DEPARTMENT
OF
MATHEMATICAL STATISTICS

1994 – 1996

University of Lund
with Lund Institute of Technology
1997

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Matematisk Statistik

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LIST OF CONTENTS

Editors:

Mona Forsler
Georg Lindgren

INTRODUCTION

Teaching and research in mathematical statistics began in Lund around 1910 as part of the curriculum in astronomy under the influence of professor Carl Wilhelm Charlier and his student Sven Wicksell. When Lund Institute of Technology was created in 1962, Gunnar Blom became Lund's first professor of mathematical statistics and started a graduate program both at the Institute of Technology and at the Faculty of Mathematics and Natural Sciences.[1] A second chair was created in 1988, at the Faculty of Natural Sciences, and as of 1997 two of the lecturers have been promoted to professors. From 1989, the department shares a biostatistics program with the Faculties of Social Sciences and Medicine, and a formal PhD program in biostatistics was started in 1996.

The department has a comprehensive teaching and research program in statistics and probability with approximately 3500 hours of teaching per year for almost all students at the Institute of Technology and for science students, and with a graduate program in probability and statistics with its applications in science and engineering. Since 1970, the department has awarded 30 doctors degrees: Twelve men and one woman have received the degree of Doctor of Technology, and fifteen men and two women the degree of Doctor of Philosophy. Nine of these have become professors at Swedish and Scandinavian universities.

The research deals with probability and statistics, basic research in mathematical statistics theory as well as applied research, often carried out in close collaboration with researchers in other fields.

The main research themes are

- basic research in probability and applied probability, including extreme value theory, Markov processes and stochastic differential equations, stochastic simulation
- basic research in statistical theory and methods, including modelling of partially observed systems and processes, multivariate analysis and regression, and robust statistics
- time series modelling, signal analysis and statistical image analysis
- applied research in biostatistics and medical signal processing, environmetrics, ocean and marine statistics, reliability, statistics in energy systems and in telecommunication.

[1] Lund Institute of Technology is abbreviated LTH in this report, and the Faculty of Mathematics and Natural Sciences is abbreviated MNF.

Søren Asmussen

HIGHLIGHTS 1993/94 – 1996

Graduates

Six PhD-students defended their theses during the period: Tobias Rydén, Roland Perfekt, Roger Pettersson, Anders Rosenqvist, Pär-Ola Bendahl, and Stefan Peterson. Tobias and Roger now work as research assistants at the department, while the other four went to industry (Roland to Pharmacia & Upjohn in Helsingborg, Anders to Gambro in Lund, Stefan to Astra Draco in Lund) or a hospital clinic (Pär-Ola to the Department of Oncology in Lund).

To and from

Lena Zetterqvist got a permanent position as lecturer at the Faculty of Engineering, LTH, from May 1, 1994. She had previously been assistant lecturer at the department. Søren Asmussen became new professor in mathematical statistics at the Faculty of Mathematics and Natural Sciences, MNF, from July 1, 1995. He came from Ålborg, Denmark, where he was research professor in mathematical statistics. Søren replaced Holger Rootzén, who left the department December 31, 1993, for Chalmers University of Technology, Göteborg.

Tobias Rydén holds, from October 1, 1995, a position as research assistant in Hidden Markov Models, awarded by the Swedish Natural Science Research Council. Ola Hössjer left his position as research assistant December 31, 1994, to pick up his position as lecturer at the Faculty of Mathematics and Natural Sciences. Roger Pettersson replaced him as research assistant July 1, 1996.

Jonny Olsson left the department September 30, 1995, to become lecturer at the University College in Karlskrona. He is back from February 1, 1997.

Jan Holst was promoted to professor ('biträdande professor') 1996.

Conference

The 15^{th} Nordic Conference in Mathematical Statistics was held i Lund, August, 15–19, 1994, with 225 participants. from the Nordic countries, and the rest of the world. A special effort was made to attract participants from the Baltic states and 22 statisticians from these countries attended.

Some new things

The department became in 1994 one of eleven partners in a European Union HCM network for Stochastic mechanics, and in 1996 an Environment project on the use

of satellite information for wave statistics was granted.

In 1996 the department became a major node in ASN, A Stochastic Network, funded by the Foundation for Strategic Research. The network supports research in Lund in stochastic problems in telecommunication and in energy systems.

Five new research projects were funded by grants from different agencies. The Swedish Research Council for Engineering Sciences supported the projects Mathematical Statistics in Engineering and Stochastic mechanics, the Natural Science Research Council granted support for Environmental statistics in cooperation with the Department of Atomic Physics, and the Board for Technical Development decided on a major project in Statistics in Energy production and distribution. The Swedish Institute for Applied Mathematics, together with three major Swedish industries, supported a program in Stochastic fatigue and load analysis.

The Council for the Renewal of Undergraduate Education supported an educational project in order to incorporate chemical applications in the basic course in mathematical statistics for Chemists and for Chemical Engineering.

STAFF and GRADUATE STUDENTS

The employee display on this page reflects the situation in September 1997.

Teachers

Anderson, Harald	Biostatistics
Asmussen, Søren	Markov Processes
Blom Gunnar	Combinatorial Probability
Holmquist, Björn	Multivariate Statistics
Holst, Jan	Statistics in engineering
Holst, Ulla	Environmetrics
Holtsberg, Anders	Engineering Statistics
Hössjer, Ola	Nonparametric Statistics
Lanke, Jan	Biostatistics
Lindgren, Georg	Stochastic Processes
Lindoff, Bengt	Non-stationary time series
Olsson, Jonny	Image Processing, Perimetry
Pettersson, Roger	Stochastic Differential Equation
Ringnér, Bengt	Time Series Analysis
Rychlik, Igor	Stochastic Processes
Rydén, Tobias	Hidden Markov models
Turova, Tatyana	Stochastic processes
Zetterqvist, Lena	Environmetrics
Zhao, Hongping	Energy Statistics

Technical personnel

Engelbert Jönsson, Eva	Secretary (on leave)
Forsler, Mona	Secretary
Hakim, James	Computer Engineer
Persson, Åsa-Katrin	Secretary
Rasmusson, Christel	Secretary

Graduate students

Andersson, Sofia
Anevski, Dragi
Aronsson, Mattias
Arvastson, Lars
Frigyesi, Attila
Grage, Halfdan
Johannesson, Pär
Jonsson, Pia
Lindgren, Anna
Lindgren, Finn
Lindström, Torgny
Machado, Ulla
Michna, Zbigniew
Møller, Jakob Riishede
Pavlenko, Tatjana
Rikte, Tord
Rydén, Jesper
Sjö, Eva
Sköld, Martin
Svensson, Anders
Thuvesholmen, Mikael
Wiktorsson, Magnus

EDUCATION

Undergraduate program

The department gives courses both at the Faculty of Technology (LTH) and at the Faculty of Mathematics and Natural Sciences (MNF). Most of the advanced courses and all graduate courses are common to both schools, and the teachers are not restricted to courses at the school at which they are formally employed.

Basic and advanced courses

There are four different basic courses in Mathematical Statistics for students in the different engineering programs and for students in the mathematics, statistics and computer science programs. These courses cover probability and statistics and are prerequisits for further studies. Service courses, based on statistical applications are given for students in biology, geology, chemistry and physics.

After the basic courses the students can choose among 16 different intermediate or advanced courses, covering many aspects of probability and statistics, as well as different applied topics.

The undergraduate program is displayed on pages 10 and 11, and a description of the advanced courses is given in the Appendix.

Self-assessment

In 1995, the department made a self-assessment of the undergraduate education at the School of Mathematics and Natural Sciences as a part of a large quality assessment at the school. Interviews with teachers and employers for students in statistics were made and a questionnaire was distributed to students. Two external evaluaters, Bent Natvig (Oslo) and Bernhard Huitfeldt (Uppsala), visited the department. Several of the changes described below are the result of the analysis.

Tendencies

During the period, starting 1993/1994, the basic program at the Engineering School underwent substantional changes. In order to make the basic courses for the different engineering programs more similar we now have a first basic course in Mathematical Statistics followed by a general course in Stochastic Processes. The latter is compulsory for students in Electrical Engineering and Computer Engineering.

At the same time as the statistical core of the basic courses is similar, we have for the different programs, worked in the direction of

focusing on applications and integration within the program. Some examples are the course for Chemical Engineering which developed towards experimentally based statistics with chemical applications[2] and the course for Civil Engineering where material from simultaneous courses within the program are used.

Increased student activity

In many of our basic courses more emphasis is put on enhanced student activity, often by increasing the number of compulsory computer exercises in the course. Sometimes we require written reports which are used in the assessment of the student. In most undergraduate courses the amount of self-activity is large and statistical problems are often solved by students in small groups. The assessment in these courses normally consists of take-home projects. All courses now have their own homepage.

New undergraduate courses

The advanced undergraduate courses are often initiated by, and take advantage of, research activities at the department. Several new advanced undergraduate courses have been introduced during the period, some are common to both schools. The course Monte Carlo Methods for Stochastic Inference offers an overview of simulation techniques and different resampling methods. The advanced course in Non-linear Time Series Analysis, which gives a thorough knowledge on modelling of dynamic systems, is given jointly by our department and the Institute of Mathematical Modelling at the Danish Technical University in Lyngby.

Our biostatistical course package has been extended by a course in Clinical Trials. An advanced course, giving the Mathematical Basis for Probability Theory has been added. The course Statistical Multivariate Analysis gives an overview of methods for simultaneous analysis of several variables.

Revisions of the texts have been made in the course Time Series analysis and in the course Extreme Value Theory and Risk Analysis, the latter course name being a fresh variant of the old course title Reliability Theory.

Forthcoming changes

At MNF, a change in our courses on the intermediate level will take place, starting 1997. The older courses in Statistical Theory and Design of experiments will be replaced by the two courses, Inference Theory, and Statistical Models and Methods, which together will cover a broader range of statistical models and methods than before. At the same time, statistical analysis using statistical pro-

[2]This work was supported by the Council for the renewal of Undergraduate Education.

gram packages on large data sets, as well as both oral and written presentations by the students will be emphasized.

Master theses

The master thesis provides an opportunity for the undergraduate student to use statistics in applied problems. It is also possible to include further study of some theoretical problem in a thesis. The topics range from medical statistics and epidemiology, engineering applications, e.g. fatigue and prediction, financial applications, to theoretical studies of estimation algorithms. During the period, 29 master theses were completed at the department. A list of them is included in the Appendix.

Pedagogical activities

At the same time as the way of teaching is changing, partly since the computer has become a natural tool in the courses and the neccessity of an enhanced student activity, the interest for pedagogical questions and discussions at the department has increased. During the period a serie of pedagogical seminars has started, a list of them is included in the Appendix. Several of the teachers at the department have participated in pedagogical courses at the University, see Appendix.

Courses at LTH

Number	Course	Students from
First courses		
	Mathematical statistics, basic course	Engineering physics Electrical engineering Computer engineering
	Mathematical statistics, basic course	Mechanical engineeering Civil engineering Survey engineering
	Mathematical statistics for chemical engineers	Chemical engineering
Special course		
	Stochastic processes	Electrical engineering Computer engineering Engineering physics Mechanical engineering
Advanced courses		
FMS051	Time series analysis (also at MNF)	Engineering physics Electrical engineering Computer engineering Mechanical engineering
FMS061	Extreme value theory and risk analysis (also at MNF)	Engineering physics Electrical engineering Computer engineering Mechanical engineering Civil engineering
FMS072	Design of experiments	Engineering physics Computer engineering Mechanical engineering Civil engineering
FMS091	Monte Carlo methods for stochastic inference (also at MNF)	Engineering physics Electrical engineering Computer engineering
FMS110	Non linear time series analysis (also at MNF)	Engineering physics Electrical engineering Computer engineering
Service course		
	Experimental design	Single subject course

Courses at MNF

Number	Course	Students from
1:st semester		
	Mathematical statistics general course	Mathematics, Physics Mathematical statistics Computer science
2:nd semester		
MAS203	Probability theory, advanced course	Mathematics Mathematical statistics
MAS207	Statistical theory, advanced course	Mathematics Mathematical statistics
MAS208	Statistical models and methods	Mathematical statistics
3:rd semester		
MAS204	Markov processes	Mathematical statistics
MAS209	Design of experiments	Mathematical statistics
MAS210	Stationary processes	Mathematical statistics
MAS212	Multivariate analysis	Mathematical statistics
MAS213	Survival analysis	Mathematical statistics
MAS214	Clinical trials	Mathematical statistics
MAS216	Time series analysis (also at LTH)	Mathematical statistics
MAS223	Extreme value theory and risk analysis (also at LTH)	Mathematical statistics
4:th semester		
MAS209	Design of experiments (also at LTH)	Mathematical statistics
MAS221	Monte Carlo methods for stochastic inference (also at LTH)	Mathematical statistics
MAS222	Non-linear time series analysis (also at LTH)	Mathematical statistics
MAS230	Mathematical basis for probability theory	Mathematical statistics
Service courses		
	Mathematical statistics,	Biology and Geology
	Mathematical statistics,	Chemistry
	Mathematical statistics,	Physics
	Mathematical statistics for teachers	School of education
	Experimental design	Biology, Geology, Chemistry

EDUCATION

Graduate program

As of September 1997, the department of Mathematical Statistics had 22 graduate students, funded through teaching assistanships from LTH and MNF ('doktorandtjänster') or from external research grants (NFR, NUTEK, TFR, the Foundation for Strategic Research (SSF), and the Institute of Applied Mathematics (ITM)).

As is the general policy of LTH all our graduate students, also those at the Faculty of Mathematics and Natural Sciences, take part in the undergraduate teaching. This has the positive effect that they become better trained as professional statisticians and it gives them a chance to qualify for a future academic career. However, qualified teaching takes much time and during the period we have reduced the amount of teaching to 20% of a PhD position for new PhD students. We also encourage the PhD students to take part in the statistical consultant service that is being set up at the department.

The nominal time for a fulltime student to complete her/his graduate studies is four years – five years with maximal teaching. Coursework is measured in points, where 40 points corresponds to one year of study. The course requirement for the doctor's degree is 80 points, the remaining years being allotted to preparing a dissertation. Of the courses, approximately 30 points are required for mandatory basic statistics, probability, and stochastic process courses, which are taught at regular intervals, while the remaining points are chosen after consultation with the advisor. In addition we give advanced courses on topics of current interest, and the students go through oral examinations on books and articles which they have read on their own. Our graduate courses are regularly followed by students from other departments.

A dissertation may consist of the solution of some problems in theoretical probability or statistics, or in the development and use of methods for solving applied problems, usually in cooperation with researchers from other departments or from industry.

The nominal time for the licentiate degree is two years, with 40 points course works and a thesis, which is similar, but less comprehensive, than a PhD thesis.

During the period July 1, 1993 – December 31, 1996 the department has held the graduate courses listed on the next page.

Graduate courses

1993/94

- Statistical theory (Ola Hössjer)
- Stochastic processes (Georg Lindgren)
- Spatial statistics and random fields (Georg Lindgren)
- Dependencies in stochastic processes (Tobias Rydén)
- Analysis of longitudinal data (Jan Lanke)

1994/95

- Robust statistics (Ola Hössjer)
- Computer intensive statistical methods, model choice and resampling methods (Anders Holtsberg)
- Probability theory (Igor Rychlik)
- Detection and analysis of abrupt changes in dynamic systems (Jan Holst)
- Asymptotic optimality in statistics (Dragi Anevski)
- Statistical inference theory (Ola Hössjer)
- Non-linear time series (Jan Holst)

1995/96

- Markov processes (Roland Perfekt)
- Probability theory (Roland Perfekt)
- Statistical extreme value theory with applications (Georg Lindgren, Igor Rychlik)
- Stochastic processes (Søren Asmussen)
- Stochastic optimization (Reuven Y. Rubinstein)
- Wavelet transform with statistical applications (Stefan Peterson)
- Mathematical foundations of probability theory (Søren Asmussen)
- Simulation of stochastic processes (Søren Asmussen)
- Non-linear time series (Jan Holst)

fall 1996

- Non-linear time series (Jan Holst)
- Probability theory (Tobias Rydén)

In addition, the advanced undergraduate courses in Time series analysis, Reliability theory, Survival analysis, Monte Carlo methods for stochastic inference and Design of experiments and linear models often serve as introductory courses for graduate students in mathematical statistics and other subjects.

During the period July 1, 1993 to December 31, 1996, eight doctors or licentiate theses have been defended at the department.

Tobias Rydén, who got a licentiate degree in Telecommunication theory in 1991, defended his PhD thesis in Mathematical statistics on Markov modulated Poisson processes, with the thesis subtitle 'Statistics and telecommunication', on November 26, 1993. Søren Asmussen, Ålborg, was the opponent. After an NFR-supported PostDoc-year at Berkeley, Tobias is back at the department as research assistant and lecturer.

Roland Perfekt finished his PhD thesis work on extreme value theory with a defense January 28, 1994, with Tailen Hsing, Texas A&M University, as opponent. After a period as lecturer, Roland took on a position as biostatistician at Pharmacia & Upjohn in Helsingborg.

Anders Rosenqvist completed both his Licentiate thesis and his PhD thesis during the period, August 22, 1994, and June 2, 1995, respectively. The theme for the theses was Doppler-bearing tracking and Alf Isaksson, Stockholm, and Knud Conradsen, Lyngby, were discussant and opponent. Anders has left the department to work at Gambro in Lund.

Roger Pettersson defended his PhD thesis on stochastic differential equations November 11, 1994, with Ludwig Arnold, Bremen, as opponent. A TFR grant brought Roger to the Center for Stochastic Processes in Chapel Hill for a year as PostDoc, after which he returned to the department as research assistant.

Pär-Ola Bendahl combined his PhD studies with work as biostatistician at the Department of Oncology. His thesis on DNA-estimation in cancer cells was defended November 24, 1995, with Åke Svensson, Stockholm, as opponent. Pär-Ola continues to work with cancer statistics after he got his PhD-degree.

Bengt Lindoff discussed his Licentiate thesis on recursive least squares algorithms on January 9, 1996, with Lennart Ljung, Linköping, as discussant. Bengt continues towards the PhD degree, which will be completed 1997.

Stefan Peterson developed a technique to analyse exercise ECG with wavelet regression methods and applied to nasty ECG signals from the medical practise. He defended his thesis on October 18, 1996, with Guy Nason, Bristol, as opponent. Stefan had then already taken up a position as statistician with the biostatistics group at Astra Draco, Lund.

Doctorates and Licentiates, July 1, 1993 – December 31, 1996

PhD theses

Tobias Rydén (PhD in engineering, November 26, 1993): Parameter estimation for Markov modulated Poisson processes

Roland Perfekt (PhD, January 28, 1994): On extreme value theory for stationary Markov chains

Roger Pettersson (PhD, November 11, 1994): Approximations for ordinary, reflecting, and multivalued stochastic differential equations

Anders Rosenqvist (PhD in Engineering, June 2, 1995): Fast robust estimators for linear regression and Doppler-bearing tracking

Pär-Ola Bendahl (PhD, November 24, 1995): Estimation and prognostic value of S-phase fractions in cancer cell populations

Stefan Peterson (PhD in Engineering, October 18, 1996): Filtering and wavelet regression methods with application to exercise ECG

Licentiate Theses

Anders Rosenquist (Licentiate in Engineering, August 22, 1994) Pseudo-linear and ML estimation in doppler-bearing tracking

Bengt Lindoff (Licentiate in Engineering, January 9, 1996): Distribution properties of the recursive least squares algorithm with forgetting factor

The Swedish Foundation for Strategic Research, SSF, decided in March 1996 to establish a National Network in Applied Mathematics, in order to support graduate education in mathematical methods for industry and science, and to support and promote research cooperation between i.a. statistical sciences, industry, and other scientific disciplines, nationally and internationally.

The Network is based on four main components: a research program in Industrial Computational Mathematics, A Stochastic Network (called ASN), a Graduate and Exchange Program, and ITM for industrial contacts.

ASN

The ASN network has one major node at the Department of Mathematical Statistiss in Lund, and the other major node in Göteborg at the Chalmers Stochastic Centre. The program plan includes two main themes: one PhD program in selected topics of industrial mathematical statistics, and one visitor program with concentrated activities in relevant areas. These visitor programs are planned for the five year period 1997–2001, and shall support and encourage graduate education in industrial statistics, as well as exchange of people and ideas with industry.

During the start up phase, two PhD students have been enrolled in Lund, one in Stochastic problems in telecommunication and one in Stochastic problems in energy production and distribution.

ECMI

Within the graduate part of the National Network, support has also been allocated to Lund for a graduate program in industrial mathematics under the ECMI concept (European Consortium for Mathematics in Industry). This European program involves 13 major European technical universities, i.a. Chalmers, the Danish Technical University, Lyngby, the Norwegian University of Science and Technology, Trondheim, and the University of Kaiserslautern. In Sweden, the ECMI program leads to a licentiate degree. The first two ECMI students to Lund were recruited in 1997, one to the Department of Mathematics (specializing in Computer vision) and one to Mathematical Statistics (specialising in statistics for ocean engineering).

RESEARCH

The research at the department can be grouped around several themes, concerned with theory as well as applications, in many different fields: The main themes are

- basic research in probability and applied probability,
- basic research in statistical theory and methods,
- time series modelling, signal analysis and statistical image analysis
- applied research in biostatistics and environmetrics, ocean statistics, reliability, energy systems and telecommunication

Extreme value theory for stochastic processes has for a long time been one of the main research areas at the department. It includes probability theory and statistical methods for extremes, as well as engineering and environmental applications, e.g. in reliability theory, fatigue analysis, and design and analysis of alarm systems. Heavy–tailed distributions are also important in the new areas represented at the department, related to insurance mathematics, where i.a. the control aspects of dynamic models are studied. Stochastic differential equations and stochastic simulation are other fields of probability represented in the department research.

Signal processing and statistical algorithms are other major research areas. A speciality is the construction and analysis of robust, recursive estimation procedures for real time analysis of highly disturbed data. Contacts with natural and medical sciences have inspired the development of statistical theory for multivariate data and directional processes, as well as technique for density estimation and general mixture distributions.

Time series analysis and modelling of dynamic systems are other characteristic research areas which encompass e.g. the development of single- and multivariable techniques and algorithms, recursive estimation, nonlinear filtering and detection. Applications are found in prediction of power loads and power consumption for the planning of energy production, analysis of heating systems for buildings and local districts, target motion analysis and navigation, and surveillance of water and air quality and other environmental systems.

Algorithms for image analysis in perimetry, flow cytometry for DNA-analysis and real time algorithms for ECG analysis are three major medical signal processing projects. Epidemiological studies and clinical trials are areas in biostatistics, as well as techniques for survival analysis which are developed and applied in collaboration with various medical study groups.

PROBABILITY AND APPLIED PROBABILITY

Probability theory deals with the mathematical study of random structures. Some important areas today are martingales, central limit theory, stochastic analysis, large deviations and statistical physics. Applied probability can be described as the part of probability directed towards the study of specific models rather than abstract mathematical structures. Traditional areas are reliability, queueing theory, renewal theory among many others. The area is classical but the current research activity is extensive, not least because of an increased relevance for systems engineering, insurance, finance etc.

Stochastic processes in insurance mathematics

Søren Asmussen

The stochastic part of insurance mathematics was initiated by Lundberg (1903, 1926) and Cramér (1930). The classical theme is the probability of ruin, and this has remained an active area of research up to now. Within this framework, results have been obtained on finite horizon ruin probabilities for Markov–modulated models (with B. Højgaard, Aalborg), classical risk processes with heavy–tailed increments (with C. Klüppelberg, Mainz, and J.L. Teugels, Leuven), renewal models (with B. Højgaard), and risk processes with a premium dependent reserve.

More recently, insurance mathematics is merging with areas like mathematical finance and control theory. Whereas the classical ruin problem assumes a static policy of the company, the control aspect involves dynamic allocation of premiums, dividend payouts, reinsurance covers etc. Here results on dividend payouts have been obtained (with M. Taksar, SUNY, Stony Brook).

Heavy–tailed distributions and self–similarity

Søren Asmussen, Zbigniew Michna

In rare events studies, one traditionally works with distributions with light tails and imposes quite a few assumptions on independence in time. Recent studies in telecommunications have, however, shown considerable long–range dependence which is most often modelled by self–similarity. A possible explanation for this phenomenon is the presence of heavy–tailed distributions, which are also receiving considerable recent attention in insurance mathematics for the purpose of modeling catastrophic events like floods or earthquakes.

The rare events behaviour is fairly well understood for the light–tailed case. For the heavy–tailed case, the folklore predicts rare events to occur as consequence of one big

jump, but sofar few precise results have been available. Contributions to this problem have been made for various problems in queueing and ruin theory (with C. Klüppelberg, Mainz, and J.L. Teugels, Leuven). The applications and further studies also involve storage models and extreme value theory.

Investigations of weak approximations include approximations of the risk process by a stable Levy motion with drift, where the ruin probability within a finite time horizon was estimated (with H. Furrer, Zürich, and A. Weron, Wroclaw), and by a continuous self-similar processes with drift. The ruin probability within finite time was estimated for fractional Brownian motion. A similar model is applicable in queueing systems describing long range dependence in on/off processes and associated fluids models. The obtained results are useful in communication network models as well as storage and inventory models.

The asymptotics of the tail of the supremum of certain dependent processes has been studied, in particular for fractional Brownian motion, a nonlinearly scaled Brownian motion or some integrated stationary Gaussian processes (with K. Debicki and T. Rolski, Wroclaw).

Phase–type distributions

Søren Asmusen, Tobias Rydén

Phase–type distributions were introduced by Erlang (1907) and are a main vehicle for obtaining exlicit or algorithmically tractable results. Their importance therefore stimulates the study of also other aspects than performance evaluation. In particular, results on equivalence of phase-type distributions have been obtained and two lower bounds on their order have been related, and the statistical estimation problem studied (with M. Olsson and O. Nerman, Göteborg.

Stochastic simulation

Søren Asmussen

In many realistic applied probability problems, neither explicit solutions nor empirical data are available and one must resort to simulation. This involves not only practical computer implementation but also theoretical aspects like the design of new algorithms and analysis of existing ones. For example, simulation of rare events probabilities is not posiible without involving advanced mathematical tools.

The effects of perturbating the parameters in a number of problems taken from insurance risk have been studied (with R.Y. Rubinstein, Haifa). Some efficient algorithms for simulation in the presence of heavy tails have been deve-

loped and it has been shown via a number of examples that the large deviations approach used for light tails has little promise (with K. Binswanger, Zürich, and B. Højgaard, Aalborg).

Stochastic differential equations

Roger Pettersson, Magnus Wiktorsson

Advances in martingale theory have lead to profound extensions of classical limit theorems, as well as a highly developed theory of stochastic differential equations (SDE's), with applications ranging from survival analysis and stochastic mechanics to pure mathematics.

An active area at the department is approximation tehnique for constrained SDE's, in particular reflected and multivalued equations, (RSDE's and MSDE's). Convergence rates for numerical approximations of RSDE's were obtained, e.g. by approximating the reflection by a penalty acting outside the permitted domain. The existence of solutions to MSDE's was shown by two types of approximations, a Yoshida approximation or polygonal approximation for the driving Brownian motion. This Wong-Zakai approximations also workes for RSDE's.

RSDE's give an elegant representation of solutions of deterministic parabolic equations with reflecting boundary conditions and they are also crucial for singular control of diffusion processes, queueing systems with heavy traffic, and in financial calculus for look-back options and Russian options. MSED's are convenient to describe non-purely elastic mechanical systems. Applications are made to models for disturbed physical systems to and extraction of signals from noise.

Extremes and crossings

Georg Lindgren, Zbignev Michna, Roland Perfekt, Igor Rychlik

The early work on extreme values of stochastic processes were made in communication theory and oceanography. Thus the pioneering work of S.O. Rice around 1940, published in 1944-45, gave communication engineers new tools, based on stationary normal processes for analysis of fading, envelope detection, click-noise in FM-receivers, etc. Through the 1967 monograph by Cramér and Leadbetter, research on extremes was brought into close contact with general probability theory. Extremes and crossings of stationary processes, for example, were one of the first non-trival uses of the emerging theory of point processes. By 1980, extremes of normal processes had become well understood, and were in widespread use in applied areas.

The Department of mathematical statistics in Lund has for many ye-

ars been internationally leading in extreme value theory and its engineering applications and has also been active on statistical methods for extreme value data. Many of the guest researchers to the department work with extreme values and applications. The results include both detailed results for special processes, such as ARMA-processes, α-stable processes, Markov chains, and functions of multidimensional normal processes, and to more abstract and general results, such as central limit theorems for wave functionals (with V. Piterbarg, Moscow).

The research on extremes has lead to results of interest in other fields of statistics, which are described under their individual headings. The most important of these are statistical description and analysis of ocean wave patterns, random fatigue load analysis, and stochastic alarm systems. The methods have also found applications in regression analysis for computation of simultaneous confidence bounds and in image analysis for the analysis of detection algorithms.

Applications of crossings and extreme value theory, alarm systems

Halfdan Grage, Jan Holst, Georg Lindgren, Igor Rychlik, Eva Sjö, Anders Svensson

The objective of alarm prediction is to detect events before they occur. One example is flooding alarm, where hydrological and other measurements are used to predict high water levels. We have developed optimal alarm techniques for Gaussian linear processes with extreme indluence, like ARMAX-processes, and to some classes of nonlinear processes. In addition to prediction of flooding, we have applied these methods for stochastic unit commitment in energy production.

Neural network modelling of optimal alarm systems gives a possible mechanization of a suboptimal alarm system, applicable also to non-Gaussian processes. We have shown that a neural network is able to reconstruct the (known) optimal alarm predictor for Gaussian processes, and that it works well also for highly non-Gassian processes. We also study methods for stochastic on–off control where the crossings of a switching level or the duration of the excursion are predicted.

As an example of the use of Gaussian crossings theory we have analysed click noise in zero-crossing detecting FM-receivers. Clickproducing events were identified and classified in terms of crossings behaviour. An explicit model for the behaviour of noise in the neighbourhoood of these events was analysed, and showed to give very precise estimates of the number of clicks as a function of the signal-to-noise ratio. Crossings

theory for random field is developed and applied to the search for "hot spots" in random fields, reliability of level curves in reconstructed fields, and edge detectors in image analysis.

The main tool for the general analysis of crossing dependent events was the Slepian model, developed to great generality and applied to a number of concrete crossings problems.

Statistical methods and computer programs for estimation of extreme quantiles and probabilities are developed, as well as computer programs for calculation of general crossing probabilities.

Miscellaneous

Søren Asmussen

Stationarity properties of neural networks have been studied and related to queueing theory (with T. Turova, Moscow).

The Wiener–Hopf integral equation, which is of relevance in random walk problems occuring for example in queueing theory, has been studied using purely probabilistic tools.

PARTIALLY OBSERVED MODELS

A partially observed model is a stochastic models in which some of the random quantities remain unobserved and unknown, and inference about parameters and model structure is to be made based on a partial set of observables. This includes the classical Bayesian statistics, in which the parameters themselves are the unobserved random variables. With increased compting power, inference in rather complex partially observed models has been possible, and such models are now widely used in many application areas, such as speech recognition and image analysis, as well as in many biostatistical applications.

Hidden Markov models

Pär Johannesson, Jan Holst, Ulla Holst, Georg Lindgren, Tobias Rydén, Mikael Thuvesholmen

A hidden Markov model (HMM) is a special type of unobserved model. It is a stochastic process for which the properties of the observable part are governed by an unobserved (hidden) m-state Markov chain (the regime). The most common setup is that when the observable variables are conditionally independent (but not identically distributed) given the regime. Inference in HMM's is in most cases carried out using likelihood-based methods. We study the asymptotic distributions of such estimators, and how they can be penalized to obtain AIC/BIC-like measures that allow for estimation of the size m of the regime process. Bayesian inference through MCMC methodology is also of interest, posing questions on convergence control and the possibility of parameter blocking within the MCMC scheme.

An important subclass of HMM's are the Markov-modulated Poisson processes (MMPP's). An MMPP is a doubly stochastic Poisson process, with intensity governed by a continuous-time Markov chain. We have derived an EM algorithm for such models and study asymptotic properties of likelihood-based estimators, penalization of such, and identifiability problems.

We have also studied recursive procedures for estimation of MMPP's, HMM's and linear autoregressions with Markov regime, which could be an attractive alternative to iterative off-line methods in real-time applications and applications with large data sets. For maximum-likelihood estimation of non-linear autoregressive models with Markov regime, we have obtained results on consistency and identifiability. HMMs extend to hidden Markov random fields in a natural way, but

inference in such models is inherently difficult and approximations are needed. We have studied an MCMC-type estimation algorithm involving the pseudo-likelihood of the random field.

Applications of hidden Markov models include modelling of financial time series, modelling of time-varying loads in fatigue analysis and target tracking in presence of false measurements.

Mixture distributions

Pär-Ola Bendahl, Ulla Holst

Least squares fits are popular for inference in models based on mixture distributions, a special case of partially observed model. Likelihood estimation would be a better choice also providing error estimates for the parameter estimates. We have studied quasi-Newton and EM algorithms for maximum-likelihood estimation, as well as recursive estimation algorithms that incorporate the observed information as a substitute for the true Fisher information. Our main application is modelling of DNA histograms containing up to nine component distributions.

Nonparametric statistics

Nonparametric density function estimators are important for e.g. nonparametric classification and semiparametric adaptive procedures, where the density is a nuisance parameter, maximum likelihood estimation and change-point problems. Nonparametric regression function estimation is of great use in numerous fields.

Different methods (kernel, orthogonal series, splines, wavelets) have a tradeoff between bias and variance controlled by the smoothing parameter. The kernel method is theoretically most developed, with automatic (data-dependent) choices of smoothing parameter (bandwidth) being available.

Density estimation

Dragi Anevski, Attila Frigyesi, Ulla Holst, Ola Hössjer, Martin Sköld

Much research is done on methods with bandwidth depending on location, which facilitates finding interesting features of the density. One such variable bandwidth estimator is the transformation kernel density estimator, which we have been studying theoretically (with D. Ruppert, Cornell University). This estimator has very good asymptotic performance. We have also developed a general asymptotic theory for a broader class of varying bandwidth estimators (partly with M.C. Jones, The Open University).

We have constructed a recursive, on-line kernel density estimator with built in automatic bandwidth choice. Its efficiency is practically

the same as the traditional off-line density estimator.

When a discrete sample of a continuous time stationary process is available, one possibility is to first extrapolate the observed data vector to a function and then to compute a continuous time kernel density estimator. This technique is currently being investigated.

Fractal measures typically occur as stationary distributions of nonlinear time series. Somewhat surprisingly, kernel density estimates are useful for estimating the fractal dimension spectra of such measures (which have no density)! We have found consistent estimators of (generalized Renyi) dimension spectra that do not require the choice of any grid (as does Box counting).

In a communication system, the optimal maximum aposteriori (MAP) detector typically depends on the density of the channel noise. Traditionally Gaussian noise is assumed, but we have analyzed an adaptive detector (with Tommy Öberg, Uppsala university and Rolf Gustafsson, Responsor AB). It uses the kernel density estimator of the channel noise density from training data as plug in to the MAP detector.

Nonparametric regression

Claes Björklund, Ulla Holst, Ola Hössjer, Anna Lindgren, Torgny Lindström, Martin Sköld, Mikael Thuvesholmen

Nonparametric estimation of regression curves has numerous applications. A method that has gained recent popularity is the local polynomial regression methods, by which the regression function and its derivatives can be estimated. We are studying methods for automatic bandwidth selection (smoothing parameters) for these estimators.

In the recursive setting we have developed an on-line bandwidth selector based on approximate crossvalidation.

For heteroscedastic error models, we have developed a local polynomial estimator of the variance function with automatic bandwidth selection (with D. Ruppert, Cornell University and M. Wand, Sydney). This is inspired by and applied on the analysis of LIDAR (LIght Detection And Ranging) data.

A modified local polynomial estimator has been developed for size biased data, e.g. when the dependent variable is observed with size bias.

Further, we have applied a robust local polynomial estimator on the DOAS (Differential Optical Absorption Spectrosco py) filtering process.

Due to limited measuring range, measurements of biological variables, e.g. of light sensitivity of the eye, are often censored. To measure the progress of a disease,

e.g. in terms of unexpected variability, one has sometimes to rely on such censored data. We study relationships between censored data and work with techniques for parametric and non–parametric quantile regression and density estimation that can handle censored data.

Inference under order restriction

Dragi Anevski, Ola Hössjer

A general asymptotic scheme has been developed for estimating monotone (convex) functions by greatest convex minorants (least concave majorants), e.g. regression functions or density functions. Previous asymptotic results for the Grenander estimator of a monotone decreasing density function, isotonic regression with independent errors and isotonized kernel estimates are included. New results for e.g. isotonic regression with long range dependent errors are also included.

This is a general problem which for instance can be applied to finding the resting period of migrating birds.

Robust and recursive methods

Robust statistics and robust signal detection

Jan Holst, Ulla Holst, Ola Hössjer, Stefan Peterson, Anders Rosenqvist

The area of robust statistics has gone through a rapid development since the mid sixties, when Huber published his classical paper on M-estimators and min-max-methods. Various concepts, such as breakdown points, influence functions and qualitative robustness have been analyzed for several statistical models as different measures of stability (robustness).

We have been interested in developing new robust estimators in the linear regression model which combine a high breakdown point with statistical efficiency and computational tractability. A new class of estimators (GS) has been introduced (with P. Rousseeuw and C. Croux, University of Antwerp) to meet these requirements. A related estimator (LTD) has also been developed (with D. Hawkins, University of Minnesota and A. Stromberg, University of Kentucky). We are also looking for fast algorithms of already existing estimators.

We have developed rank statistics for estimating and testing multivariate location (with C. Croux, University of Antwerp). These generalized signed rank statistics in

the one-dimensional location model, are distribution-free for elliptically symmetric data and robust in terms of breakdown points.

The connection between the Hough transform (frequently used in image analysis) and M-estimators has been investigated. It leads to new insight in both areas and in addition to a new possibility also of robustly estimating scale. The implementation of this algorithm is very fast. It has found an application in estimation and control algorithms used in artificial kidneys produced at Gambro AB. We have also constructed a computationally fast method for diagnosing outliers.

Another area of research has been repeated median estimators, which are robust versions of traditional U-statistics, where the average operation is replaced by two medians. Several statistics are of this type, the most well known is Siegel's repeated median estimator of slope in regression. A general asymptotic formula for repeated median estimators has been derived (with P. Rousseeuw and C. Croux, University of Antwerp). A closely related class of statistics, so called generalized L-statistics, (GL) has also been studied. The Theil-Sen estimator of slope in simple linear regression and the Hodges-Lehmann location estimator are two examples. We have considered computationally fast modifications of such statistics, which have essentially the same efficiency as the corresponding GL-statistics.

We have been working with recursive robust algorithms in time series analysis, also insired by the abundance of proposed batch algorithms (with K. Seijling and H. Madsen, DTU).

The behaviour of robust estimators for data with long-range dependence has been studied (with J. Mielniczuk, Polish academy of sciences). Such dependence is stronger than the one in e.g. ARMA-models, and occurs frequently in hydrology, geophysics, and other fields. The situation is very much different from the independent or weakly dependent case.

Finally, a robust nonparametric, wavelet inspired regression mehtod have been proposed and studied. It is based on resursive subtraction by robust location estimators. A parametric bootstrap method is proposed in order to estimate the contaminated signal.

Recursive estimation and recursive algorithms

Lars Arvastson, Jan Holst, Ulla Holst, Anders Holtsberg, Ola Hössjer, Georg Lindgren, Bengt Lindoff, Stefan Peterson, Anders Rosenqvist

Recursive estimation methods, where the parameters or the model structure are updated when new observations are obtained, are

used in real time applications to time-varying systems and/or in situations where the observations are too many to be handled simultaneously. Recursive estimation algorithms can work with or without supervision, but have to be equipped with means to withstand large deviations from the assumptions on the noise process, of the previous discussion on robustness. The research is oriented towards both theory and application.

The theoretical results concern recursive robust methods and comprise almost sure convergence and representation theorems from which asymptotic distributions can be derived.

One of the major reasons for using recursive estimation algorithms is time-variations in the process to be modeled, and recursive forgetting method are commonly used. We have derived the exact distribution and moments of the Recursive Least Squares (RLS) algorithm with forgetting for an AR(1) process. Furthermore approximations and asymptotic error expansions of bias and variance of the parameter estimation errors in general Gaussian VARX processes and nongaussian AR(p) processes have been derived. The optimal choice of forgetting factor when using the RLS algorithms is also given. Quadratic forms are abundant in these estimation algorithms and the first inverse moment of a generalized quadratic form is produced.

Recursivity is a commonly used tool in many time series applications, such as adaptive prediction problems of power load, adaptive estimation in ECG modelling, and target motion analysis. The reduction of the computational burden is considerable.

Recursive estimates of certain quantiles related to U-statistics have been developed. These have applications to recursive estimation of regression and scale parameters in linear regression, as well as scale in nonparametric regression.

Control of time-varying systems

Jan Holst, Bengt Lindoff

Optimal control of time-varying stochastic systems is a very difficult task, having to take the character of the unknown time-varying parameters as well as the fulfillment of the control action into consideration, i.e. the optimal controller have to be dual.

A new general optimal adaptive predictive controller for time-varying system has been presented. It can be explicitly computed for arbitrary prediction horizons. It furthermore has been used as a suboptimal dual controller, showing superiour control of systems with heavily time-varying description.

Multivariate analysis

Björn Holmquist

Analysis of co–variation of several variables is well developed in linear spaces under the assumption of normality but is only in a beginning phase for other types of distributions. The robustness of inference procedures is studied within classes of distributions such as the classes of spherical and left-invariant distributions.

Procedures for testing homoscedasticy in correlated normal variables are derived and the question of unbiasedness of such tests is addressed. Studies are also made on measures of correlation in nonlinear spaces.

Further studies include projection operator representations for projections of direct product spaces onto moment spaces.

Quantile and extreme value statistics

Jonny Olsson, Holger Rootzén

Quantile estimators for a nonparametric variance component model are developed. Quantile estimators based on linear combinations of empirical distribution functions are studied in a situation with repeated measurements with different number of measurements on different subjects.

Our quantile estimator will be generalized to quantile estimation from more complicated measurement schemes, varying between subjects, and to estimation of quantiles of statistics calculated using a larger number of measurements within the same subject than is easily obtainable.

Spatial statistics

Ulla Holst, Ola Hössjer, Georg Lindgren, Igor Rychlik, Eva Sjö

The kriging method has been combined with a nonparametric variance function estimate to allow for heteroscedasticity in the stochastic field (with Jean Opsomer, Iowa State Univeristy, David Ruppert and Matt Wand).

"Hot spots" in regional measured data are often identified in a reconstructed map, constructed by means of kriging. We have studied the accuracy of such estimates by means of methods from crossings and extreme value theory, and applied the methods to environmental data. Similar methods have been used to assess the accuracy of estimated level curves in a random field from partial or disturbed observations. Work is under way to analyse common edge detectors in image analysis by the same methods.

Extremes and crossings

Martin Sköld

A nonparametric estimate of crossing intensities has been developed based on Rice' formula, with automatic bandwidth selection.

Detection by neural nets

Georg Lindgren

Neural networks are used in particle physics to discriminate between different particles produced in high energy collisions (quarks and gluons). The efficiency of classification algorithms, based on observed energy, has been studied (with C. Jacobsson and L. Jönsson, Lund).

The methodological development in the time series, signal and image analysis part of the research at the department aims at general applicability, with two major application areas being energy management and signal processing onboard marine vehicles (NUTEK and TFR). The specilized projects, devoted to a certain application hence will rely on the independent methodological studies of e.g. timevarying systems, grey box modelling and robustness that are described previously in this progress report.

Modelling of real systems demands that nonlinearities and nonstationarities given by basic physics or by normal operator practice have to be included in the models together with descriptions of random phenomena. This is a basic paradigm in all work reported below.

Target Motion Analysis and Navigation

Jan Holst, Anders Holtsberg, Anders Rosenqvist, Anders Svensson

Target motion analysis problem aims at determining the relative position and velocity of a target from very noisy data. Methods for target motion analysis based on bearings only or on bearings and frequency information have been developed (with Kockums AB). Essential results are e.g. synthesis and analysis of a pseudolinear Doppler-bearing method working with varying frequency information and including handling of accelerations, such as yaws; methods for passive sonar ranging; and a general treatment of pseudolinear problems of this kind. All algorithms are robust, i.e. protected against gross errors. Furthermore a tracker that works in the bearing-time plot has been developed.

The navigation problems include in particular sensor fusion ideas, i.e. how to merge the information from various sensors in order to improve the estimates of position and velocity. The inclusion of a logg that exploits the terrestial magnetic field makes it possible also to estimate the drift in the gyros.

Our methods have been tested on an airborne platform with nice results.

Statistics in Energy Systems

Lars Arvastson, Jan Holst, Anders Holtsberg, Gudmundur Jonsson, Pia Jonsson, Anders Svensson, Magnus Wiktorsson, Hongping Zhao

The prediction task for electric, district heating and gas loads has been studied, as part of studies aiming at improving energy efficiency and customer comfort. Essential problems that occur in all cases, like timevariation of the non-

linear system description, periodicity, abnormal days, abberrant measurements, have all been subject to investigation, and some of the solutions are being implemented in the running systems. It is essential to have a reasonable model for local temperature, in particular when doing district heating prediction and control. This is a cooperation with Sydkraft AB, Malmö Värme AB, Sydgas AB, Grundfos A/S, Veks A/S.

District heating system modelling demands a combination of physical and statistical methods and we have used such combinations, also in connection with modelling buildings and modelling individual components, like valves or heat exchangers. This is an area where the cooperation with Denmark is particularly intensive (H.Madsen, IMM, DTU and Grundfos A/S). The general results also concern modelling, simulation and estimation in general stochastic differential equations.

Optimal planning in power systems demands modeling of the power plant, optimal use of storages, aggregation of groups of consumers, etc. The optimal scheduling of power production in addition demands good models for components and net and working optimization methods for unit dispatch and unit committment. We are working on these problems as such as well as aiming on expoiting the relations to alarming.

The design criteria used in the design phase of an energy system, are most often based on extreme events, which however most often is not reflected in the assumed statistics. We have applied extreme values statistics to achieve a system design, that is better adopted to the design rules.

The core in a nuclear power plant is supervised for detection of any possible deviation from normal behaviour. We work with system analysis, models for deviations in radiation measurements and suggestions for further development of a system for supervision and detection of anomalies.

Experiment design for grey box modelling and detection

Jan Holst

The physical significance in parametrization and the partial prior information that is available e.g. about parameter values, affect the design of optimal experiments for identification and for detection, and classical theory for experiment design has been extended to design for partially known systems. The design is performed in a Bayesian spirit. Application examples include modelling of the energy conditions in buildings.

Fault Detection and alarm

Lars Arvastson, Halfdan Grage, Jan Holst, Anders Svensson

Fault detection based on process modelling demands a description of the system under normal conditions and a description of the normal variations, as a basis for detection when normality no longer prevails. We have used generalized likelihood ratio methods for testing erroneous behaviour of an engine, and used such methods as a tool for surveillance of components in complex systems. Furthermore, our yaw detectors in the marine applications are based on this type of techniques.

The optimal alarm is connected to an extreme event in the process without leaving its normal performance. It is a question of timing and we have developed an algorithm for the optimal alarm, i.e. an alarm which amongst all alarms with the same detection probability has the lowest amount of false alarms. Since the optimal alarm is computationally demanding, we have also constructed reasonable approximations. The optimal alarm predictor is extendable to cases where the process is subject to external influence, or the alarm level is timevarying or stochastic. This alarm principle has been used for prediction of floodings and it should also be used for unit committment.

In backpropagation neural network the weights of the various signals in the net are determined via optimization of a certain loss function. By a suitable choice of that loss, the net acts like an optimal alarm predictor, which in case can be ad hoc extended to nonlinear and nongaussian processes. This algorithm demands however a large sample size.

Robustness in parameter estimation

Jan Holst, Ola Hössjer, Stefan Peterson, Anders Rosenqvist

Parameter estimation algorithms are bound to have a high degree of robustness against incorrect measurements, faulty signals or large disturbancies in order not to give very awkward results in case of large disturbancies etc. We have studied the robust regression problem, and presented a number of possible solutions, like e.g. a method based on wavelets, a method based on the Hough transform in image analysis and a method based on a second order extension of an existing, commonly used method of just cutting the large residuals. Both batch and recursive methods are proposed and tested. The methods are to be applied in all practical data handling situations.

Smoothing by wavelet methods, ECG-analysis

Jan Holst, Bengt Lindoff, Stefan Peterson, Magnus Wiktorson

Filtering, denoising and wavelet regression with particular emphasis on treatment of ECG-signals obtained under working conditions have been studied. It is shown that carefully chosen Kalman filters makes it possible to retrieve the heartbeat signal. Using a wavelet regression makes it possible to treat very noisy signals. The existing wavelet methods are extended by combining the stationary wavelet transform and wavelet matrices to a very efficient and powerful denoising technique. Methods for model selection are analysed and connected to likelihood techniques. A new method for robust nonlinear regression based on recursive subtraction of robust location estimators is proposed.

In mobile communication, that signal is heavily disturbed by noise from the environment where the signal is generated, typically inside a car. Wavelet based methods are adopted to this denoising problem with promising results.

A wavelet based method has also been used in order to describe the velocity of the gas in a cylinder in a car engine as a function of the design of the piston.

Statistical Image Processing

Jan Holst, Anders Holtsberg, Finn Lindgren

The reconstruction of a three-dimensional object from two-dimensional projections, is a problem which has a statistical solution by creating alternative three-dimensional objects that are consistent with the projections. We have developed a technique for this reconstruction and applied it to modelling of the flame in a spark ignition engine, in order better to understand the combustion process, and to estimate e.g. the volume of the flame. The flame is modelled using a deformable template technique and Markov Chain Monte Carlo methods to fit the template to the images and to get a reasonable flame shape. A technique for cutting three-dimensional meshes is also developed.

We have also worked with subpixel resolution in PIXE-images, and implemented a deblurring algorithm using simulated annealing for increasing the resolution in the image beyond the experimentally given limit.

The image processing work also includes projects like perimetric threshold estimation discussed below, and construction of a bearing-time plot based tracker mentioned above.

Multivariate time series

Björn Holmquist

Simultanenous description of several processes is performed to gain insight in the covariation of different variables. Properties of linear processes obeying a periodic parameter structure are studied. Characteristics of the subprocesses and influence of intrinsic dynamics and external signals are studied.

Matching of climatic dependent pollen sequences is important for dating purposes. Records of relative abundance of qualitative variables or sizes of quantitative variables are either matched with dated records or a relative dating is made based on several undated sequences. Such sequences exhibit fluctuations due to characteristic level variations and fluctuations due to random components. The main point in dating is that corresponding extremes in the different sequences can be identified.

ENGINEERING STATISTICS

Fatigue, Stochastic mechanics

Pär Johannesson, Georg Lindgren, Igor Rychlik, Jesper Rydén

This field is closely related to extreme value theory and stochastic differential equations. It deals with static and dynamic properties of random linear and non-linear mechanical systems, important for safety and reliability analysis. Fatigue due to random loads is studied, theoretically and experimentally.

A new mathematical formalism for the important Rain Flow Cycle counting method has been developed, which facilitates load analysis and simulation, as well as fatigue life prediction. Algorithms and program packages for extreme value analysis with safety applications which include new techniques to analyse extreme responses of mechanical non–linear systems of a switching type are developed. These new methods has permitted fatigue life prediction for classes of load processes which have a Markov structure (with Y.K. Lin, Boca Raton) or which switches between different Markov structures depending on the load conditions.

The problem of simulation of random fatigue loads from observed Rain Flow counts has been studied. The question of when there exists a Markov model for the peak-trough load sequence with the same Rain Flow structure as a given observed load has been investigated, and the Markov model has been shown to accurately reproduce observed load behaviour.

A toolbox FAT with MATLAB routines for fatigue analysis has been developed and used at a number of industries and engineering departments.

Ocean and marine statistics

Georg Lindgren, Pär Johannesson, Igor Rychlik, Jesper Rydén

Ocean engineers have used stochastic fields since the early fifties to model the wave structure of the ocean surface. Gaussian models prevail, but non-linear models for non-Gaussian waves are emerging. Wave characteristics, most important wave height, wave period, and wave length, need to be calculated and their statistical properties derived from the models.

We have developed a number of analytic and numerical tools for the calculation of the wave characteristic distributions in Gaussian and non-Gaussian waves. The numerical algorithms have been collected in a toolbox of MATLAB routines in the package WAT. These routines are probably the most accurate routines that exist for statistical analysis of Gaussian wave models

with general spectra. The resulting distributions have been checked on shallow and deep water waves (with M.R. Leadbetter, Chapel Hill). It has also been shown that the common Rayleigh hypothesis for wave amplitude gives rise to conservative results when used to predict fatigue effects from waves.

The relation between wave period and wave length has been studied, as well the random Doppler effect occurring when moving on a random sea (with M. Prevosto, Brest).

Statistics in telecommunications

Søren Asmussen, Tobias Rydén

Statistical modelling of traffic in modern, complex communication networks has received little attention until quite recently. We are currently starting up research efforts in this area, and intend to use the department's knowledge of inference in stochastic processes for finding versatile traffic models and efficient statistical algorithms. Of particular interest will be Markovian models such as (marked) Markovian arrival processes, but also other models such as for example long range dependent ones should be examined.

Biostatistics

Orientation data analysis

Björn Holmquist in cooperation with the Department of Zooecology and the Department of Quarternary Geology

Orientation processes are a special type of multivariate processes with data constrained to lie on a (hyper-)sphere or other submanifolds. Traditional estimation techniques do not apply here because of the non-linearity of the manifolds.

In one project, methods for measuring preferred orientation in bird migration and their dependence on various factors are investigated. Here the dependence in data due to registration equipment requires special techniques. Studies have been made on discrete type directional data and for models of multimodal distributions.

Magnetic declinations and inclinations vary with time due to polar wanderings. Records of declination measurements exhibit smooth paths with time dependent variation of scatter where the smooth characteristic variations are used for dating purposes. A kernel smoothing technique for directional data is devised, taking into account the strongly varying dispersion along time.

Image processing and perimetric threshold estimation

Anna Lindgren, Georg Lindgren, Jonny Olsson, Holger Rootzén, Eva Sjö, in cooperation with Humphrey Instruments, California, Ophthalmic Imaging Systems, California, and the Department of Ophthalmology, Malmö

Perimetry is the measurement of the visual field, i.e. a person's ability to detect light stimuli. This ability may be impaired by glaucoma or neurological disorders. The project is aimed at improving the measurement of visual fields and to give a statistical background for diagnoses and treatments. Image processing techniques for quantal responses, in particular Markov random field models and non–parametric statistical methods, are developed for this purpose. Robust inference in Bayesian image analysis is studied, as well as the influence of prior distributions in image reconstruction.

Application of these methods has been shown to half perimetric test time, with no increase in measurement error.

The deflection of lines projected to an area of cupping is used for estimation of the papillary topography. A Gaussian field model of the optic nerve head is developed for this purpose.

Clinical and epidemiological studies in cancer research

Harald Anderson, Per-Ola Bendahl, Roland Perfekt, Ulf Strömberg, in cooperation with the Department of Cancer Epidemiology, the Department of Oncology, and the Department of Occupational and Environmental Medicine, Lund.

Techniques for planning and analysis of clinical studies are developed in cooperation with the Department of Oncology, Lund University. Identification of prognostic indicators for cancer growth is then of particular interest.

Epidemiologic and clinical research is done in collaboration with various national and international groups. The cancer risk in offspring of mothers who had cancer earlier or later in their lives is studied by means of the national cancer and fertility registries. In a Scandinavian cooperation the risk of a second malignancy is studied for people who had a primary cancer in their childhood. Also within Scandinavia, large clinical trials are planned and performed to study various treatments for breast cancer.

Methods to analyze mortality due to different causes of death are studied in order to be able to evaluate screening programs, new therapies and changes in autopsy frequency.

Flow Cytometry, DNA-analysis

Ulla Holst, Georg Lindgren, Pär–Ola Bendahl, Eva Sjö

Models based on mixed distributions are developed for DNA-histograms produced by flow cytometry. Quasi–Newton– and EM–algorithms are used for ML–estimation of the component distributions. Of special interest is the proportion of the S–phase distribution, which is believed to have great importance for cancer diagnosis. A study, where the choice of treatment is decided partly by the S–phase–fraction, is started in the Southern Swedish Health Care Region. This is further studied by means of statistical techniques for survival analysis.

Survival analysis

Pär–Ola Bendahl, Jan Lanke

Survival analysis is a growing research area, which often requires special methods; an important example is Cox's regression model. We are working on extensions of this theory, such as alternative ways of estimating the baseline survival function, and combinations of Cox–type models and methods for mixed distributions. Applications include cancer prognoses by cell DNA measurements, response times in visual field measurements, and epidemiological problems. We also investigate the appropriateness of different techniques for determining, from power requirements, the cohort size in a survival study; the effect of using certain stopping rules are considered as well. Finally, in collaboration with the Department of Statistics, we apply survival analysis techniques to demographic problems.

ECG

Jan Holst, Ulla Holst, Stefan Peterson

Recursive estimation of ECG signals from exercise tests as part of a development of improved diagnostics contains many statistical challenges: detection of an almost periodic slowly time–varying profile, removing of a wandering baseline and protection against outliers. Models for the profile, high frequency noise and the baseline are developed. These models are formulated in state–space form and the estimation is made by Kalman filtering.

Wavelet analysis has successfully been applied for denoising the ECG signal. A multiple wavelet extension of the standard Haar wavelet, to Haar wavelet matrices showing similarity with the Chebyshev system of orthogonal polynomials have been proposed, and also used together with the stationary wavelet transform in the noise reduction problem. Furthermore, methods for thresholding

have been analysed and a robust regression technique proposed.

ENVIRONMENTAL STATISTICS

Environmental statistics is today a fast-growing field of statistical problems dealing with e.g. monitoring, extreme values, nonparametric methods, time serieas analysis, spatial and spatial-temporal modelling.

Quantile estimation

Sofia Andersson, Georg Lindgren, Lena Zetterqvist

When studying airborne pollution, quantiles of the concentration distribution are often of great interest. We have studied the relation between the empirical quantiles in the observed measured distribution, and the quantiles in the true distribution without measurement error when the true distributions are assumed to be generalized Pareto and the measurement errors are normal. The results are applied on NO_x-emissions from a gas furnace.

Environmental time series

Georg Lindgren, Bengt Ringnér, Lena Zetterqvist

Careful analysis of environmental time series is needed to separate long term trends and possible effects of human activities from random fluctuations. We have developed and used robust parametric time series techniques as well as non–parametric methods, and used them on water quality series in order to detect long term tendencies and find relations between different quality measures. Techniques for revealing common patterns in simultaneous time series are used on air quality and water quality series.

LIDAR curves

Claes Björklund, Ulla Holst, Ola Hössjer, Torgny Lindström

The LIDAR (Light Detection And Ranging) technique has proven to be an efficient tool in monitoring the distribution of several atmospheric pollutants. The DIAL (DIfferential Absorption Lidar) technique employs two different wavelengths, one in resonance with an absorption line of the species of interest and the other off resonance. The backscattered light is detected as a function of time.

Statistically this means that we have a highly heteroscedastic nonparametric regression problem, where we have to estimate the derivative of the regression function. We are working with local polynomial regression methods and studying methods for automatic bandwidth selection (with D. Ruppert, Cornell University, M. Wand, Sydney, H. Edner, P. Ragnarson and P. Weibring, Atomic Physics, Lund) in these models. Further, we have

estimated the total amount of the species in a certain area.

Analysis of DOAS measurements

Ulla Holst, Ola Hössjer, Torgny Lindström

The received light intensity in a DOAS measurement (Differential Optical Absorption Spectroscopy) can be divided into two parts. One part explains the extinction that varies slowly as a function of wavelength and the other part explains the more rapidly varying light extinction. We have applied robust nonparametric filtering techniques on the slowly varying part of the regression function.

RESEARCH – TEACHING RELATIONS

Resources

The department has tried to integrate research and teaching in all types of positions. We have been rather successful in this – mainly due to support from research councils and industry, and almost all lecturers have research support in one form or another.

The extremely low budget for undergraduate teaching in mathematical statistics (in 1996/97 at the very bottom of the list at LTH), puts a severe strain on teachers: while they work hard at being good teachers, they must qualify for future grants by keeping their research at the highest possible level.

Professors regularly give undergraduate courses, lecturers and older graduate students give graduate courses, and all lecturers work as advisors in the graduate program.

Graduate students take part in undergraduate teaching. We also encourage them to take part in the consultant service that is being set up at the department. Both activities make the students better trained as professional statisticians and give them a chance to qualify for future careers, either at a university or in industry or government agencies.

Scientific bridges

On the basic level, introduction of computer intense methods has been accelerated by the research in time series analysis, recursive algorithms, and extreme value theory. The course in Stationary processes, together with the subsequent advanced course in Time series analysis, has for a long time been a hallmark of the department. The course material produced at the department is now being used at many other universities.

As a result of research cooperation with the Institute of Mathematical Modelling at the Danish Technical University, Lyngby, a joint course in Non-linear time series has been developed and is now taught jointly with the Danish department.

The advanced course in Statistical methods in reliability, given for the first time in 1985, emerged from a longstanding interest in the research of stochastic processes and their applications to reliability and fatigue problems.

The undergraduate course in Survival analysis and the new course in Clinical trials have been initiated to satisfy growing demands in biostatistics.

The new course in Monte Carlo based methods for statistical inference is also inspired by the research interests at the department.

EXTERNAL CONTACTS

The Department of Mathematical Statistics has a large network of national and international contacts, both inside and outside of the university sphere. The most important cooperation partners are listed in the Appendix. To qualify for the list, the cooperation must have resulted in at least a masters thesis or other publication. Many of the joint projects have led to solution of practical problems and subsequent implementations.

A list of the seminars given at the department and by those given by our staff out of the department is given in the Appendix. The department is regularly visited by researchers and research students. A list of these is also given in the Appendix. Furthermore, some research students at the department have received part of their education abroad.

The most important nodes in our research exchange network are the Department of Statistics at the University of North Carolina, Chapel Hill, USA and the Institute of Mathematical Modelling at the Technical University of Denmark, Lyngby, Denmark.

Mathematical statistics also plays a role in interdisciplinary projects, where data analysis, modelling and stochastic signal processing are important subjects. This means that many of the cooperative efforts are directed towards organizations which are not basically statistical. This is believed to be of importance for our partners, and it is certainly most important for the development of mathematical statistics as such, since it leads to a considerable influx of research topics. We are aiming at ramifying this part of the contact network by introducing new nodes while keeping most of the established connections active.

A list of conferences attended by the staff and PhD students of the department is included in the Appendix.

EQUIPMENT AND LIBRARY

Computer equipment

We provide all our graduate students and staff members with personal workstations with access to powerful computation servers. Our computers are mainly Sun and Digital Alpha servers and workstations but we also use Pentium PS's running Windows NT.

Students have access to three computer laboratories equipped with Sparc Classic workstations, Pentium PC's with Windows NT, and 486 PC's.

All computers have 10 Mbit Ethernet connection and are integrated with the local and world wide network, We have started the transition to 100 Mbit communication.

The present computer network has been made possible by generous grants from the Knut and Alice Wallenberg foundation, NFR, and LTH.

Computer status, September 1997

- ⋆ 31 Sparc and Ultra Sparc workstations
- ⋆ 11 Digital Alpha workstations
- ⋆ 10 Pentium workstations

Jointly with the mathematics department, the department also has 3 Sun servers, a powerful Digital Alpha server 2000, equipped with 4*275 MHz CPU's and 576MB of primary memory, two PC laboratories (30 Pentium PC's), and one Unix laboratory equipped with 12 Sun Sparc Classic.

The Department Library

The library is one of the best equipped libraries on mathematical statistics in Scandinavia.

It now counts more than 3,000 titles, and the number is growing by about 100 titles each year. The library also holds a large number of periodicals, the figure for 1997 being 75 titles.

The library budget for 1995/96 was 250 kSEK, entirely paid by the department's university FFU and GU grants and external research grants.

ECONOMY

Source	MNF		LTH		Total	
	1000 kr	%	1000 kr	%	1000 kr	%
Undergraduate teaching	2658	10	6655	26	9313	36
Research, LU	3769	15	2788	11	6557	26
PhD support, LU	1395	5	1829	7	3224	13
Research, external support	960	4	2553	10	3513	14
PhD support, external	68	0	276	1	344	1
Industry	724	3	1948	8	2672	10
Total	9574	37	16049	63	25623	100

The table shows the expenses during the 18 month period July 1, 1995 – December 31, 1996.

APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
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APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX
APPENDIX

APPENDIX

Department of Mathematical Statistics

Lund University
Lund Institute of Technology

1994–1996

LIST OF CONTENTS

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299. Bäckman, P.L., **Lanke, J.**, Barlow, L. and Andrén-Sandberg, Å.: Decreasing incidence of exocrine pancreatic cancer in Sweden. Manuscript.

300. **Holtsberg, A.** and **Holst, J.**: Curved wavefront ranging and bearings only tracking. Manuscript.

301. Ljungquist, B., **Lanke, J.**, Berg, S., McClearn, G.E. and Pedersen, N.L.: The effect of genetic factors for longevity: a comparison of identical and fraternal twins in the Swedish Twin Registry. Manuscript.

302. Lidfeldt, J., **Lanke, J.**, Sundquist, J. and Lindholm, L.: Old patients with hypertension: a 25-year longitudinal study of a geographically defined population (Dalby), aged 67 at entry. Manuscript.

303. **Johannesson, P.** and **Lindgren, G.**: Rainflow cycles for switching processes with Markov structure. ITM report 1996:4, October 1996.

304. Madsen, H., Melgaard, H. and **Holst, J.**: On parameter identification in stochastic differential equations. Manuscript.

Theses

Doctors Theses

1994

Roland Perfekt: On extreme value theory for stationary Markov chains. LUNFD6/NFMS-1004-SE, ISBN 91-628-1106-1.

Roger Pettersson: Approximations for ordinary, reflecting, and multivalued stochastic differential equations. LUNFD6/NFMS-1005-SE, ISBN 91-628-1419-2.

1995

Anders Rosenqvist: Fast robust estimators for linear regression and Doppler-bearing tracking. LUTFD2/TFMS-1008-SE, ISBN 91-628-1630-6.

Pär-Ola Bendahl: Estimation and prognostic value of S-phase fractions in cancer cell populations. LUNFD6/NFMS-1006-SE, ISBN-91-628-1807-4.

1996

Stefan Peterson: Filtering and wavelet regression methods with application to exercise ECG. LUTFD2/TFMS-1009-SE, ISBN 91-628-2192-X.

Licentiate Theses

1994

Anders Rosenquist: Pseudo-linear and ML estimation in doppler-bearing tracking. LUTFD2/TFMS-2001-SE, ISBN 91-628-1316-1.

1996

Bengt Lindoff: Distribution properties of the recursive least squares algorithm with forgetting factor. LUTFD2/TFMS-2002-SE, ISBN 91-628-1861-9.

Masters Theses

1994

Jeppa Grosshög, Henrik Värendh: Kalman filters for increased precision in inertial navigation.

Elias Jonsson: Kernel density estimates in stochastic differential equations.

Rickard Bertilsson, Örjan Pettersson: A study of the wavelet transform applied to the electrocardiogram.

Mikael Thuvesholmen: Recursive estimation and segmentation in autoregressive progresses with Markov regime

Mieczyslaw Saklak, Halfdan Grage: Catastrophe prediction with neural network.

Attila Frigyesi: Testing singularity and estimating Hausdorff dimensions using kernel estimates.

Anna Eriksson, Hanna Svensson: Dimensionering av kliniska prövningar inom överlevnadsanalys - prospektiva kohortundersökningar.

Helena Olsson: A study of extreme significant wave heights in the Norwegian Sea.

Fredrik Björnsson: Parameter estimation and model order selection for Markov modulated Poisson processes.

Marie Olsson: Klusteranalys - några begrepp, förklaringar och exempel.

Claes Björklund: Statistisk analys av LIDAR-kurvor med hjälp av en lokalt viktad minsta-kvadrat-metod.

1995

Johan Kleberg: Load prediction during odd days.

Nedjad Losic: A clinical trial with one interim analysis and a stopping rule for futility.

Niklas Karlsson: Interactive target tracking in the bearing-time plot.

Jens Bergström: User interface in a program system for modelling and prediction - Structure and data handling.

Ann-Sofie Hörstedt: Några viktiga prognostiska faktorers tidsberoende effekt på överlevnaden vid bröstcancer.

Martin Sköld: Kernel intensity estimation for marks and crossings of differentiable stochastic process.

Otto Elmgart: Adaptive Kalman filtering.

Anders Karlsson, Mattias Jansson: Flerstegsprediktion av elförbrukning med användning av väderfaktorer.

Erik Sparre: Derailments, collisions and fires on Swedish railways during the period from 1985 to 1995.

Hassan Özduman, Örjan Svensson: Wavelet transform applied on ECG signals and ECG images.

Björn Liljeberg: Användargränssnitt i programsystem för modellering och prediktion - modellspecifikation och estimering.

1996

Torgny Lindström: Robust local polynomial regression with application on the DOAS filtering process.

Henrik Amilon: Valuations of options using neural networks.

Jesper Rydén: Detection of wheel flats using stochastic wave analysis.

Rebecka Jörnsten: Sub-pixel resolution in PIXE images.

Ann-Cecilia Karlsson: Analysis of truncated data by means of a stochastic EM algorithm.

Mattias Morén: A comparison of various methods for parameter estimation in a Markov modulated Poisson process.

Eleonóra Szabó: Generalized rank correlation as a measure of variable importance in survival data sets with censoring and truncation.

Advanced courses

Description of advanced courses in the undergraduate program

MAS203**Probablity Theory, 2nd course**

This course gives further knowledge in Probability Theory. It deals with random variables in one and several dimensions, conditional distributions, moment generating functions and characteristic functions, multivariate normal distributions, quadratic forms, order statistics, convergence criteria for random variables, the Borel-Cantelli Lemmas, convergence via transforms, the Central Limit Theorem and strong law of large numbers. Poisson processes; conditioning on number of occurrences/occurence times, thinned and compound Poisson processes.

MAS204 **Markov Processes**

The course covers different aspects of Markov chains with a countable number of states and either discrete or continuous time: Stationary distributions, limit theorems, time-reversability, branching processes, Poisson processes, birth-death processes, renewal processes, the renewal equation, single server queues with diffent inter-arrival and serving time distributions, martingales.

MAS207 **Inference Theory**

The course gives more advanced knowledge of inference theory, as a continutation of MAS101. It contains theory of exact methods; Factorization Theorem, exponential families, Rao-Blackwell's Theorem, ancillary estimators, Cramér Rao's Inequality, Neyman-Pearson's Lemma, permuation tests and interrelations between hypothesis testing and confidence intervals. Further considered are asymptotic methods; maximum likelihood estimators, standard errors, marginal, conditional and penalized likelihood and hypothesis testing according to the likelihood ratio, Wald ore scores method. The next topic is Baysian inference; estimators, hypothesis tests, confidence intervals and differences from the frequentist interpretation. Finally, some orientation is given about sequential tests and inference for finite populations.

MAS208 **Statistical Models and Methods**

The theory covers linear normal models, variance component models, multivariate analysis, basic time series models, survival analysis, the EM-algorithm, kernel estimators, contingency tables and generalized linear models. The computer assignments are a substantial part of the course.

MAS209/FMS072 **Design of Experiments**

The course gives theory and methodology of how to model, design and evaluate experiments. Important concepts are: Simple comparative experiments. Analysis of variance; transformations, model validation and residual analysis. Factorial design with fixed, random and mixed effects. Additivity and interaction. Complete and incomplete designs. Randomized block designs. Latin squares and confounding. Regression analysis and analysis of covariance. Response surface methodology. Off-line quality control and Taguchi methods.

MAS210 **Stationary Processes**

The course gives an overview of how to model processes (some of) whose characteristics are time invariant. Important concepts are covariance, correlation and cross-correlation functions. Gaussian processes and white noise. Linear filters, autoregressive and moving average processes. Spectral density function, phase and amplitude spectra. Estimation of mean, covariance function and spectral density. Ergodicity. Frequency analysis. Signal-to-noise ratio. Matched filters and Wiener filter. Some properties of the Brownian motion.

MAS212 **Multivariate analysis**

The course covers basic distributional theory, in which the multivariate normal distribution and the Wichart distribution are treated, multivariate linear models, multivariate multiple regression and multivariate analysis of variance. Further, component analysis is treated by means of principal component analysis, factor analysis and canonical correlation. Models and tests for categorical variables, including correspondence analysis and its canonical form.

MAS213 **Analysis of Survival Data**

Survival data describe, for a number of individuals, the length of the time period from a certain starting point, e.g. diagnosis of a certain disease, to some well-defined end-point, often death. Such data almost always contain so called censored observations. These arise from the fact that some individuals have not yet reached the end-point when the investigation is closed; for such indivuduals the exact values of their survival is not known, only lower bounds are available. First the one-sample case is considered, i.e. the survival function for one homogeneous group is to be estimated. Next the two-sample case is treated, i.e. how to compare the survival functions of two groups. Finally methods are given for investigation of how the survival function depends on one or several explanatory variables.

MAS214 **Clinical Trials**

The course treats statistical problems encountered during a clinical trial: parallel groups or cross-over designs; determining the size of a trial; randomization; stratification; possible correction for unbalance in covariates; drop-outs and withdrawals; interim analysis; analysis according to intention to treat or per protocol; planned and unplanned analyses; correction for multiple inference. The particular situation encountered in a bioequivalence study is also discussed. Further considered are statistical and other problems that may face a safety committee. Finally, a number of non-statistical aspects are treated: different phases of testing new drugs; writing protocols ; inclusion and exclusion criteria; construction of forms; the Helsinki Declaration; blind statistical analysis; efficacy, tolerability, safety; data quality; data security.

MAS216/FMS051 **Time Series Analysis**

The course treats modelling of stochastic systems using knowledge and data. Important concepts: Stationary and nonstationary processes, ARIMA processes, seasonal variation. Prediction, filtering and reconstruction in transfer function models and state space models. Parameter and structure estimation by least squares, maximum likelihood and predictive error methods. Spectral analysis, recursive estimation, adaptive techniques, robustness and outlier detection. Multivariate time series. Spectral density estimation.

MAS221/FMS091 **Monte Carlo Methods for Stochastic Inference**

The course offers an overview of simulation techniques; transformation methods, Acceptance-Rejection Method, Markov Chain Monte Carlo techniques such as Gibbs samplining and the Metropolis-Hastings algorithm. Applications to hierarchical models, image analysis and Ising models are mentioned. Further considered are resampling methods such as bootstrap, parametric bootstrap, jackknife, permutation tests and their use for construction of confidence intervals and in linear models. The final part dels with model selection; succesive tests, Cross validation, information based criteria as well as their interrelations. Model selection for linear models (subset regression) is covered.

MAS222/FMS110 **Non-linear Time Series Analysis**

The course is given jointly by the Dept. of Mathematical Statistics at Lund University and the Institute of Mathematical Modelling at the Danish Technical University (DTU), Copenhagen. The course treats advanced time series analysis, with a primary goal being to give a thorough knowledge on modelling of dynamic systems. A special attention

is paid on non-linear and non-stationary systems, and the use of stochastic differential equations for modelling physical systems. The contents encompasses e.g. non-linear time series models, kernel estimators and time series analysis, identification and estimation in non-linear models, state space models, state filtering, prediction in non-linear models, estimation of linear and (some) non-linear stochastic differential equations, parameter tracking in time series, experiment design for dynamic system identification.

MAS223/FMS061 **Extreme Value Theory and Risk Analysis**

The first part covers statistical models and methods, for instance extreme value distributions, in particular the Weibull distribution, failure rates, model construction, graphical methods and accelerated tests. The second part dels with binary systems; Markov chains and Markov Processes applied to reliability, availability and redundancy. The third part treats risk analysis; structural safety for static systems and stochastic models for fatigue analysis. The final part covers dynamical models; study of time varying stochastic loads (e.g. wind and wave loads, noise) using the theory of normal processes and their extreme values. Applications to fatigue analysis are given.

MAS230 **The Mathematical Basis for Probability Theory**

The course extends and deepens basic knowledge in Probability Theory. Central topics are existence and uniqueness of measures defined on sigma fields, integration theory, Radon-Nikodyn derivatives and conditional expectation, weak convergence of probability measures on metric spaces, some topology.

MAS192/FMS820 **Degree Project in Mathematical Statistics**

Degree projects are often carried out in close collaboration with industry or researchers in other fields. Typically, they consist of finding an appropriate model and/or statistical method for analysing a given data set. The work can also be part of a research project at the department, purely theoretical, implementation of a toolbox or investigation of a new statistical technique by means of either simulation or evaluation of data sets. Each student has a supervisor from the department. For further information, see the current list of projects.

FMS041 **Stochastic Processes**

The course consists of two parts, Markov processes and stationary processes. The first part covers general definitions of stochastic processes, discrete Markov chains, Poisson and renewal processes, point processes, (continuous time) Markov processes, birth-death processes, transition in-

tensities, stationarity, classification and simulation of Markov processes, inference for Markov processes. The second part deals with covariance, correlation and cross-correlation function. Gaussian processes and white noise. Linear filters, autoregressive and moving average processes. Spectral density function, phase and amplitude spectra. Estimation of mean, covariance function and spectral density. Ergodicity. Frequency analysis. Signal-to-noise ratio. Matched filters and Wiener filter.

External Contacts

Seminars given at the Department

1994

Jan Tailen Hsing, Texas: Point process and partial sim convergence for weakly dependent random variables with infinite variance

Feb Jeppa Grosshög, Henrik Värendh: Kalman filters for increased precision in inertial navigation.

Feb Sven Erick Alm, centrum för säkerhetsforskn.: Risken för extrema "klumpar" av slumphändelser (om fördelningen för scan-statistikan till en Poisson-process).

Feb Björn Holmquist: Om modalitet hos riktningsdata.

Mar Rikard Bertilsson, Örjan Pettersson: En studie i wavelettransform på EKG-signaler.

Mar Rainer Schwabe, Berlin: Optimal designs for multi-factor models.

Mar Y.K. Belyaev, Umeå: Statistical inference based on reliability data with three types of events related to the same cumulative hazard function.

Mar V.I. Piterbarg, Moskva: High level excursions of Gaussian fields and the optimal choice of the smoothing parameter.

Mar Henrik Nyberg, Stockholm: The birth and death process in a random environment (BDRE).

Apr Jeff Steif, Chalmers: An exact critical value for phase transition in a 1-dimensional cellular automaton.

Apr Ingemar Kaj, Uppsala: Stokastiska system med svagt samverkande beteende.

Apr Taivo Arak, Göteborg: Polygonella Markovfält som bildmodeller.

Apr Christophe Croux, Univ of Antwerp: High breakdown regression by minimization of an explicit scale estimator.

May Elias Jonsson: Kärnskattningar använda på stokastiska differentialekvationer.

May Mikael Thuvesholmen: Recursive estimation and segmentation in autoregressive processes with Markov regime.

May Georg Lindgren, Igor Rychlik: Hur tillförlitliga är nivå-kurvor - om att göra konfidensband för höjdkurvor i ett uppmätt fält.

May Halfdan Grage, Mieczyslaw Saklak: Catastrophe prediction with neural networks.

Jun R.J. Bhansali, Liverpool: Recent developments in analysis of time series with infinite variance: a review.

Aug Alf Isaksson, KTH: A Bayesian approach to manoeuvre tracking and detection.

Sep Tomas Björk, KTH: Parameter estimation and reverse martingales.

Sep Pär Johannesson, Anders Rosenqvist, Björn Holmquist: Rapporter från konferenser: Undersea defense technology in London, 2nd European conference on underwater acoustics in Copenhagen, 5th Tartu conference on multivariate statistics and workshop on matrices in statistics in Tartu.

Sep Jacek Leskow, Santa Barbara: How to detect a nonstationarity? A complicated (partial) answer to an easy question.

Sep Anna Lindgren, Georg Lindgren, Roger Pettersson, Igor Rychlik, Mikael Thuvesholmen: Rapporter från konferenser: Third World Congress of the Bernoulli Society, Chapel Hill, North Carolina.

Sep Thore Egeland, Oslo: Statistikk og Bevis.

Sep Johan Kleberg: Prediktion vid avvikande data och onormala processförlopp i elförbrukningen.

Sep Attila Frigyesi: Testning av singularitet och skattning av Hausdorffdimension med hjälp av kärnskattningar.

Sep Anna Eriksson, Hanna Svensson: Dimensionering av kliniska prövningar inom överlevnadsanalys - prospektiva kohortundersökningar.

Oct Claes Björklund: Statistisk analys av LIDAR-kurvor med hjälp av en lokalt viktad minsta-kvadrat-metod.

Oct Fredrik Björnsson: Parameter estimation and moder order selection for Markov modulated Poisson processes.

Oct Anders Holtsberg: Målfaktorberäkning.

Oct Richard Wilson, Univ of Queensland: Random set models, excursion sets and image analysis.

Nov Niels Keiding, Copenhagen: Three current topics in survival analysis.

Nov Helena Olsson: A study of extreme significant wave height in the Norwegian Sea.

Nov Johan Erland: Rekonstruktion och parameterskattning i ARX-processer med Markovregim.

Nov Ludwig Arnold, Univ of Bremen: Stabilization by noise.

Nov Peter Olofsson, Chalmers: Branching processes with and without dependencies.

Nov Ola Hössjer: Hur man skattar kurvor och sannolikhetstätheter?

Nov Marie Olsson: Klusteranalys - några begrepp, förklaringar och exempel.

Dec Vladimir Egorov, Univ of St Petersburg: Limit theorems for order sum of random variables.

Dec Steve Maybank, Oxford Univ: Application of the cross ratio to model based vision.

Dec Michel Olagnon, Brest: Satellite measurements of sea-states and some related statistical problems.

1995

Jan Bengt Ringnér: Om finansmatematik

Feb Mattias Morén: Jämförelse av några algoritmer för ML-skattning av parametrarna i MMPP.

Mar Håvard Rue, Trondheim: Loss function modeling in Bayesian imaging.

Mar Agnar Höskuldsson, DTU, Lyngby: PLS regression and the H-principle of mathematical modelling.

Apr Dietrich von Rosen, Uppsala: PLS och linjära modeller.

May Sture Holm, Chalmers: Monoton regression och isoton regression.

May Nedjad Losic:A clinical trial with one interim analysis and a stopping rule for futility.

May Bengt Lindoff: RLS-algoritmen med glömskefaktor, hur uppför den sig? eller Problemet att beräkna vissa skumma moment.

Jun Niklas Karlsson: Target tracking in the bearing-time plot.

Jun Lars Holst, Stockholm: Om en tillväxtmodell.

Jun Harry Ascher, Potomac, Maryland: Misconceptions in reliability and their consequences.

Jun Eva Sjö: Konfidensområden för maxima och minima hos rekonstruerade ytor.

Jun Ann-Sofi Hörstedt: Några viktiga prognostiska faktorers tidsberoende effekt på överlevnaden vid bröstcancer.

Aug Otto Elmgart: Adaptive Kalman filtering.

Aug Martin Sköld: Kernel intensity estimation for marks and crossings of differentiable stochastic processes.

Sep Claudia Klüppelberg, Mainz: Analysis of time series with large fluctuations.

Sep Marita Olsson, Göteborg: EM-skattning i fastyps-modeller.

Sep Peter Taylor, Univ of Adelaide: Calculation of quasi-stationary distributions of quasi-birth-and-death processes.

Sep Tobias Rydén: On recursive estimation for hidden Markov models.

Oct Z. Michna: Limit theorems in collective risk theory.

Nov Mattias Jansson, Anders Karlsson: Flerstegsprediktion av elförbrukning med användning av väderfaktorer.

Nov Pär-Ola Bendahl: An overview of my thesis Estimation and prognostic value of S-phase fractions in cancer cell populations.

Dec Anders Holtsberg: Vad är Partiell Minsta Kvadrat och hur många parametrar är det egentligen i en anpassad modell?

Dec Kasra Afserinejad, Linköping: The present position and potential developments of statistical design and analysis of experiments.

Dec Hasan Özduman, Örjan Svensson: Wavelettransformering tillämpad på EKG-signaler och EKG-bilder.

1996

Jan Bengt Lindoff: Distribution properties of the recursive least squares algorithm with forgetting factor.

Jan Torgny Lindström: Robust local polynomial regression with application on the DOAS filtering process.

Jan Erik Sparre: Urspårningar, kollisioner och bränder på svenska järnvägar mellan åren 1985 och 1995.

Mar Timo Koski, KTH: Clustering of binary vectors by minimization of stochastic complexity.

Mar Anders Nordgaard, Linköping: Bootstrap och tidsserier.

Mar Isaac Meilijson, Tel Aviv: A hidden Markov model for neuronal firing while concentrating on a task.

Mar Henrik Amilon: Valuations of options using neural networks.

Mar Jesper Rydén: Detection of wheel flats using stochastic wave analysis.

May David Nott, Univ of Queensland: Image modelling with excursion sets.

May Paul Glasserman, Columbia Univ: A continuity correction for discrete barrier options.

May Rebecka Jörnsten: Subpixel resolution in PIXE-images. Implementation of a deblurring algorithm using simulated annealing.

May Krzysztof Debicki, Wroclaw: Gaussian fluid models.

Jun Tomas McKelvey, Linköping: From frequency data to state-space models using subspace methods.

Jun Ann-Cecilia Karlsson: Analysis of truncated data by means of a stochastic EM algorithm.

Aug Fred Godtliebsen, Tromsø: Statistical Methods Applied in Medical Imaging.

Aug Matt Wand, Univ of New South Wales: Nonparametric variance and autocovariance function estimation

Aug Michael Taksar, New York: Singular control of multidimensional stochastic processes.

Sep Roger Pettersson: Reflekterande Brownsk rörelse och dess approximationer.

Sep Georg Lindgren: Om fördelningen för våglängd och vågperiod på ett stokastiskt hav.

Sep Bengt Ringnér: Modellering av multipla tidsserier.

Sep Lars Arvastson: Statistiska modeller för användning inom kraftindustrin.

Oct Vladimir Kalashnikov, Moskva: Bounds of ruin probabilities in the presence of heavy-tailed claims.

Oct Dragi Anevski: Gränsfördelningar vid skattning av monotona och konvexa/konkava funktioner.

Nov Tatyana Turova, Moskva: Analysis of neural networks with inhibitory connections.

Nov Per Kragh Andersen, Copenhagen: A multi-state model for bleeding episodes and mortality in liver cirrhosis.

Nov Oleg Seleznjev, Moskva: Sampling designs for linear approximation of a random process.

Nov David Nott, Univ of Queensland: Multi-phase excursion set image models.

Dec Stefan Peterson, Astra Draco: Filtering and wavelet regression methods with application to exercise ECG.

Dec Eleonóra Szabó: Generalized rank correlation as a measure of variable importance in survival data sets with censoring and truncation.

Pedagogical seminars

1994

Dec Eva Åkesson, PUS: Pedagogiskt seminarium

1995

Feb Anders Holtsberg: Bootstrap, statistik och cyberrymden - en animerad datorföreställning utan virtuellt skyddsnät.

May Geoff Smith and Leigh Wood, Sydney: The influence of assessment strategies on student learning in university mathematics.

Sep Marita Bruzell-Nilsson and Leif Bryngfors: Supplemental instruction - Mentorprogrammet!

Nov Pär Johannesson: Konsten att använda och presentera sig på World Wide Web.

1996

Mar Olle Sjöström, Uppsala: Grundutbildning i statistik.

May Björn Johansson, Stockholm: Att undervisa med casemetoden.

Nov Kerstin Vännman, Luleå: Statistikundervisning med lärarsamverkan och dator i klassrummet.

Meetings and External Courses arranged by the Department

- 15:e Nordiska konferensen i Matematisk statistik. Lund, August 1994
- Bengt Ringnér: Graduate course in economics "Continuous time financial models" 1994.
- Applied probability workshop. Lund, June 1996

Conferences Attended

*** = contributed paper; ** = invited lecture; *** = forum lecture;**
% = organizer

Conference	Participants
European Academic Software Award Heidelberg, 1994	Lena Zetterqvist (deltog som jurymedlem)
15:e Nordiska konferensen i Matematisk statistik. Lund 1994	Lars Arvastson, Jan Holst Ulla Holst*, Ola Hössjer* Pär Johannesson,Jan Lanke% Georg Lindgren%, Bengt Lindoff, Anders Svensson Mikael Thuvesholmen* Lena Zetterqvist%
3rd World Conference of the Bernoulli Society Chapel Hill, North Carolina, 1994	Anna Lindgren, Georg Lindgren*, Roger Pettersson Mikael Thuvesholmen*
System Identification Applied to Building Performance Data. Ispra, Italy 1994	Lars Arvastson
International Perimetric Society, XIth meeting, Washington D.C. 1994	Jonny Olsson*
European Science Foundation Network on Highly structured stochastic systems, Cortona, Italy 1994	Jonny Olsson*
Vinterkonferens: Bootstrap in Theory and Practice Hemavan, 1995	Pär Johannesson Anders Holtsberg* Anders Rosenqvist
The 2nd International Symposium on Automation of District Heating Systems. Helsingfors, Finland 1995	Lars Arvastson* Hongping Zhao*

The 2nd International Symposium on Heating, Ventilation and Air Conditioning. Beijing, China 1995.	Lars Arvastson, Jan Holst* Hongping Zhao*
21st European Meeting of Statisticians Århus, Danmark 1995	Ulla Holst, Ola Hössjer* Pär Johannesson, Anna Lindgren, Georg Lindgren Tobias Rydén* Lena Zetterqvist
First International Conference on Matrix-Analytic Methods in Stochastic Models, Flint, Michigan, USA 1995	Søren Asmussen**
Stochastic Networks: rare events and stability, Columbia Univ, New York, 1995	Søren Asmussen**
SPRUCE III Merida, Yucatan, Mexico 1995	Ulla Holst*
AMS Stochastic Analysis, Los Angeles, 1995	Roger Pettersson*
AMS Stochastic Differential Euqations, Orlando, 1995	Roger Pettersson*
Svenska Mekanikdagar Lund, 1995	Pär Johannesson
Stochastic Dynamical Systems: Theory and Applications First Ukrainian-Scandinavian Conf. Uzhgorod, Ukraina, 1995	Pär Johannesson* Martin Sköld*
5th IFAC Symposium on Adaptive Systems in Control and Signal Processing Budapest, Hungary, 1995	Bengt Lindoff* Jan Holst*

Workshop on image analysis Danish Informatics Network in the Agricultural Science Copenhagen 1995	Jonny Olsson**
International Workshop on the Mathematical Theory of Ruin Probabilities, Bankya, Bulgaria 1996.	Søren Asmussen** %
Vinterkonferens: Regression and Regression Graphics Hemavan, 1996	Pär Johannesson, Igor Rychlik, Georg Lindgren Rebecka Jörnsten
Highly Structured Stochastic Systems Rebild, Danmark 1996.	Søren Asmussen**
INFORS 13, Vancouver, Canada, 1996	Søren Asmussen**
Stable processes and other heavy-tailed phenomena, Wroclaw, Poland 1996.	Søren Asmussen**
The International Symposium on the Mathematical Theory of Networks and Systems, St Louis, 1996	Tobias Rydén*
Seminar on Stochastic Processes Durham, USA, 1996	Martin Sköld*
Symposium on Estimating Functions Athens, USA, 1996	Martin Sköld
Workshop in Nonparametrical Statistival Methods: The road ahead, Canberra, 1996	Mikael Thuvesholmen
Sydney International Statistical Congress, Sydney, 1996	Mikael Thuvesholmen*

4th World Congress of the Bernoulli Society, Wien 1996	Dragi Anevski, Ulla Holst Pär Johannesson, Georg Lindgren, Igor Rychlik** Jesper Rydén, Tobias Rydén, Martin Sköld* Lena Zetterqvist
Workshop on Asymptotic Methods in Stochastic Dynamics and Nonparametric Statistics Berlin, 1996	Pär Johannesson
International Workshop on Statistical and Computational issues for stochastic processes, Cremona Italy, 1996	Martin Sköld
Idédagar för lärare vid Lunds Universitet, Lund, 1996	Lena Zetterqvist* Jan Holst
Int Soc Clin Biostat Budapest 1996	Jan Lanke*
Workshop on Stochastic mechanics in Structural and Mechanical Engineering, Lisbon, 1996	Pär Johannesson* Georg Lindgren* Igor Rychlik*, Jesper Rydén*
13th World Congress of IFAC San Francisco, 1996	Jan Holst*, Niklas Karlsson* Anders Svensson
Deutsche ASTIN Meeting Köln, 1996.	Søren Asmussen**
SAE International Fall Fuels and Lubricants Meeting and Exposition San Antonio, Texas, 1996	Bengt Lindoff Magnus Wiktorsson*
Workshop on Recent Developments in Time Series and Chaos Canberra, Australia, 1996.	Attila Frigyesi*

Kliemann, Dynamical Systems Ames, 1996	Roger Pettersson**
ECMI Mathematics in Industry Lyngby 1996	Jan Holst*% Roger Pettersson*
ASCE Probabilistic mechanics structural reliability, Worcester 1996	Georg Lindgren* Roger Pettersson*
Conference on Methodological Issues in Official Statistics, Stockholm, 1996	Georg Lindgren* Lena Zetterqvist**

Pedagogical courses

Pedagogisk inspirationskurs, 1994/95 LTH	Bengt Ringnér Lena Zetterqvist
PBI - ett startpaket, 1996	Halfdan Grage, Björn Holmquist, Bengt Ringnér Lena Zetterqvist
Kurs i utvecklingssamtal	Bengt Ringnér

Visitors

1994

Tailen Hsing	Texas A&M Univ	22 Jan–2 Feb
Sven-Erick Alm	KTH	8 Feb
Rainer Schwabe	Freie Univ. Berlin	4 March
Y.K. Belyaev	Umeå	8 March
V.I. Piterbarg	Moskva	1–31 March
Henrik Nyberg	Ericsson Telecom	22 March
Jeff Steif	Chalmers	5 April
Ingemar Kaj	Uppsala	11–12 April
Taivo Arak	Göteborg	19 April
Christophe Croux	Univ of Antwerp	29 April
R.J. Bhansali	Univ of Liverpool	6–7 June
Richard Wilson	Univ of Queensland	12 July–22 Nov
David Nott	Univ of Queensland	12 July–3 Sep
Peter Diggle	Lancaster	14–21 Aug
Jotun Hein	Aarhus	14–21 Aug
Tönu Möls	Tartu	14–21 Aug
Howell Tong	Canterbury	14–21 Aug
Alf Isaksson	KTH	22–23 Aug
Tomas Björk	KTH	1 Sep
Jacek Leskow	Univ of California	3–23 Sep
Thore Egeland	Oslo	23–24 Sep
Vladimir Egorov	St Petersburg	16 Oct–22 Dec
Niels Keiding	Köpenhamn	1–4 Nov
Ludwig Arnold	Univ of Bremen	9–11 Nov
Martin Jacobsen	Köpenhamn	11 Nov
Steve Maybank	Oxford	27 Nov–11 Dec
Michel Olagnon	Ifremer, Brest	10–13 Dec

1995

Håvard Rue	Trondheim	2–5 March
Agnar Höskuldsson	DTU, Lyngby	16 March
Dietrich von Rosen	Uppsala	27 April
Sture Holm	Göteborg	4 May
Lars Holst	Stockholm	8 June
Harry Ascher	Maryland	9 June
Hermann Thorisson	Reykjavik	16–18 Aug
R.Y. Rubinstein	Haifa	17 Aug–17 Sep
Claudia Klüppelberg	Mainz	4–10 Sep

Marita Olsson	Göteborg	15 Sep
Peter Taylor	Univ of Adelaide	13–19 Sep
Zbigniew Michna	Wroclaw	10 Oct–10 Nov
Kasra Afserinejad	Linköping	15 Dec

1996

Olle Sjöström	Uppsala	1 March
Timo Koski	KTH	8 March
Anders Nordgaard	Linköping	15 March
Isaac Meilijson	Tel Aviv	25–31 March
David Nott	Univ of Queensland	15 April–1 June
Paul Glasserman	Columbia Univ	10 May
Björn Johansson	Stockholm	24 May
Krsysztof Debicki	Wroclaw	6 May–3 June
Tomas McKelvey	Linköping	10 June
Andrew Logothetis	Melbourne	11 June
Alf Isaksson	KTH	11 June
Claudia Klüppelberg	Mainz	27 June–10 July
Martin Jacobsen	Copenhagen	28 June
Tatyana Turova	Moskva	29 May–31 July
Torgny Lindvall	Göteborg	28 June
Mogens Bladt	Mexico C	26–28 June
Tomasz Rolski	Wroclaw	26 June–1 July
Karl Sigman	New York	28 June
Jean Opsomer	Cornell Univ	30 June–7 July
David Ruppert	Cornell Univ	30 June–7 July
Fred Godtliebsen	Tromsø	27 July–9 Aug
Matt Wand	Univ of New South Wales	1 July–10 Aug
Michael Taksar	New York	14–21 Aug
Vladimir Kalashnikov	Moskva	29 Sep–27 Oct
Guy Nason	Bristol	17–20 Oct
Per Kragh Andersen	Copenhagen	8 Nov
Oleg Seleznjev	Moskva	1–30 Nov
Kerstin Vännman	Luleå	22 Nov

External Cooperation Partners

Cooperation partners at Lund University

- Center for Environmental Measurement Technology, on environmental statistics ;
- Dept of Animal Ecology, on orientation data;
- Dept of Atomic Physics, on evaluation of LIDAR measurements;
- Dept of Chardiothoracic Surgery, on sinusnode disease;
- Dept of Chemical Technology, on chemometrics;
- Dept of Clinical Chemistry, on data analysis
- Dept of Clinical Physiology, on ECG estimation;
- Dept of Hand Surgery, Malmö General Hospital, on nerve regeneration;
- Dept of Heart surgery, on survival for pace-maker patients;
- Dept of Heat and Power Engineering, on district heating and physical modelling;
- Dept of Industrial Engineering on, HMI in district heating operation;
- Dept of Medical Microbiology, on malignant lymphomes;
- Dept of Neurology, on chemotherapy;
- Dept of Occupational and Environmental Medicin, on epidemiological studies;
- Dept of Oncology, on DNA-analysis, flow cytometry, chemotherapy, radiotherapy and cancer diagnosis;
- Dept of Ophthalmology, Malmö General Hospital, on perimetry and visual field modelling;
- Dept of Oto-Rhino-Laryngology, on optokinetic nystagmus analysis;
- Dept of Pediatrics, on measuring sleep latency;
- Dept of Physical Geography, on orientation processes;

- Dept of Quarternary Geology, on orientation processes;
- Dept of Radiophysics, on tomography;
- Dept of Statistics, on biostatistics;
- Dept of Surgery, Malmö General Hospital, on cancer diagnosis;
- Dept of Telecommunications Theory, on ECG estimation;
- Dept of Urology, on bladder cancer and prostatic cancer;
- Dept of Zoophysiology, on nerve regeneration;
- Regional Tumour Registry, on cancer epidemiology and clinical studies;

Cooperation partners at other universities

- Aalborg University, Denmark, on optimal operation of wind/diesel energy production system;
- Australian Graduate School of Management University of New South Wales, Sydney, Australia, on nonparametric statistics;
- Center for Applied Stochastic Research, Florida Atlantic University, Boca Raton, on stochastic mechanics and fatigue;
- Department of Applied Statistics, University of Minnesota, on robust statistics;
- Dept of Engineering, University of Iceland, on prediction of power load, district heating and well modelling;
- Dept of Electrical Engineering, University of Melbourne, Australia, on hidden Markov models and on submarine navigation,
- Dept of Electrical and Computer Engineering, University of Newcastle, Australia, on modelling and fault detection;
- Dept of Mathematical Statistics, University of Copenhagen, on survival analysis;
- Dept of Mathematics and Computer Science, University of Antwerp, on robust statistics;
- Dept of Statistics, University of North Carolina, Chapel Hill, on theory of stochastic processes;

- Dept of Statistics, University of California, Santa Barbara, USA, on predictive likelihood;
- Dept of Statistics, University of California at Berkeley, on inference in hidden Markov models;
- Dept of Statistics, University of Kentucky, on robust statistics;
- Dept of Statistics, The Open University, on nonparametric methods;
- Dept of Statistics, University of Glasgow, on inference in hidden Markov models;
- Dept of Structural Engineering, Cornell University, Ithaca, on stochastic mechanics;
- Division of Nephrology and Immunology, University of Alberta Hospital, on dialysis modelling;
- Erasmus University, Amsterdam, on statistics for extremes;
- Faculty of Industrial Engineering and Management, Israel Institute of Technology, Haifa, Israel, on theory of stochastic processes;
- Hugo Steinhaus Center, Tech. University of Wroclaw, Poland on stochastic
  processes and extremes
- Institute of Mathematical Modelling, Technical University of Denmark, on prediction and alarm, modelling and prediction of thermal characteristics of buildings, district heating, modelling of nonlinear and timevarying systems;
- Institute of Computer Science, Polish Academy of Sciences, Warsaw, on long-range dependence;
- Institute of Mathematical and Physical Sciences, University of Tromsø, on nonparametric methods;
- Kretselektronikgruppen, Teknikum, Uppsala University, on robust statistics and nonparametric methods in signal
- Laboratory of Probability, Moscow State University, on theory of stochastic processes;
- Mathematical Research Institute, University of Utrecht;

- School of Operations Research and Industrial Engineering, Cornell University, Ithaca, on recursive estimation and stochastic approximation, nonparametric statistics;
- Servolaboratory, Technical University of Denmark, Lyngby, on modelling of nonlinear systems and path prediction for ships;
- Statistical Laboratory, Iowa State University, on nonparametric methods;
- Swedish Institute of Applied Mathematics (ITM), on load- and fatigue analysis;
- University of Wroclaw, Poland, on the supremum of Gaussian processes;
- Zoologisches Institut, Johann Wolfgang Goethe Universität, Frankfurt am Main, on orientation data;

Cooperation partners in government and industry

- ABB Network Control AB, Västerås, on district heating and prediction of energy loads;
- ABB Atom, Västerås, on nuclear safety;
- Barsebäck Kraft AB, on nuclear safety;
- Ellips AB, Malmö, on prediction of power load;
- Ericsson, Lund, on denoising;
- FMV, Stockholm, on positioning;
- Grundfos AS, Bjerringbro, Danmark, on energy modelling;
- Humphrey Instruments, California, on perimetry and visual field modelling;
- IVL, Göteborg, on analysis of air quality data;
- Kockums AB, Malmö, on positioning;
- Malmö Värme AB, Malmö, on district heating;
- Maridan AS, Horsholm, Danmark, on navigation;
- Ophthalmic Imaging Systems, California, on retinal modelling;

- Perstorp AB, Perstorp, on quality approvement;
- Saab Dynamics, Göteborg, on positioning,
- SCANIA, on load- and fatigue analysis;
- Swedish Ordnance, Eskilstuna, on identification;
- Sydgas AB, Malmö, on prediction of gas consumption;
- Sydkraft AB, Malmö, on prediction of power load and nuclear power safety;
- Televerket, on the use of multimedia in education;
- Tetra-Laval, Lund, on quality approvement;
- The Swedish National Rail Administration, on load- and fatigue analysis;
- Volvo Cars, on load- and fatigue analysis;
- Volvo Trucks, on load- and fatigue analysis;