA. *The sinc function, numerical integration and boundary value problems.*
May 24, 1991	Professor Per Lindström, Umeå University. *A method of Gauss-Newton type for nonlinear least squares problems with nonlinear constraints.*
May 31, 1991	Professor Terry L. Friesz, George Mason University, USA. *On the use of projection operators for solving constrained tatonnement models of network traffic disequilibrium.*
Jun. 10, 1991	Professor Walter Murray, Stanford University. *Quasi-Newton methods for large-scale optimization.*
Jun. 19, 1991	Professor Subash C. Narula, Virginia Commonwealth University. *The current state of nonlinear multiple criterion decision making.*
Jun. 19, 1991	Professor Jasmin N. Karaivanova, Bulgarian Academy of Science and Professor Subash C. Narula, Virginia Commonwealth University. *An interactive procedure for the multiple objective integer linear programming problem.*

7.2 Informal seminars in Systems and Control

Oct. 15, 1990– Nov. 2, 1990	Ruggero Frezza, Universita di Padova, Italy. A series of 8 seminars on *Reciprocal processes.*
Mar. 4, 1991	Yu-Fan Zheng, East China Normal University, Shanghai, China. *Disturbance decoupling with asymptotic stability.*
Mar. 18, 1991 Mar. 20, 1991	Andrea Gombani, LADSEB-CNR, Padova, Italy. *Balanced realizations.*

Mar. 25, 1991 Mar. 27, 1991	Andrea Gombani, LADSEB-CNR, Padova, Italy. *Model reduction.*
Apr. 8, 1991– Apr. 17, 1991	György Michaletzky, Eötvös Loránd University, Budapest, Hungary. *Minicourse on robust control (H^∞).*
Apr. 22, 1991 Apr. 24, 1991	György Michaletzky, Eötvös Loránd University, Budapest, Hungary. *Stochastic model reduction.*
May 21, 1991	B.S. Ilya Shmulecich, Departement of Computer Science, Purdue University. *On positive boolean functions and theory of stack filters.*
May 21, 1991 May 23, 1991	John Lund, Montana State University, Bozeman, Montana, USA. *Boundary value problems and control.*
May 27, 1991	Anders Rantzer, Division of Optimization and Systems Theory. *Minimax estimation.*
Jun. 3, 1991	Janne Sand, Division of Optimization and systems Theory. *Något om geometrisk styrteori.*

7.3 Informal seminars in Mathematical Programming

Seminar course on Global Optimization

Oct. 11, 1990	Krister Svanberg. *Rinnooy Kan: Global Optimization.*
Oct. 17, 1990	P. O. Lindberg. *Törn and Zilinskas: Global Optimization.*
Nov. 15, 1990	Anders Forsgren. *Pardalos and Rosen: Constrained Global Optimization.*
Nov. 22, 1990	Omar Viera. *Horst and Tuy: Global Optimization.*
Dec. 14, 1990	Ulf Brännlund. *J. Mockus: Bayesian Approach to Global Optimization.*
Dec. 19, 1990	Torgil Abrahamsson. *Dixon and Szegö: Towards Global Optimisation.*

Other informal seminars in Mathematical Programming

Sep. 20, 1990	Anders Forsgren. *Demonstration optimeringslaboratoriet.*
Sep. 27, 1990	P. O. Lindberg. *Reservmaterieloptimering.*
Nov. 1, 1990	P. O. Lindberg. *Beräkning av beställningspunkt och orderkvantitet för en lagermodell med stycktidskostnad.*
Nov. 8, 1990	Peter Butovitsch, TTT. *Perceptronnät.*
Dec. 6, 1990	Klaus Schittkowski, University of Bayreuth. *Numerical optimization.*
Jan. 24, 1991	Martin Nilsson, SICS. *Prolog, satisfiering, LP mm.*
Feb. 7, 1991	P. O. Lindberg. *Komponentstandardisering.*
Feb. 14, 1991	Torgil Abrahamsson. *SOR på matrisbalansering.*
Feb. 20, 1991	Göran Skugge, EKC. *Presentation gasprojekt.*
Mar. 13, 1991	Anders Forsgren. *Simplexmetoden som active set metod.*
Mar. 20, 1991	A Skarlind, Logikkonsult. *LP och nyttoteori.*

Apr. 10, 1991	Krister Svanberg. *2:a ordningens MMA*.
Apr. 25, 1991	P. O. Lindberg. *Danskins sats.*
May 2, 1991	Ulf Brännlund. *Konvergens för Polyak 2 med mixade subgradienter.*
May 17, 1991	P. O. Lindberg. *Mer känslighetsresultat av Danskin, Gauvin och Rockafellar.*
May 22, 1991	Prof Frank Harary, University of New Mexico, Las Cruces. *Connectivity of graphs and its relationships to flows in networks and conditional connectivity with constraints.*
May 23, 1991	Björn Lisper, TDS. *Systoliska nät.*

8 Other activities

Torgil Abrahamsson

- Participated in 30th RSA European Congress, Istanbul, Turkey, August 28–31, 1990.
- Participated in Nordic Council Course "Problem Structuring Methods", June 1-9, 1991, Reykjavik, Iceland.

Tomas Björk

- Director of Undergraduate Studies (studierektor) in Optimization and Systems Theory.
- Refereed one paper for Scandinavian Actuarial Journal.
- Refereed one paper for Journal of Mathematical Systems, Estimation and Control.
- Invited visitor at the Department of Electronics and Informatics, University of Padova, Italy, August 1990.
- Invited visitor at the Central Institute of Mathematics and Economics, Moscow, June 1991.

Ulf Brännlund

- Refereed one paper for Engineering Costs and Production Economics.
- Demonstrated GAMS at SOAF's course "Beslutsstöd på persondator", October 3, 1990.
- Gave with PO Lindberg a 1 day course in "Modelling and Optimization" at Swedish Defense Research Establishment (FOA), November 30, 1990.
- Organized and gave with PO Lindberg a 4 day course for industry in "Optimization Modelling and Problem Solving with GAMS", January 8-11, 1991.
- Participated in Nordic Council Course "Problem Structuring Methods", June 1-9, 1991, Reykjavik, Iceland.
- Participated in "Course in Non-Differentiable Optimization", June 30-July 9, 1991, Erice, Italy.

Anders Forsgren

- Refereed two papers for Mathematical Programming.
- Visited the Department of Operations Research at Stanford University, January 1991.

Martin Hagström

- Participated in Svenska Reglerdagarna in Linköping, October 24-25, 1990.

Xiaoming Hu

- Referee for the Journal of Dynamic Systems, Measurement, and Control.

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, August 12-13 1991.
- On editorial board of Computational Optimization and Applications.
- Joint organizer of kursen "Optimeringsmodellering och problemlösning med GAMS".

- Joint organizer of Svenska Operationsanalysföreningens temadag “Beslutsstöd på persondator”, December 3, 1990.
- Participated in Nordic Coucil Course “Problem Structuring Methods”, June 1-9, 1991, Reykjavik, Iceland.

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 six 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).
- International Board of Advisors, Second SIAM Conference on Linear Algebra in Signals, Systems and Control, San Francisco, November 1990.
- Steering Committee, International Symposium on the Mathematical Theory of Networks and Systems (MTNS).
- Member, International IFAC Committee for Mathematics in Control.
- Organizing Committee, Pre-Conference to MTNS-91, Hangzhou, China, June 12–14 1991.
- Organizer of an Invited Minisymposium for the Second SIAM Conference on Linear Algebra in Signals, Systems and Control, San Francisco, November 5–7 1990.
- Organizer of three sessions at MTNS-91 in Kobe, Japan, June 1991.

Anders Rantzer

- Refereed three papers for Systems & Control Letters.
- Refereed three papers for IEEE Transactions of Automatic Control.
- Refereed one paper for Automatica.
- Participated in Reglermöte in Linköping, October 1990.

Jan-Åke Sand

- Invited visitor at the Department of Electronics and Informatics, University of Padova, Italy, February 1991.

Krister Svanberg

- Refereed two papers for Numerical Methods in Engineering.
- Refereed three papers for Structural Optimization.

Yishao Zhou

- Participated in the Second Conference on Computation and Control, Bozeman, Montana, USA, August 1-7, 1990.
- Participated in Svenska Reglerdagarna in Linköping, October 24-25, 1990.