EURANDOM

Annual Report 2003

EURANDOM is a European research institute for Statistics, Probability, Stochastic Operations Research and their Applications, founded June 30, 1997.

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Mission statement

The mission of EURANDOM is to foster research in the stochastic sciences and their applications. It achieves this mission by helping talented young researchers find their way to tenured positions in academia and industry, by carrying out and facilitating research through postdoctoral and graduate appointments, visitor exchange and workshops, and by taking initiatives for collaborative research at the European level.

1. INTRODUCTION

The year 2003, like previous years, has been very busy for EURANDOM. We said goodbye to 10 postdocs, welcomed 13 new postdocs and PhDs, organised 10 workshops with over 400 participants and participated in another 3 workshops, hosted 43 visitors for periods of 1 week up to 1 month, ran 93 seminars, and published 45 scientific reports. These figures show that EURANDOM continues to be a place of intense scientific activity.

EURANDOM is particularly proud of its junior staff. About 80% leaves EURANDOM for tenured positions in academia and industry. This is evidence of the fact that the stochastic sciences are flourishing and at the same time shows that EURANDOM manages to play an important role on the international mathematical stage by helping young top talent on its way to a successful international career. Since the start of EURANDOM, 14 junior researchers found a position in The Netherlands. One third of our junior staff are women.

The year 2003 has also been one of reflection and of strategic planning. Our research, currently carried out in five parallel research programmes, will be re-aligned into three larger programmes with three research themes each, operational by Summer 2004:

Random Spatial Structures:
* Critical Phenomena
* Disordered Systems
* Combinatorial Probability

Queueing and Performance Analysis
* Performance Analysis of Production Systems
* Performance Analysis of Communication Systems
* Queueing Theory

Statistical Information and Modelling:
* Statistical Learning
* Biomedical and Biomolecular Statistics
* Industrial Statistics

In addition, two current projects will be continued:

* Re-insurance
* Battery Management and Modelling

The re-alignment has been the fruit of extensive discussions with the board and with the scientific council of EURANDOM, as well as with the scientific advisors of the various programmes. It will allow us to focus more on the areas where EURANDOM is strong, thereby further increasing our impact and visibility.

At the end of 2002, NWO (Netherlands Organisation for Scientific Research) and TU/e (Technical University Eindhoven) decided to continue funding EURANDOM up to 2007. Together they provide 60% of the total running cost. We are grateful to both institutions for their continued support. Additional funding comes from industry (5 researchers), European Union (2 researchers), NWO (5 researchers), and various other sources.

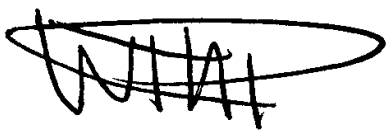
During the months of September through November, Professor Gordon Slade (University of British Columbia, Vancouver, Canada) stayed at EURANDOM as Stieltjes Professor and gave a series of lectures on the lace expansion and its application to critical phenomena. We are grateful to the Thomas Stieltjes Institute (a research school through which several Dutch mathematics departments collaborate) to make his visit possible. Dr. Nelly Litvak, former PhD of EURANDOM and currently assistant professor at Twente University, was awarded the Stieltjes Prize for best PhD-work in the research school in 2002.

On January 1, 2004, the chair of the board, Professor P.J. Zandbergen (emeritus professor of mathematics at Twente University and former president of the Dutch Royal Academy) stepped down. We thank him for his steady guidance in the past five years, and for his creative vision to help position EURANDOM both nationally and internationally. We are pleased that Dr. J.M.M. Ritzen (chair of the board of Maastricht University and former Dutch Minister of Education) has agreed to be the new chair. An institute like EURANDOM is constantly evolving, facing new challenges and opportunities. It is therefore of the greatest importance to have an experienced board that is both critical of the activities and receptive to the needs of the institute.

Our scientific colleagues from around the world like to come to EURANDOM, where they find an intense and stimulating environment for doing research and for exchanging ideas with colleagues of different ages. Our managing staff works hard around the clock to make their stay as pleasant as possible. They also provide the safe environment in which our postdocs and PhDs can work and flourish.

I want to thank everyone involved in making EURANDOM into the wonderful place it is today.

Frank den Hollander
scientific director



Eindhoven, April 2004

2. THE INSTITUTE

2.1. Management

EURANDOM is a foundation with the mission to advance scientific research in statistics, probability and stochastic operations research and its applications in Europe. To realise this goal the foundation has established a research institute with the same name.

The Board of the foundation consists of:

Professor P.J. Zandbergen (chair); until 31-12-2003
Professor P.C. Baayen (secretary / treasurer)
Professor R.A. van Santen (member).

Directors:

Professor W.Th.F. den Hollander, scientific director (TU/e & EURANDOM)
Professor H.P. Wynn, scientific co-director (LSE & EURANDOM)
Ir. W.J.M. Senden, managing director.

2.2. Scientific Council

EURANDOM has a Scientific Council, which advises the Board and the directors on the scientific programme and on strategic research issues. The following scientists serve / served as member of the Scientific Council:

Professor P.J. Bickel (chairman), University of California, Berkeley, USA
Professor F. Baccelli, École Normale Supérieure, Paris, France
Professor O.E. Barndorff-Nielsen, University of Aarhus, Denmark
Professor E. Bolthausen, University of Zürich, Switzerland
Professor R.D. Gill, University of Utrecht, The Netherlands
Professor F. Götze, University of Bielefeld, Germany
Professor M.S. Keane, Wesleyan University, Middletown, Connecticut, USA & Korteweg de Vries Instituut, University of Amsterdam & EURANDOM, Eindhoven, The Netherlands
Professor F.P. Kelly, University of Cambridge, UK
Professor C. Klüppelberg, Technical University München, Germany
Professor P. Massart, Université Paris Sud XI, Orsay, France.

New members as of July 1, 2003:
Professor S. Asmussen, Department of Mathematical Statistics, Lund University, Sweden
Professor F. Delbaen, Swiss Federal Institute of Technology, Zürich, Switzerland
Professor A. Greven, Mathematisches Institut, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
Professor P. Hall, Centre for Mathematics and its Applications, Australian National University, Canberra, Australia.

Members who stepped down on June 30, 2003:
Professor P.A.L. Embrechts, Swiss Federal Institute of Technology, Zürich, Switzerland
Professor P. Jagers, Chalmers University of Technology, Göteborg, Sweden
Professor B.W. Silverman, University of Bristol, UK
Professor J.L. Teugels, Catholic University of Leuven, Belgium.

The Scientific Council of EURANDOM met on June 6 and 7, 2003. Together with the Board they discussed the re-alignment, the profile of the proposed future programmes, as well as future strategies. They met and discussed with a group of postdocs who just arrived and with a group of postdocs who had been at EURANDOM for one year or more. Both groups impressed the members of the scientific council. Other topics of discussion were: funding and the EURANDOM chair.

2.3. Programme co-ordinators and steering committees

The research of EURANDOM consisted of five programmes: Interacting Stochastic Systems (ISS), Stochastics of Extremes and Risk Analysis, (SERA), Statistical Information and Modelling (SIM) -a combination of the former CSM and AS group-, Stochastic Networks (SN), and Computational Molecular Biology (CMB).

Each programme has co-ordinators, senior scientists who supervise the programme and provide guidance to the research of the postdocs and PhD students. The activities in each programme are overseen by an international steering committee. In addition, programmes have a senior advisor.

Interacting Stochastic Systems (ISS)

- Co-ordinator:

Professor W.Th.F. den Hollander (Eindhoven University of Technology & EURANDOM, The Netherlands)

- Advisor:

Professor M.S. Keane (Wesleyan University, Middletown, Connecticut, USA & Korteweg de Vries Instituut, University of Amsterdam & EURANDOM, Eindhoven, The Netherlands), until November 2003.

- Steering Committee:

Professor E. Bolthausen (University of Zürich, Switzerland)
Professor A. Greven (Mathematisches Institut, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany)
Professor G.R. Grimmett (University of Cambridge, UK)
Professor J.F. Le Gall (École Normale Supérieure, Paris, France)
Professor C. Maes (Catholic University Leuven, Belgium)
Professor E. Olivieri (University of Roma Tor Vergata, Italy)
Professor J.E. Steif (Chalmers University, Göteborg, Sweden)

Stochastics of Extremes and Risk Analysis (SERA)

- Co-ordinators:

Professor J.H.J. Einmahl (Tilburg University & EURANDOM, The Netherlands)
Professor C.G. de Vries (Erasmus University Rotterdam & EURANDOM, The Netherlands)

- Advisor for the re-insurance project:

Professor J.L. Teugels (Catholic University Leuven, Belgium)

- Steering Committee:

Professor O.E. Barndorff-Nielsen (University of Aarhus, Denmark)
Professor Dr. R. Davis (Colorado State University, Fort Collins, USA)
Professor F. Drost (University of Tilburg, The Netherlands)
Professor P.A.L. Embrechts (Swiss Federal Institute of Technology, Zürich, Switzerland)
Professor L.F.M. de Haan (Erasmus University Rotterdam, The Netherlands)
Professor J. Hüsler (Universität Bern, Switzerland)
Professor C. Klüppelberg (Technische Universität München, Germany)
Professor F. Longin (Cergy Campus, ESSEC Faculty, France).
Professor T. Mikosch (Copenhagen University, Denmark)
Professor J.M. Schumacher (Catholic University of Tilburg, The Netherlands)
Dr. P.J.C. Spreij (University of Amsterdam, The Netherlands)
Professor J.L. Teugels (Catholic University of Leuven, Belgium)

Statistical Information and Modelling (SIM)

- Co-ordinators:

Dr. A. Di Bucchianico (Eindhoven University of Technology & EURANDOM, The Netherlands)
Professor R.D. Gill (University of Utrecht & EURANDOM, The Netherlands)
Professor A.W. van der Vaart (Vrije Universiteit Amsterdam & EURANDOM, The Netherlands), until July 2003
Professor H.P. Wynn (London School of Economics, UK & EURANDOM, The Netherlands)

- Advisor for the battery project:

Dr. W. Rey (previously Philips Research Laboratories)

- Steering Committee:

Professor W. Albers (University of Twente, The Netherlands)
Professor T. Bedford (University of Strathclyde, UK)
Professor P.J. Bickel (University of California, Berkeley, USA)
Professor N. Fischer (ValueMetrics, McMahons Point NSW and University of Sidney, Australia)
Professor U. Gather (University of Dortmund, Germany)
Professor S.A. van de Geer (University of Leiden, The Netherlands)
Professor F. Götze (University of Bielefeld, Germany)
Professor P. Groeneboom (Delft University of Technology, The Netherlands)
Professor C.A.J. Klaassen (University of Amsterdam, The Netherlands)
Professor J. Ledolter (Vienna University of Economics and Business Administration, Austria)
Dr. M.-C. van Lieshout (Centre for Mathematics and Computer Science, Amsterdam, The Netherlands)

Professor V. Nair (University of Michigan, USA)
Professor D. Picard (Université Pierre et Marie Curie, Paris, France)
Dr. J. Praagman (Centre for Quantitative Methods, Eindhoven, The Netherlands)

Stochastic Networks (SN)

- Co-ordinator:

Professor O.J. Boxma (Eindhoven University of Technology & EURANDOM, The Netherlands)

- Advisor:

Professor J. Wessels (Eindhoven University of Technology & EURANDOM, The Netherlands)

- Steering Committee:

Professor F. Baccelli (École Normale Supérieure, Paris, France)
Professor S.G. Foss (Heriot Watt University, Edinburgh, UK)
Professor A. Hordijk (University of Leiden, The Netherlands)
Professor F.P. Kelly (Cambridge University, UK; chairman)
Professor V. Schmidt (University of Ulm, Germany)
Professor J. Wessels (Eindhoven University of Technology & EURANDOM, The Netherlands)

Computational Molecular Biology

- Co-ordinators:

Dr. M.C.M. de Gunst (Vrije Universiteit of Amsterdam, The Netherlands)
Professor C.A.J. Klaassen (University of Amsterdam, The Netherlands)

- Steering Committee:

A panel of experts in the field has been acting as steering committee:
Professor A. Apostolico (Università di Padova, Italy)
Professor A. Barbour (University of Zürich, Switzerland)
Professor P.J. Bickel (University of California, Berkeley, USA)
Professor S. Brunak (Technical University of Denmark, Denmark)
Professor P. Donelly (University of Oxford, UK)
Professor R. Durbin (Informatics Division at the Sanger Institute, Hinxton, Cambridge, UK)
Professor A. von Häseler (Universität Düsseldorf, Germany)
Professor O. Nerman (Chalmers University of Technology, Göteborg, Sweden)
Professor D. Siegmund (Stanford University, USA)
Professor S. Tavare (University of South Carolina, USA)
Professor E. de Turckheim (Institut National de la Recherche Agronomique, Jouy en Josas, France)
Professor M. Vingron (Max-Planck-Institut für molekulare Genetik, Berlin, Germany)
Professor M. Waterman (University of South Carolina, USA)

2.4. Scientific staff

Most postdoctoral fellows have an appointment for 2 years, Ph.D. students for 3 - 4 years. Research fellows typically have part-time appointments.

8 post-docs and 3 PhD students were financed by external funds:

- 1 post-doc was working on a Marie Curie Fellowship until the end of November and in December he continued with an NSF grant;
- 1 post-doc was working on a FOM contract (from November 2002 until October 2003 at the University of Groningen, since November 2003 at EURANDOM);
- 1 post-doc was appointed by the Mathematics Department of the TU/e (since February 2002);
- 1 post-doc was appointed half-time by the Department of Technology Management (since December 2003);
- 2 post-docs were appointed on an NWO contract (one post-doc finished in September 2003, another post-doc started in October 2003);
- 1 Ph.D. student in a contract with Philips;
- 1 post-doc and 1 Ph.D. student in an EET contract, with Philips, Shell and the Department of Chemical Engineering at TU/e;
- 1 post-doc and 1 Ph.D. student in an EET contract with Flextronics, the Department of Technology Management and the Department of Mathematics and Computer Science, at TU/e.

On December 31, 2003, 25 researchers (part-time research fellows, postdocs and Ph.D. students) were working at EURANDOM.

Interacting Stochastic Systems

Post-docs:

Dr. F. Camia (April 2003)
Dr. A. Le Ny (August 2001 - August 2003)
Dr. B. Lemmens (September 2001 - September 2003) - NWO grant
Dr. K. Netočný (November 2003) - FOM grant
Dr. A. Sakai (January 2003)
Dr. F. Toninelli (February 2003)
Dr. P. van der Wal (August 2002)
Dr. D. Znamenski (October 2003) – partly in SN, NWO grant

Research Fellows:

Dr. F. Redig (January 2001) - 0,4 fte
Dr. R. van der Hofstad (January 2002) - 0,4 fte

Stochastics of Extremes and Risk Analysis

Post-docs:

Dr. S. Ladoucette (March 2003)
Dr. T. Lin (January 2002 - November 2003)
Dr. J.C. Rodriguez (December 2001 - December 2003)
M. Sarma (May 2003)

Statistical Information and Modelling (a combination of the former CSM and AS)

Post-docs:

Dr. L. Artiles Martinez (January 2002- July 2002 and since May 2003)
Dr. D. Danilov (October 2002), industry contract
Dr. F. Enikeeva (May 2003)
Dr. M. Guta (January 2002)
Dr. A. Koloidenko (October 2002)
Dr. V. Kulikov (May 2003), partly on industry contract
Dr. J. Lember (February 2001 - August 2003)
Dr. N. Mushkudiani (September 2001- September 2003), industry contract
Dr. W. Bergsma (September 2003), mainly on industry contract

Ph.D.-students:

T. Figarella (June 2003), industry contract
I. Snihir (September 2003), industry contract
P. van de Ven (February 2003)

Research Fellows:

P. Grünwald (January 2002) - 0.2 fte

Stochastic Networks

Post-docs:

Dr. H.C. Gromoll (November 2001), Marie Curie Fellowship, NSF grant
Dr. K. Maulik (September 2002)
Dr. Z. Palmowski (September 2000 - March 2003)
Dr. A. Sleptchenko (December 2002)
Dr. D. Znamenski (October 2003) – partly in ISS, NWO grant

Ph.D.-students:

J. van Leeuwaarden (September 2002), industry contract
M. Vlasiou (September 2002)

Computational Molecular Biology

Post-docs:

Dr. B. Basrak (July 2000 - July 2003)
Dr. S. Hernández Alonso (September 2000 - September 2003)
Dr. P. Lindsey (September 2001 - September 2003)
Dr. N. Armstrong (February 2002)

Research Fellows:

P. Lindsey (September 2003) - 0,2 fte

For details on their work, see section 3, and for their publications, see section 5.

2.5. Administrative staff

Mrs. M.E.J.G.H. Brangers-Lempens, management assistant (April 2001) - 0,9 fte
Drs. C.M.M. Cantrijn, policy officer (October 1997) - 0,8 fte
Mrs. L. Coolen-van Will, workshops officer (June 1998) - 0.7 fte
Drs. J.J. Kamperman, personnel officer (October 1998) - 0,8 fte
Mrs. P.M. Koorn-van Hulten, administrative officer (January 2003) - 0,4 fte

From Eindhoven University of Technology assistance was received in the following areas:

- workshops and conferences (congress office)
- arranging for accommodation, support and advice on matters like first registration with the foreign police and the municipal office (back-office personnel department)
- scientific and administrative staff is appointed by the university and is detached at EURANDOM
- library services (especially from the Department of Mathematics and Computer Science)
- installation and management of the EURANDOM computing facilities (ICT services)
- financial administration (administrative office)

A total of 31 persons were employed by EURANDOM on December 31, 2003, including the scientific and managing directors. In addition, 14 senior scientists were associated with EURANDOM as co-director (1) or co-ordinator / scientific advisor (13).

3. RESEARCH PROGRAMMES

The research description below is listed under the name of the principal investigator, but collaboration is the normal habit at EURANDOM.

For details concerning the scientific results obtained, we refer to the EURANDOM Report series and to the published reports (see section 5).

3.1. Interacting Stochastic Systems

Co-ordinator for this programme is professor W.Th.F. den Hollander (EURANDOM and Eindhoven University of Technology), advisor is professor M.S. Keane (Wesleyan University, University of Amsterdam and EURANDOM), until November 2003.

ISS focuses on systems consisting of a large number of interacting random components, possibly with disorder. It aims to capture their large space-time behaviour through a combination of probabilistic, combinatorial and ergodic techniques, with special emphasis on critical phenomena and universality.

3.1.1. Summary of the research by members of the ISS-group

Together with C. Newman (Courant Institute, New York), **Dr. Federico Camia** has worked on a construction of the full scaling limit of two-dimensional critical percolation, using the Stochastic Loewner Evolution. In joint work with C. Newman and V. Sidoravicius (IMPA, Rio de Janeiro), he has given explicit examples of the universal behaviour of critical exponents and scaling limits in percolation. He has also worked on the issue of universality in the context of bootstrap percolation.

Dr. Remco van der Hofstad has been working on several problems for high-dimensional percolation and random graphs, proving mean-field behaviour. Examples are random subgraphs of high-dimensional tori, oriented percolation and the contact process above four spatial dimensions. Another line of research involves random graph models for the Internet.

Professor Frank den Hollander worked with M. van den Berg (Bristol) and E. Bolthausen (Zürich) on survival asymptotics for Brownian motion in a Poisson random field of randomly shaped traps, with J. Gärtner (Berlin) on intermittency for the parabolic Anderson model in a catalytic random medium, with A. Bovier (Berlin) and F. Nardi (Rome) on nucleation characteristics for Kawasaki dynamics at low temperature, with R. van der Hofstad (TU/e, EURANDOM) and G. Slade (Vancouver) on survival asymptotics for oriented percolation above the upper critical dimension, and with P. van der Wal (EURANDOM) on continuity of conditional probabilities for random walk in random scenery.

Dr. Bas Lemmens worked with dr. O.W. van Gaans (TU-Delft) on the dynamics of nonexpansive maps and the geometry of the ranges of norm one projections. They have been extending their results in EURANDOM Report 2002-038 to more general Banach spaces. He also worked with prof. M. Scheutzow from TU-Berlin on a conjecture of Nussbaum concerning the periods of periodic points of sup-norm nonexpansive maps. They have been able to significantly improve the upper bound for the periods of these periodic points. His contract ended in September. He then moved to Berlin, where he now is working with professor Scheutzow on a NWO visitor fellowship.

Dr. Arnaud Le Ny studied interacting particle systems coming from statistical mechanics. His work includes Gibbs and Non-Gibbs random fields, disordered systems, and random walks in random environments. He also studied extremal and large deviation properties of such systems. His contract ended in August. He then moved to France, where he now fulfils the position of Maître de Conférence at the Université de Paris-Sud XI.

Dr. Karel Netočný started at EURANDOM in December 2003, after finishing the first part of his post-doc programme in Groningen. His research there mainly concerned the chaotic size-dependence of lattice models under random boundary conditions. This work has been carried out jointly with A.C.D. van Enter and H.G. Schaap, and a publication is being prepared.

Together with Remco van der Hofstad (TU/e and EURANDOM), **Dr. Akira Sakai** has proved Gaussian scaling for the critical contact process above four spatial dimensions, when the interaction range is finite but sufficiently spread out. This result implies a sufficient condition for various critical exponents to take on their mean-field values, i.e., the values for branching random walk. Sakai has proved that, under the same condition, the critical exponent for the survival probability also takes on its mean-field value. (A similar result for percolation has also been obtained in the same way.) The proof of the Gaussian scaling is based on the lace expansion, which has been obtained in the literature for self-avoiding walk and oriented and unoriented percolation, where the lace expansion coefficients are model-dependent. Computing the expansion coefficients, van der Hofstad and Sakai have derived, in a unified fashion, asymptotic expressions of the critical exponents for the spread-out version of these models above their respective upper critical dimensions.

Together with F. Guerra (Rome), **Dr. Fabio Toninelli** has studied the high temperature region of some diluted meanfield spin glass models and obtained some new results. Together with S. Franz and M. Leone (ICTP, Trieste), he has extended some important inequalities, discovered by Guerra for the Sherrington-Kirkpatrick model, to a wide class of diluted models. His second main research subject has been the relation between finite range and mean-field spin glasses. With S. Franz he has proved the convergence of the free energy of the former to that of the latter in the Kac limit where the interaction range diverges.

In the beginning of 2003, **Dr. Peter van der Wal** worked on perturbations of covering algorithms, which led to a draft version of a paper. At the same time, he started a project with Frank den Hollander on weak Bernoullicity of random walk in random scenery. In the fall, he submitted a paper on this subject to the Annals of Probability. After that, he revised a paper on fractal percolation, which is now available as EURANDOM report 2004-004, and he started a new project with Frank den Hollander and Jeffrey Steif on continuity of conditional probabilities for random walk in random scenery.

3.1.2. Activities, collaboration and contacts

Seminars:
23; see 6.2.
Some of the seminars consisted of a series of lectures, like the course in October (8, 15, 22, and 29) and November (5 and 12) on "The Lace Expansion and its Applications" by professor Gordon Slade (Vancouver), Stieltjes professor.

Workshops:
* June 23-27, 2003

Dutch-Hungarian Workshop "Randomness in Space and Time" (held in Budapest).
Participants: 35.
Sponsored by NWO/OTKA funds.

* December 8-10, 2003.
"Gibbs vs. non-Gibbs in Statistical Mechanics and Related Fields".
Participants: 25.
Sponsored by the ESF programme Phase Transitions and Fluctuation Phenomena for Random Dynamics in Spatially Extended Systems (RDSES).

Visitors:
24 researchers visited the ISS-group. Many of these visits were funded by DFG or OTKA, or took place within the framework of the Stochastic Analysis project supported by NWO.

External contacts / cooperation:
The ISS-group continued to have intensive contacts with the German Schwerpunkt 'Interacting Stochastic Systems of High Complexity', this year again through an intensive visitor programme, for which the DFG had allocated special funds. Also exchange took place with Hungarian researchers through an NWO/OTKA grant.

The ISS-group participates in the Dutch-German Bilateral Research Group on Mathematics of Random Spatial Models from Physics and Biology (2002-2008) which is funded by DFG and NWO.

Frank den Hollander chairs the ESF Scientific Programme "Random Dynamic Systems in Spatially Extended Systems" (2002-2006), which involves 13 European countries.

General remarks:
Arnaud Le Ny left EURANDOM in August for a permanent position as assistant professor at the Centre Universitaire Technologique de Sceaux (IUT). Bas Lemmens left in September for a visiting research position (supported by a TALENT fellowship of NWO) at the Institut fur Mathematik, TU-Berlin, Germany. New people in the group are: Akira Sakai (January), Fabio Toninelli (February), Federico Camia (April) and Karel Netočný (November). The latter was working for one year at Groningen University on a joint research project of A. van Enter and F. den Hollander on Gibbs measures under stochastic dynamics.

Lemmens had an NWO grant; Netočný has a FOM grant.

Remco van der Hofstad received a NWO-VIDI grant.

See section 6 for more details on publications, authors, workshops and visitors mentioned in section 3.

3.2. Stochastics of Extremes and Risk Analysis

Co-ordinators for this programme are professor J.H.J. Einmahl (Tilburg University) and professor C.G. de Vries (Erasmus University Rotterdam);
advisor, especially on Re-insurance, is professor J.L. Teugels (Catholic University Leuven).

3.2.1. Summary of the research by the members of the group

The SERA programme focuses on theoretical and applied issues in probability and statistics related to finance, insurance and economics. It has built up particular expertise in the area of extreme value theory and its application to risk management procedures. The SERA group is leading in the analysis of financial market risks that occur relatively infrequently but have a dramatic impact on the economy, such as the 1987 minicrash and the more recent IT meltdown. The group has specialised in

developing estimation techniques suited for fat-tail natured financial data. In 2003 the scientific projects of the SERA group focused on multivariate risk analysis and on statistics of extremes for function-valued data, relevant for portfolio decisions. Special attention was given to the fact that the typical financial data exhibit volatility dependence, which influences the quality of the estimators. With the arrival of new postdocs the research of the group branched into reinsurance mathematics. Major projects are to develop optimality criteria and appropriate risk measures to decide what type of reinsurance should be taken and for what premium. Also the financial and economical issues of reinsurance are taken up. Several members of the group collaborated with dr. Liang Peng during his visit.

Dr. Juan Carlos Rodriguez. During the nineties, the study of financial contagion was conducted mostly around the notion of "correlation breakdown": a statistically significant increase in correlation during the crash period. However, these studies were recently challenged because of the difficulty to measure changes in correlation in the presence of heteroskedasticity (high volatility around the crisis). Dr. Juan-Carlos Rodriguez introduced copulas with Markov switching parameters in the study of financial contagion. These models deal directly with the heteroskedasticity problem and go beyond the simple analysis of correlation breakdown. They also provide a careful characterization of nonlinearity and asymptotic dependence, while avoiding discretion in the identification of the contagious episodes and in the definition of extreme outcomes. He applied these models to the study of the Mexican and East-Asian financial crises.

Professor John Einmahl worked on statistical problems in extreme value theory. A paper with Tao Lin on estimating the extreme value index for function-valued data was substantially revised and resubmitted to The Annals of Statistics. In particular, examples and applications were presented. Major progress was made on a project with de Haan and Li (both Erasmus University, Rotterdam) on testing the domain of attraction condition for multivariate data. Among others a weighted approximation of the tail empirical process was established. A third project on the application of extreme value theory to aviation safety was started with Liu and Li (both Rutgers University, New Brunswick, New Jersey).

Together with Professor Jef Teugels (KULeuven), **Dr. Sophie Ladoucette** has studied some questions related to the large claims reinsurance treaty ECOMOR. The aim was to reopen the discussion on the usefulness of including the largest claims in the decision-making procedure. Together with Jef Teugels, she has obtained some interesting results. They have derived new mathematical results connected to distributional problems of this reinsurance form, such as asymptotic estimates for the tail of the distribution of the ECOMOR-quantity, its weak laws and remainder theorems.

Dr. Tao Lin worked with Laurens de Haan and John Einmahl on a project to define and estimate the tail quantile of a random vector, when its distribution is in the domain of attraction of a max-stable distribution. With John Einmahl, he improved their paper about asymptotic normality of extreme estimators in continuous function spaces; the paper is submitted to the Annals of Statistics.

Together with Professor Jef Teugels, Dr. **Mandira Sarma** studied the "quantile" principle of insurance premiums. Under this principle, insurance premiums are obtained as the p-quantile on

the distribution of the risk reserve of the insurer, where p is a (small) prespecified probability of ruin. Using various distributions, they obtain the explicit forms of the premium as a function of the parameters of the distributions. They also investigate whether this premium principle satisfies certain properties of well-defined premium principles.

Furthermore, they investigated, with the help of a Monte Carlo simulation, the behaviour of the ratio of reinsured amount by total claims in the re-insurance treaty ECOMOR. Assuming claim sizes to be Pareto distributed and the claim number to be Poisson distributed, they estimate the values of the mean and the standard errors of the ratio under consideration as the claim number becomes very large. This simulation exercise is carried out for various values of the parameter α of the Pareto distributed claim size and the various values of the ECOMOR parameter *r*. They find that the value of the ratio under consideration depends very much on the value of α and also on *r*.

Professor Jef Teugels investigated with Hansjörg Albrecher in how far the condition of independence between claim size and claim times could be lifted in the Anderson (or renewal) risk process. Using an approach from classical random walk theory, they could derive exponential type estimates for the probability of ruin in infinite and in finite time. The independence condition has been replaced by conditions on the copula function that links the claim size to the waiting time immediately preceding it.

With Giovanni Vanroelen he made a survey of the effect of transformations on the extreme value properties of random variables. The special case of a Box-Cox transformation has been singled out as a particularly attractive possibility to substantially diminish the bias of the Hill estimator, used in classical extreme value theory.

Professor Casper de Vries worked on theoretical results regarding the interdependency between portfolios of financial intermediaries during stress periods. In particular, banks are linked through their syndicated loans. The similarity in exposures carries the potential for systemic breakdowns. This potential is either weak or strong, depending on whether the linkages remain or vanish asymptotically. It is shown that the linearity of the bank portfolios in the exposures, in combination with a condition on the tails of the marginal distributions of these exposures, determines whether the potential for systemic risk is weak or strong.

General Remarks:
Tao Lin left in November for an associate professorship at XiaMen University, China. Juan Carlos Rodriguez continued his research at EURANDOM after the end of his contract, until March 2004; he then started an assistant professorship in econometrics at Tilburg University, The Netherlands. Sophie Ladoucette started in March this year and Mandira Sarma in May. Both are working with Jef Teugels in the area of Re-insurance.

Visit of dr. Peng at EURANDOM. Dr. Liang Peng from the Georgia Institute of Technology, Atlanta, USA, visited EURANDOM from June 2 to July 13, 2003. He cooperated with Professors de Vries, de Haan and Einmahl and with Dr. Tao Lin. During his stay at EURANDOM he also visited Tilburg University and Erasmus University, Rotterdam, for one day. At EURANDOM Liang Peng presented a seminar talk entitled *Empirical likelihood methods with heavy tails*; at Tilburg University he talked about *GARCH models and*

nonparametric regression with infinite variance.
While at EURANDOM, Liang Peng was a very active researcher and started new work on:

1. A bootstrap central limit theorem for the tail dependence function.
2. The asymptotic normality for an estimator of the spectral density of an extreme value distribution.
3. Confidence intervals for a copula function

In summary, the visit of dr. Peng was very fruitful and the cooperation with him will be continued in the future, in particular the collaboration on the aforementioned papers. He also published two other papers in the EURANDOM Report Series.

3.2.2. Activities, collaboration and contacts

Seminars:
7; see 6.2.

Workshops:
*January 23-25, 2003.
"Dependence in extreme value theory"
Sponsored by NWO.

*February 12 and 13, 2003.
Tutorial on Re-insurance: "Actuarial Aspects", by Jef Teugels.
Participants: 25.

* September 18 and 19, 2003
AON Re Europe Science Team Meeting; Statistical Issues in Actuarial Risk Modelling: Dependence Modelling and Detrending.
Participants: 30.
In cooperation with Aon-Re.

See section 6 for more details on publications, authors, workshops and visitors mentioned in section 3.

External contacts / cooperation:
There are regular contacts between the EURANDOM SERA researchers and KULeuven (Jef Teugels, Hansjörg Albrecher, Wim Schoutens), Andreas Kyprianou (University of Utrecht) and Tilburg University (Johan Segers).

3.3. Statistical Information and Modelling

(this programme is the result of the merge of the programmes Statistical Inference in Complex Statistical Models and Applications of Statistics).

Co-ordinators for this programme are dr. A. Di Bucchianico (Eindhoven University of Technology and EURANDOM), professor R.D. Gill (University of Utrecht and EURANDOM), professor A.W. van der Vaart (Vrije Universiteit of Amsterdam and EURANDOM; until July 2003) and professor Henry P. Wynn (London School of Economics, UK and EURANDOM); advisor is dr. W. Rey (Philips and EURANDOM) for the battery management project.

3.3.1. Summary of the research by the members of the group

SIM combines analytic and algebraic methods to address a variety of statistical questions, including statistical classification, bootstrap, micro-arrays, gene expression, design of experiments, predictive maintenance and quantum statistics.

As the two formerly separate programmes on Application of Statistics and Statistical Inference in Complex Statistical Models merged, we have chosen the field of "statistical learning" as a key area of exciting new developments and much promise, where the two groups come together in a very natural way. P. Grünwald and A. Koloidenko are already active in Statistical Learning. The research of F. Enikeeva is also very close. At the beginning of the year a EURANDOM workshop brought together top international researchers in Statistical Learn-

ing and helped us form our research strategy for the near future. The new name "Statistical Information and Modelling" was chosen to reflect the shared interests of the two groups. In the coming year our focus will lie on Statistical Learning and Industrial Statistics. In addition we will also incorporate applications in Molecular Biology and Genetics. In quantum stochastics EURANDOM will continue to form a meeting place in this field, in particular, through a national seminar "Qrandom" that is organized jointly by Nijmegen, Utrecht and EURANDOM.

Together with M. Guta, **Dr. Luis M. Artiles** has studied the problem of efficient statistical estimation of the quantum state. They have studied the Quantum Tomography technique. Concretely, they have considered the homodyne detection scheme and looked for estimators for the density matrix and the Wigner function of the light given the data obtained for the measurements of the quadratures X_θ at random angles θ in $[0,\pi]$. In particular, they have proven consistency of the Pattern Function Projection estimator and the Maximum Likelihood Sieve estimator of the density matrix and its Wigner function in different corresponding norms. They have also suggested an EM algorithm for practical implementations of the ML estimator and studied numerically the performance of such estimators. They have further studied the possibility of introducing classes of quantum states and classes of estimators for which Minimax rates of convergence can be proven.

Dr. Wicher Bergsma is the leading EURANDOM post doc on the Flextronics project (see below) with responsibility for day-to-day liaison with other partners. He is also doing research in the fields of categorical data analysis and nonparametric statistics. This includes the conditions for the existence and the uniqueness of maximum likelihood estimates of a large class of categorical data models, and generalizes previous results obtained by Haberman in several papers for loglinear models. Recently he has derived nonparametric tests of the conditional independence hypothesis. The standard test done in practice is based on the partial correlation. The new tests generalize this approach and allow for tests using Kendall's tau, Spearman's rho and Hoeffding's coefficient. The approach is based on the theory of U-statistics.

Dr. Dmitri Danilov developed a mathematical model of the Li-ion battery. This model permits to simulate the behaviour of the battery during charge and discharge, but it also describes the battery's aging effects (in particular, the battery's capacity fade can be predicted). It is an important contribution to the EET project in Battery Modelling and Management (see below).

Dr. Alessandro Di Bucchianico worked on both industrial projects and theoretical projects. His main industrial project is the Signature Analysis project with Flextronics, in which he collaborates with Talia Figarella, Wicher Bergsma, Vladimir Kulikov, Henry Wynn (EURANDOM) and Maarten Jansen (TU/e). This project has received a second grant for two additional years from the Dutch government. Wavelet methods have been successfully applied to extract features from current signals. The results have been presented at the ENBIS 2003 conference and were awarded a prize. A paper on this topic has been accepted for publication in Quality Reliability Engineering International. A specific experimental design constructed for this project has been studied. The results were submitted in a joint paper with Henry Wynn. He has also worked with Nino

Mushkudiani, Wicher Bergsma and Henry Wynn on a data-analytic approach to FMEA (Failure Modes and Effects Analysis), a widely used engineering tool.

A new line of research is the analysis and construction of software release procedures, together with computer scientists Van Hee and Groote (both TU/e). A new release procedure is being studied. Preliminary results were presented at the Dutch Testing Day. He is actively involved in the new software laboratory LaQuSo at TU/e. In particular, he is trying to establish a joint research project between EURANDOM and LaQuSo on statistical methods for software reliability.

In line with the new focus of the SIM programme, he has submitted an application to STW (Wiskunde Toegepast) on statistical learning for sensors. Dutch industrial partners are Dow Chemicals (Terneuzen) and Flextronics (Venray).

His work on statistical process control has concentrated on a joint project with Hušková (Prague) and Van Zwet (Leiden). An alternative framework for control charts based on alternative hypotheses has been developed and studied for a number of interesting alternative hypotheses. Hušková visited EURANDOM in June.

With Peter van de Ven he has worked on establishing links between different definitions and algorithms for effect calculations in two- and three-level factorial designs, and on a framework for understanding aliasing of mean and variance effects in factorial designs.

He has served in the local organisation committee of two conferences that will take place in 2004: the MODA conference on optimal design (organised by EURANDOM) and the ECMI (European Consortium for Mathematics in Industry) 2004 conference in Eindhoven. For the MODA conference he obtained a large grant from the European Union (together with Werner Müller, Vienna) and a small grant from NWO (together with Henry Wynn). Together with Jef Teugels, he organised a special EURANDOM session within the ECMI conference.

Together with Eduard Belitser (Utrecht University) **Dr. Farida Enikeeva** has been investigating the question of empirical Bayesian inference for unknown smoothness of the signal in the white noise model. This problem is closely related to the problem of adaptive estimation of the signal in the white noise model under a Sobolev class assumption. Together with Eduard Belitser she has obtained some results for this problem. Moreover, she has been working on the problem of adaptive estimation of fractional derivatives of an unknown density from observations in the Gaussian white noise. This problem is closely related to the Wicksell problem. Under the assumption that the density belongs to a Sobolev class with unknown smoothness, an adaptive estimator was constructed.

Ms. Talia Figarella has been participating in the joint project between the Mechatronics Laboratory of Flextronics Netherlands, EURANDOM, OCE and the reliability group within the Faculty of Technology Management of TU/e. The goal of the project is to develop methods to monitor the machine on-line and assess the re-use of its components. The project has been supported by grant EETK 20015 from the Dutch government. Talia gave the paper on Signature Analysis, which was jointly authored by researchers on the Flextronics project and which won the "best paper" prize at the ENBIS annual conference in Barcelona (August 2003). The paper has now been accepted for

"Quality Reliability Engineering International".

Professor Richard Gill is working on statistical and probabilistic problems concerning measurements on quantum systems. During the year a major overview paper was published, with discussion, by the Royal Statistical Society (joint with O.E. Barndorff-Nielsen and P. Jupp). This paper forms the kernel of a book project on quantum stochastics, which is moving forward swiftly now.

The field of Bell-type experiments - experiments designed to show that quantum mechanics violates locality restrictions which would hold under any classical physical model - provides an exciting area where statistical methods for dealing with missing data (in this case - the outcomes of hidden variables) and with time dependence, can be used to aid physicists in designing better experiments than before. The work indeed led to several papers joint with (both experimental and theoretical) physicists. At EURANDOM he collaborated with P. Grünwald, and V. Kulikov also contributed.

As physicists learn to isolate, manipulate and measure a small number of quantum systems, the need grows to design optimal strategies for recovering an unknown quantum state or quantum operation, or even to calibrate a quantum measurement itself. Here techniques based on Fisher information, quantum Fisher information, and asymptotic statistical theory provide approximately optimal experimental designs, which can be applied (and are being applied) in real experiments on a modest number of copies of a quantum system. Joint work was done with M. Guta and L. Artiles; and contributions from F. Enikeeva also proved to be valuable.

Dr. Madalin Guta: Quantum mechanics ascribes to each quantum system a state represented by a density matrix on a Hilbert space. By performing a measurement on the quantum system, we obtain a random result, whose distribution depends on the initial state of the system. The inverse route is to estimate the initial (unknown) state, based on the results of the measurements. Curiously, this has been explored experimentally only in 1993 through a measurement technique called quantum homodyne tomography. From the point of view of theoretical statistics, we deal with a new class of non-parametric estimation problems.
In the research of Madalin Guta two approaches to this inverse problem, based on linear estimators and on maximum likelihood, have been examined. He studied consistency in terms of dimension of the density matrix, rates of convergence and minimax properties. In the case of maximum likelihood estimation he has used entropy techniques from the theory of empirical processes. Apart from the theoretical investigations, he has performed extensive numerical simulations in collaboration with Luis Artiles.

Together with Jyri Lember (Tartu University, Estonia), **Dr. Alexei Koloidenko** has been developing and implementing an advanced theory of the Viterbi Training procedure for parameter estimation in Hidden Markov Models. The main theoretical results established within this theory are well definedness of the infinite Viterbi alignment, the existence of the corresponding limiting emission distribution, and the asymptotic recovery of the fixed-point property for the true parameters of the corresponding algorithm. Jiri Lember and Alexei Koloidenko have also demonstrated, on simulated Gaussian mixture data, advantages of their algorithm over the baseline Viterbi Training and the EM algorithms.
Alexei Koloidenko has further introduced the notion of determinacy of

multivariate measures that are invariant under a subgroup of SL_n by fundamental invariant moments that correspond to minimal sets of generators of the ring of the appropriately invariant polynomials. He has also developed a model selection algorithm for computing probability models with this type of invariance, and is currently working on experiments involving a large data set of natural images to illustrate the significance of the developed theory.

Together with Dr. H.P. Lopuhaä from TU Delft, **Dr. Vladimir Kulikov** has been working on various aspects of density estimation under monotonicity constrain. Possible testing methods of validity of these constrains, based on concave majorants of the empirical distribution function, have been discovered and studied. Furthermore, estimation of decreasing density at the beginning of support was provided and studied under mild assumptions. This estimate was compared to a naive one and its advantage has been shown. Estimate of density of the derivative under monotonicity constraints on the derivative itself was discovered, and its quality compared to traditional kernel estimate was studied. Furthermore, Vladimir Kulikov was working together with Prof.dr. R. Gill on computational aspects of convex optimization problems in application to quantum statistics. Vladimir Kulikov is currently working on the "Signature Analysis" project of the Dutch government, commercial companies, EURANDOM and TU Eindhoven. He is also working on maximum likelihood estimates of uni- and bivariate distribution under censoring.

Dr. Jyri Lember continued his research with A. v.d. Vaart about Bayesian adaptation. In particular, they proved the adaptation-results for uncountably many priors (continuous cases); they also extended then previous results for the case when the unknown density is not bounded below. Most importantly, they embedded the previous results in a more general framework. This allows to understand the adaptation principles more generally. The paper(s) is (are) in preparation.

He worked with Alexei Koloidenko on adjusted Viterbi training. They proved a general theorem about the existence of certain limiting measures that allow to define the adjusted Viterbi training in a general HMM context. Simulation studies were made that show the good performance of the adjusted algorithms, see EURANDOM Report "Adjusted Viterbi Training".

A paper concerning the application of AVT in a mixture model was completed. Another paper about the theory of AVT in hidden Markov models is in the final stage of preparation. Research with H. Matzinger about the reconstruction of periodic sceneries was continued.

Dr. Nino Mushkudiani left in August 2003. She worked with Sandro di Bucchianico on the Signature Analysis project.

Together with Dr. William Rey, **Iryna Snihir** has been investigating the numerical research problem of finding a global extremum and of estimating of the precision of a minimizer. Closely related to the questions of optimization of battery models, she has been working with Dr. Evgeny Verbitskiy (Philips, Eindhoven) on the evaluation of the empirical relations between the internal gas pressure, voltage and temperature. These research activities are part of the Battery Modelling and Management Project.

Peter van de Ven started working in 2003 as a PhD-student on the project "Joint modelling of mean and variance using Gröbner bases" supervised by Alessandro Di Bucchianico and Henry

Wynn. He has made good progress with one paper on generalisations of the Yates method for factorial design and material towards a paper on the mean-variance aliasing problem. The latter is an important topic in robust design in which products need to be made robust against noise.

Professor Henry Wynn combines his role as Scientific co-Director of EURANDOM with responsibilities for the Industrial Statistics programme and the development of statistics at EURANDOM more widely. In February 2003 he left the University of Warwick to become Professor of Statistics and Head (Convenor) of the Department of Statistics at the London School of Economics. He transferred most of his UK-based research programme to the LSE and continues to be very active with EU programmes, now under the Sixth Framework. In 2003 he was plenary or invited speaker at six conferences. Notable was the Annual Conference of the Italian Statistical Society, the meeting on Statistical Modelling at Leuven and the Workshop of Computational Algebraic Statistics in Stanford (December 2003). In his role as Workpackage leader for the pro-ENBIS EU Thematic Network he chaired the Workshop on design of experiments in Cagliari, Sardinia in June 2003 and continues to be active in the network. One success has been the award of the PASCAL network on "Pattern Analysis, Statistical Modelling and Computational Learning". EURANDOM is a partner on both pro-ENBIS and PASCAL and was active in drafting and liaison on these grants. EURANDOM is hosting, and doing much of the local organisation for, the workshop on Model-Oriented Data Analysis MODA7 (June 2004) and much of the work took place in 2003. Henry Wynn is the Conference Chair.

His research work ranges from theoretical to applied and he has a special interest in engineering applications. On the theoretical side, the leading area continues to be "algebraic statistics", the application of algebraic methods to statistics, particularly, discrete models, although he has developed recent interests in causal models in time series. He has added reliability to areas such as design of experiments, in industrial statistics. He takes a close interest in supervision of post docs and PhD students in these areas in EURANDOM.

General Remarks:
During 2003 Peter van de Ven, Luis Artiles Martinez (who was on special leave from July 2002), Farida Enikeeva, Vladimir Kulikov, Talia Figarella, Iryna Snihir and Wicher Bergsma all started working at EURANDOM. Nino Mushkudiani left in August for the Erasmus Medisch Universitair Centrum, Department of Public Health, Rotterdam, The Netherlands.

Dr. Peter Grünwald, who left EURANDOM in June 2002 for a three year NWO research fellowship at the CWI, keeps in touch with EURANDOM via a weekly visit (since January 2002). He has a key role in the PASCAL project.

3.3.2. Activities, collaboration and contacts

Seminars (including the Quantum Seminar, which is organised jointly with the University of Utrecht and Katholic University Nijmegen): 27.

Workshops:
*January 15-18, 2003.
"Statistical Learning in Classification and Model Selection".
Participants: 48.
Sponsored by NWO and KNAW.

April 23-25, 2003.

Joint workshop on "Statistical Data Mining" followed by a Pro-ENBIS meeting.
Participants: 46 to the workshop and 28 to the meeting.
Sponsored by the EC Thematic Network programme.

Visitors:
6.

External contacts / cooperation:
Via the Qrandom seminars, contacts with the universities of Nijmegen and Utrecht were continued.

EURANDOM put in a good effort in the EU 6th Framework Programme. Besides the Thematic Network (Pro-ENBIS), which was already running under FP 5, EURANDOM participates since December 1, 2003 in the Network of Excellence PASCAL. Apart from these two EU Networks and the Dutch universities with an interest in Quantum, the group has contacts with several industrial partners, via their EET-contracts on Battery Modelling and Management (with Philips, Shell and TU/e) and the Flextronics project (with Flextronics and TU/e). An STW application (Wiskunde Toegepast) was submitted on Dynamic Statistical Learning for Intelligent Sensors.

See section 6 for more details on publications, authors, workshops and visitors mentioned in section 3.

3.4. Stochastic Networks

Co-ordinator for this programme is professor O.J. Boxma (Eindhoven University of Technology and EURANDOM); advisor is professor J. Wessels.

3.4.1. Summary of the research by members of the group

The emphasis of the research in the Stochastic Networks project is on queueing theory and on its applications to the performance analysis of computer-communication networks and production systems. The queueing-theoretic research concerns both the stochastic analysis of queueing systems (Gromoll, Van Leeuwaarden, Maulik, Palmowski, Sleptchenko and Vlasiou) and their control and optimization (Van Leeuwaarden, Palmowski and Vlasiou). The performance analysis of production systems is partly done in an industrial project with Essent and in collaboration with the department of Technology Management (Sleptchenko); in addition, special attention is given to carousel systems (Vlasiou). The performance analysis of computer-communication networks is partly done in joint projects with Philips Research (Gromoll, Van Leeuwaarden and Palmowski).

Professor Onno Boxma's main research activities in the framework of EURANDOM were:
(1) work with EURANDOM PhD student Vlasiou, Adan and Wessels on a Lindley-type equation that occurs in the performance analysis of carousels;
(2) joint research with EURANDOM visitors Kella and Perry on storage systems with state-dependent input, output and switching rates;
(3) work with EURANDOM visitor Foss, EURANDOM postdoc Lasgouttes and Núñez Queija on queues with heavy-tailed service times and random order of service;
(4) with EURANDOM visitor Albrecher, relations between queueing and risk models were explored and exploited;
(5) with EURANDOM postdoc Maulik, a queueing model has been analysed that represents the operation of a patent office.

Dr. Christian Gromoll. Stochastic networks are mathematical models that describe the behaviour of various complex random systems: communication networks (wired and wireless), computer systems, manufacturing processes, supply chains, and call centres. Christian Gromoll has been investigating several classes of stochastic networks having measure valued state spaces. These are infinite dimensional state spaces, and the models in question are difficult to analyze exactly. An achievement has been the proof of "heavy traffic limit theorems" for these models. Such theorems mathematically justify the use of certain diffusion processes, which are computationally tractable objects, as approximations to the original intractable models. New techniques have been developed for working with measure valued state spaces in this context.

Under the supervision of Onno Boxma and Jacques Resing, **drs. Johan van Leeuwaarden** investigated various models that might describe the digital transfer of data packets. In particular, models were investigated that describe the sharing of service capacity among two sequential procedures. Within this context, he worked with Jacques Resing on boundary value problems. He collaborated with Dee Denteneer and Guido Janssen (Philips Research) on several topics. In particular, exact solutions and bounds were derived for the discrete-time bulk service queue.

Dr. Krishanu Maulik' s research mainly involved the modelling of the Internet traffic. He uses techniques from heavy tailed distributions, long-range dependence and queueing theory extensively. He is also interested in modelling TCP. He is trying to obtain more realistic models for TCP and to analyze them. A related area where he has interest as well is the extreme value theory in higher dimensions - more specifically the dependence structure of the multivariate distributions with regular variation. He studied other queueing models as well. One such problem has interesting applications to the refereeing process for scientific journals. He is considering the effect of returning a paper to the same referee after revision by the author, as opposed to the first available one from a group. The research was triggered by a question regarding the handling of patent applications. Some initial approximations are already available.

Dr. Zbigniew Palmowski was investigating with T. Rolski (Wroclaw University, Poland) the relation between processes conditioned to stay in a subspace and processes transformed by Doob's h-transform. In particular, they analyzed the workload process in GI/GI/1 conditioned to stay positive. He was also interested in finding estimates of the probability of excess over an arbitrary boundary on a random time interval for a random walk with subexponential increments. This is joint work with S. Foss and S. Zachary (Edinburgh University, Scotland). At the beginning of 2003, he and Andreas Kyprianou (Utrecht University, The Netherlands) started to analyze spectrally negative Markov Additive Processes. They generalized for this class of processes classical fluctuation identities developed in Zolotarev (1964), Takacs (1967), Emery (1973), Bingham (1975), Suprun (1976), Rogers (1990) and Bertoin (1997), which concern one and two sided exit problems for spectrally negative Levy processes. Traditional techniques for Levy processes make use of the Wiener-Hopf factorization and, more recently, Ito's excursion theory. The approach avoids the use of these methods and appeals explicitly to new martingale arguments together with suitable use of the Strong Markov Property and the fact that spectrally negative MAPs creep upwards with probability.

In 2003 **Dr. Andreï Sleptchenko** was working on the VENI proposal, which was rejected at the final round (December 2003). Then, according to the plan of the proposal, he was working on general models for priority queueing systems with static priority. He revised papers on priority systems and use of repair priorities within spare parts supply systems, which had been submitted before. Besides this he has participated in an industrial project between Essent and EURANDOM, and in a master graduation project at the Department of Technology Management.

Drs. Maria Vlasiou has studied a Lindley type equation that describes a general class of problems with alternating service. This equation also describes a two carousel system operated by one picker. She has studied various performance measures for this system. Later on she has expanded this work under more general assumptions. The main goal of the project is to do a thorough analysis of this equation and to compare this model to similar well studied cases. Moreover, Ms. Vlasiou has followed various postgraduate courses organised by LNMB.

In autumn 2003, **Dr. Dmitry Znamenski** wrote a number of computer programs for fast simulations of large random graph distributions. These programs provided more accurate statistics, were faster and were able to deal with much larger graphs than the previous ones. Since the date of his employment, he participated in the article with G. Hooghiemstra (Delft) and R. van der Hofstad (TU/e, EURANDOM) on the hopcount distribution and the cluster-size in the random graph model of Internet, where degrees have a power low distribution with infinite variance.

3.4.2.

Activities, collaboration and contacts

Seminars:
15.

Workshops:
*March 13 and 14, 2003.
Benelux-Workshop on "Performance Analysis of Communication Systems".
Participants: 57.
Sponsoring: FWO paid the travel expenses of the Belgium participants.

*September 8-11, 2003.
"Heavy Traffic Analysis and Process Limits of Stochastic Networks".
Participants: about 50.
Co-sponsored by NWO.

Visitors:
6.

External contacts / cooperation:
There are close ties to the Department of Mathematics and Computer Science of TU/e, as well as with CWI. The coordinator of the group is part of a EU Network of Excellence (EURO-NGI), which will bring some activities to EURANDOM in 2004. One of the researchers of the group (a PhD student) is working on a contract with Philips on cable access networks; another PhD student participates in a joint contract with industry through the Department of Technology Management, TU/e. One of the postdocs was working on a Marie Curie Fellowship, which was followed by a NSF grant.

See section 6 for more details on publications, authors, workshops and visitors mentioned in section 3.

3.5.
Computational Molecular biology

Co-ordinators for this programme are dr. M.C.M. de Gunst (Vrije Universiteit of Amsterdam and EURANDOM), professor dr. C.A.J. Klaassen (University of Amsterdam and EURANDOM).

3.5.1. Summary of the Research by members of the group

The Computational Molecular Biology (CMB) group concerns statistics and probability for present day molecular biology and genetics. The current research focuses on statistical problems in three areas: genetic mapping, gene expression and regulation, and phylogenetics. In genomic mapping the main statistical issues concern human genetics, in particular, parameter estimation and power and significance in testing problems for complex and quantitative trait loci, as well as haplotype vs. unphased genotype analysis. For gene expression and regulation the statistical questions are presently related to experimental design, imaging, normalization, and modelling and estimation of measurement and experimental error. In phylogenetics the attention goes to probabilistic analysis of algorithms for evolutionary tree reconstruction. In all three areas theoretical as well as applied projects are running.

The CMB group has several national and international collaborations. One postdoc spent 3 months at the Max Planck Institute in Berlin on an ESF grant to work with Rainer Spang. Other international collaborations are with David Siegmund (Stanford, USA), Arndt von Häseler (Düsseldorf), and Jian Zhang (Kent). An international workshop on Statistical aspects of microarray data was co-organized with Jens Jensen (MaPhySto and Department of Mathematical Sciences, University of Aarhus), Mats Rudemo (Stochastic Centre, Gothenburg), and Michael Sørensen (Department of Applied Mathematics and Statistics, University of Copenhagen). All postdocs attended a few national and international meetings.

In collaboration with biologists at the VU and NIH, **dr. Nicola Armstrong** has worked on the design and analysis of microarray time course experiments. Spatial effects on several arrays have been identified and work is currently underway to identify the cause of these effects and to correct for them if necessary. Clustering techniques for microarray data and issues in the low-level analysis of Affymetrix chips were investigated as part of a collaboration with the Genome Centre in Maastricht. In addition, research into genetic network modelling using array data was started. As a first step, statistical methods of identifying transcription factor binding sites using array and/or sequence data are being developed. An EPS travel grant was awarded to allow further development of this work in conjunction with Rainer Spang at MPI Berlin.

Dr. Bojan Basrak has been working on problems in statistical genetics. He has investigated a method for the linkage analysis of quantitative traits in human genetics based on copulas. This method allows the analysis of traits, which are not necessarily normally distributed. This was mainly done in collaboration with Chris Klaassen (UvA, EURANDOM) and Dorret Boomsma (VUA). Part of his research was also dedicated to statistical problems in reconstruction of phylogenetic trees.

Dr. Mathisca de Gunst continued her research on model selection for hidden Markov models of ion channel data by reversible jump MCMC, and on the analysis of ion channel data of potassium channels in barley leaf with Barry Schouten (CBS, Voorburg). Also the work with Dorret Boomsma (VUA) and Aad van der Vaart (VUA) on genetic analysis of twin growth data was continued. She started a project on modelling the gene network underlying neuronal outgrowth with Nicola Armstrong (EURANDOM) and Guus Smit (Molecular and Cellular Neurobiology, VUA). Work with Jian Zhang (Kent) on

finding haplotype-interactions based on unphased geno-type data and with Sonia Hernandez (EURANDOM) on the power of tests for genetic linkage detection was finalized.

Dr. Sonia Hernández Alonso worked in statistical methods for human genetics. She studied the power of tests for genetic linkage detections based on moving averages of the identity-by-descent allele sharing proportions for relative pairs at several contiguous markers. This was done in collaboration with David Siegmund (Stanford University) and Mathisca de Gunst (VUA, EURANDOM). She also analyzed a conditional approach for sequential detection of trait-loci in situations with a trait locus with a large effect, as well as other linked trait loci with minor effects that are masked by the major gene. S. Hernández Alonso left EURANDOM in September 2003 for a tenure-track position in Spain at the Universidad Rey Juan Carlos in Madrid.

Professor Chris Klaassen started his research in the field of molecular biology in September 2002. His main interest has been in normal copula models for quantitative trait loci analysis as developed and applied by Bojan Basrak. This research has resulted in a paper in Behaviour Genetics.

Dr. Patrick Lindsey has been working on uniform designs for microarrays. In order to layout products optimally over the printing array, designs based on lattice integers can be used. Unfortunately, in discrete space solutions are only available for a prime number of products to be placed a prime number of times in grids with a prime number of columns and rows.
In practice, these settings are very inconvenient, especially when the greatest number of spots must be printed in order to have all currently known genes present once or more on a microarray. One approach to solve this issue is to subdivide the microarray into smaller grids complying to these criteria and combining them back together in order to get a design where the products are well uniformly scattered over the microarray.

3.5.2. Activities, collaboration and contacts

Seminars:
5.

Workshops and meetings:
*February 20-22, 2003.
"Statistical Aspects of Micro-array Data".
This workshop took place in Aarhus, Denmark; Mathisca de Gunst was one of the organisers.
Participants: 100.

Visitors:
2.

See section 6 for more details on publications, authors, workshops and visitors mentioned in section 3.

4. Spin glasses: A mystery about to be solved

by Frank den Hollander and Fabio Toninelli

We present here in more detail an example of the research in the ISS-group

This article has been sent to Nieuw Archief voor Wiskunde.

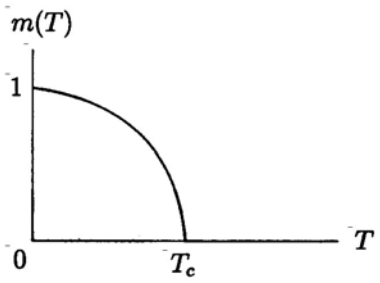
Abstract

The study of spin glasses started some 30 years ago, as a branch of the physics of disordered magnetic systems. In the late 1970's and early 1980's it went through a period of intense activity, when experimental and theoretical physicists discovered that spin glasses exhibit new and remarkable phenomena. However, a real understanding of the behavior of these systems was not achieved and little progress was made in the next 20 years, especially in mathematical terms. In the 1990's various related systems were studied with mounting success, most notably, neural networks and random energy models. Since a couple of years the field has again entered a phase of exciting development. Some of the main mathematical questions surrounding spin glasses are currently being solved and a full understanding is at hand. In this paper we sketch the main steps in this development, which is interesting not only for the physical and the mathematical relevance of this research field, but also because it is an example where scientific progress follows a tortuous path.

4.1. Ferromagnets.

Let us begin with a brief history of magnetic materials. All matter is composed of a large number of atoms.

Atoms carry a *spin*, i.e., a microscopic "magnetic moment" generated by the motion of the electrons around the nucleus. This spin, which in turn generates a microscopic magnetic field around the atom, can be viewed as a vector in three-dimensional space. To simplify matters, assume that for this vector only two opposite directions are allowed, *up* and *down*. In *ferromagnets*, materials capable of attracting pieces of iron placed in their vicinity, each spin has a tendency to align with the spins in its neighbourhood. At high temperature, the motion of the spins is so erratic that at any time about half of them are pointing up and half are pointing down. Consequently, the net macroscopic magnetisation is zero, i.e., the individual microscopic magnetic fields generated by the spins cancel each other out. As the temperature is lowered, the erratic motion of the spins reduces and the spins become more and more sensitive to their mutual interaction. The characteristic feature of ferromagnets is that there is a *critical temperature*, T_c, below which the spins exhibit *collective behavior* in that a majority of them point in the



same direction (either a majority up or

a majority down). This phenomenon is called *spontaneous magnetisation* (see Fig 1).

Figure 1. The magnetisation $m(T)$ as a function of the temperature T for a typical configuration of the spins; $m(T)$ is the difference between the number of up-spins and the number of down-spins divided by the total number of spins. By symmetry, configurations with the opposite magnetisation $-m(T)$ are equally likely.

Below T_c the individual microscopic magnetic fields sum up coherently to create a macroscopic magnetic field, which is what is ultimately responsible for the ferromagnet's capability to attract iron. It is important to emphasize that this seemingly natural picture took a long time to emerge – from 1895 (Curie) until 1944 (Onsager) – and that the genius of many illustrious theoretical physicists and mathematicians was necessary in order to fully establish that this is what actually happens.

The microscopic theory that explains the collective behavior of atoms is called *statistical physics*. According to this theory, a system in equilibrium is described with the help of an energy functional, called *Hamiltonian*, which associates with each microscopic configuration of the system a macroscopic energy. In our case a configuration means a complete list of the orientations of all the spins. If the spins are located at the sites x in a macroscopic box Λ, and if $s_x \in \{+1,-1\}$ denotes the value of the spin at site x ($+1$ for up and -1 for down), then the configuration is

$$s = \{s_x : x \in \Lambda\}$$

and the Hamiltonian of the ferromagnet is

$$H(s) = -\sum_{\substack{x,y\in\Lambda \\ x \sim y}} s_x s_y,$$

where $x \sim y$ means that x and y are neighbouring sites. Thus, each pair of neighbouring aligned spins gets energy -1, each pair of neighbouring anti-aligned spins gets energy $+1$. At a given temperature T, the state of the system is described by the *Gibbs distribution* associated with H,

$$\mu_T(s) = \frac{1}{Z_T} e^{-H(s)/kT}, \qquad s \in \{+1,-1\}^\Lambda,$$

where k is Boltzmann's constant and Z_T normalizes μ_T to a probability distribution: $\mu_T(s)$ *is the probability that the system assumes configuration* s. When T is lowered, μ_T tends to concentrate more and more around the configurations having minimal energy, the so-called *ground states* of the system. For the ferromagnet these ground states are those configurations where all the spins have the same value. Indeed, it is only when $s_x = +1$ for all x or $s_x = -1$ for all x that all terms in $H(s)$ give a negative contribution, leading to the maximal value for $\mu_T(s)$. This maximum is a pronounced peak when T is small, explaining why for low temperature in a typical configuration the majority of the spins is aligned.

4.2. Spin glasses.

Now that we have briefly introduced some important concepts from the theory of magnetism, we are in a position to explain what spin glasses are. Consider a system of spins, as before, but assume that some pairs of neighbouring spins prefer to be aligned, while the others prefer to be anti-aligned. The former are said to have a *ferromagnetic* interaction, the latter an *anti-ferromagnetic* interaction. Say that for any given pair of spins the type of interaction is chosen *randomly* with equal probability. It is because of this randomness in the interactions that such systems are called *disordered*.

In terms of the Hamiltonian, the above model can be defined as

$$H(s) = -\sum_{\substack{x,y\in\Lambda \\ x\sim y}} J_{xy} s_x s_y,$$

where, for each $x \sim y$, J_{xy} can be either $+1$ (indicating a ferromagnetic interaction) or -1 (indicating an anti-ferromagnetic interaction), with probability $\frac{1}{2}$ each. This Hamiltonian was introduced in 1975 by Edwards and Anderson [8], in an attempt to describe a class of disordered magnetic systems found a few years earlier by experimental physicists and termed "spin glasses". Examples in this class are disordered magnetic alloys, i.e., metals containing random magnetic impurities, such as AuFe or CuMn. The Edwards-Anderson Hamiltonian shows "frustration", i.e., due to the different signs of the interaction not all spin pairs or can simultaneously lower their interaction energy.

What is the analogue in this case of the behavior depicted in Figure 1 ? Even at low temperature there is no reason why the majority of the spins should be aligned. Indeed, due to the equal competition between ferromagnetic and anti-ferromagnetic interactions the corresponding magnetisation $m(T)$ will be zero for all T. One might thus conclude that the model simply has no critical temperature and therefore exhibits no interesting phenomena. However, in the early 1970's it was found *experimentally*, by Cannella and Mydosh [6] and by Tholence and Tournier [18], that there still is a critical temperature below which the system undergoes an *ordering transition*, in the sense that the spins act coherently in some sort of way (see Fig. 2). This fact came as a surprise to the physicists.

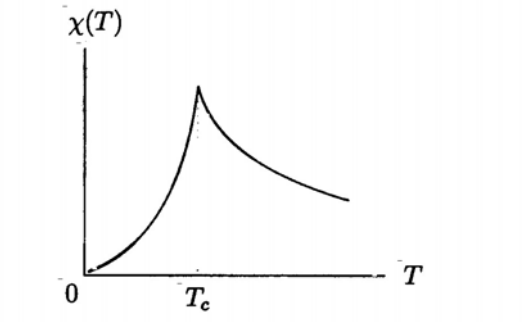


Figure 2. The magnetic susceptibility $\chi(T)$ as a function of the temperature T. $\chi(T)$ measures the sensitivity of the system to the application of a magnetic field and shows a cusp at the critical temperature T_c. This cusp signals a freezing of the spins in random directions.

In simplified terms, what happens is the following. Above T_c, the spins behave essentially independently from

one another, i.e., their orientation is hardly influenced by the spins in their neighbourhood. As a result, the typical configurations of the system are those that are completely disordered. This is true both for the ferromagnet and for the spin glass. Below T_c, however, the spins show cooperative behavior and can be found in *more than one* class of typical configurations. In the case of the ferromagnet described above, there are *two* classes of typical configurations, namely, those having magnetisation $+m(T)$ and $-m(T)$, respectively. These classes of configurations are called *pure states*. In the case of the spin glass, instead, there are *many* pure states, which are not characterised by a non-zero magnetisation, but rather by the occurrence of many "mesoscopic domains" (microscopically large but macroscopically small) in which the spins show some form of "local magnetic order". In fact, a whole "hierarchy" of such domains occurs. At present it is not yet clear what the features of these domains precisely are. The important point, however, is that the existence of a transition at T_c is experimentally observable.

The Edwards-Anderson model is far too difficult to be analysed theoretically in detail, even today. In fact, condensed matter physicists have been disputing heatedly in the past three decades about what precisely happens at low temperature. In 1975 Sherrington and Kirkpatrick [15] introduced a simplified version of this model. The difference with the Edwards-Anderson model is that each spin is influenced not only by its neighbouring spins, but by *all* the spins in the system. The corresponding Hamiltonian reads

$$H(s) = -\frac{1}{|\Lambda|^{1/2}} \sum_{\substack{x,y\in\Lambda \\ x\neq y}} J_{xy} s_x s_y,$$

where J_{xy} is $+1$ or -1, with probability $\frac{1}{2}$ each, for all $x \neq y$ (rather than for $x < y$ only), and a factor $1/|\Lambda|^{1/2}$ is added to normalise the interaction. In statistical physical jargon, the Sherrington-Kirkpatrick model is a *mean-field approximation* of the Edwards-Anderson model. Strange as it may seem, this type of approximation actually makes the model easier.

For a history of spin glasses up to 1986, we refer to Binder and Young [2].

4.3. Replica symmetry breaking.

The article by Sherrington and Kirkpatrick carried the rather innocent title "A solvable model of a spin glass". The authors never imagined that they were giving birth to one of the most exciting enigmas of modern statistical physics. The solution they proposed, assuming so-called "replica symmetry", turned out to be incorrect, and even self-contradictory as they themselves realised very well. It was only a few years later, in 1980, that the Italian theoretical physicist Giorgio Parisi [14] proposed a different solution, known as the *continuous replica symmetry breaking scheme*, which could account for many of the experimental observations (both laboratory experiments and computer simulations).

Replica symmetry breaking theory predicts the existence of a collective behavior with many *exotic features*, never before observed in any physical system. In simple words, Parisi's theory predicts that the Hamiltonian of the Sherrington-Kirkpatrick model has *many* ground states (growing in number as the volume of the system increases), which are *highly disordered* and which do not seem to be related to one another via simple transformations. In contrast, recall that the ferromagnetic Hamiltonian has only *two* ground states, one with all spins up and one with all spins down, which are *fully ordered* and which are related to one another via a global inversion of all the spins. Moreover, it turns out that for the Sherrington-Kirkpatrick model, by choosing a *different realisation of the disorder* (i.e., a different choice for the random interactions $J_{xy} = \pm 1$, again with probability $\frac{1}{2}$ each), the new ground states in general have nothing to do with the old ones. Even more surprisingly, if the disorder realisation is kept fixed but the volume of the system is increased, then the new ground states are not related to the old ones either ("chaotic size dependence"). In spite of this extremely irregular situation, according to Parisi's theory the collection of all the ground states has some regular, highly non-trivial, geometrical structure, called *ultrametricity*, which is *not* modified when the disorder realisation is changed.

So, what distinguishes the region above the critical temperature T_c from the one below, for the Sherrington-Kirkpatrick model? Suppose that we take two copies – two *replicas* – of the system, with the *same* realisation of the disorder, and compute the *overlap* between them, i.e.,

$$q(s^{(1)}, s^{(2)}) = \frac{1}{|\Lambda|} \sum_{x \in \Lambda} s_x^{(1)} s_x^{(2)},$$

where $s^{(1)}$ and $s^{(2)}$ are the configurations of the first and the second replica, respectively. Then, above T_c the overlap is zero for typical configurations (typical with respect to the Gibbs distribution and the disorder realisation), while below T_c it can assume a range of non-zero *random* values. This can be explained as follows. Recall that, at low temperature, the Gibbs distribution is peaked around the ground states of the system. Consequently, the configurations in the two replicas will each be very close to one of the ground states (not necessarily the same one), which causes a non-zero overlap. Due to the erratic nature of the ground states, the overlap does not have a fixed value: it varies randomly with the ground states.

Replica symmetry breaking theory came as a shock to the physics community, not only for the novelty of the phenomena predicted, but also for the way in which it was presented. It happens frequently that theories formulated by physicists are not mathematically rigorous, and contain a number of assumptions and simplifications that need to be justified. Often full mathematical proofs come only much later. Here the situation was more delicate: the works of Parisi and co-workers were not only non-rigorous, they were

based on such strange and such daring techniques that it was hard to see how the relevant statements could be formulated in a proper mathematical language. This is why part of the mathematics community has regarded Parisi's theory as somewhat magic. Still, the phenomena predicted by the theory were so appealing, and its range of applications so wide, that it soon became a standard tool for theoretical physicists, who were much more excited by its power than worried by its lack of mathematical sense and precision. One could say that Parisi had discovered a new world.

A review of the results of replica symmetry breaking theory up to 1987 can be found in Mézard, Parisi and Virasoro [12].

4.4. Towards a solution.

The reader might wonder at this point whether all the excitement about the Sherrington-Kirkpatrick model is really justified. After all, it is only an approximate version of the more difficult – but more realistic – Edwards-Anderson model, which remains unsolved. In fact, it is not yet clear how much we really learn about the Edwards-Anderson model from a detailed analysis of the Sherrington-Kirkpatrick model. According to a scenario put forward by Newman and Stein (see Newman [13]), the behavior of the two models may well turn out to be qualitatively different: the main phenomena related to replica symmetry breaking may not occur in "short range" models like the Edwards-Anderson model. Still, the excitement is understandable. First, the study of the Sherrington-Kirkpatrick model has taught us a lot and continues to do so. In the attempts to understand this model, new ideas and techniques have been invented and further developed that are extremely interesting and that have turned out to be fruitful for other statistical physical models as well. Second – and more importantly – it has gradually become clear that the knowledge gained through the analysis of the Sherrington-Kirkpatrick model can be applied to a variety of – apparently unrelated – problems in mathematics, physics and engineering. These problems have therefore come to be considered as belonging to the realm of spin glasses. Examples are neural networks (models for memory and learning), error correcting codes (used in communications engineering to recover the information transmitted through a noisy channel) and random combinatorial optimisation (problems of decision in the presence of many mutually competing requirements).

From the moment the replica symmetry breaking theory came into being, trying to prove – or to disprove – the predictions of Parisi and co-workers became an exciting challenge for many among the best mathematical physicists. The task proved to be quite hard and quite frustrating, and for almost 20 years progress was painfully slow. Much effort was devoted to the search for and the study of mathematical models that would be easier than the Sherrington-Kirkpatrick model, but that would still exhibit replica symmetry breaking effects. In particular, the Generalized Random Energy Model, introduced by Derrida [7] in 1985,

shows striking similarities with the Sherrington-Kirkpatrick model, yet is exactly solvable. The structure of the Gibbs distribution in this model has been analysed in full mathematical detail by Bovier and Kurkova [4]. Similarly, extensive rigorous results have been obtained by Bovier, Gayrard and Picco for the Hopfield model of neural networks (see Bovier and Gayrard [3] and references therein). The latter is a paradigm for auto-associative memory, i.e., systems that try to recognize words – or *patterns* – that were previously memorized. In this case, the spins should be interpreted as the states of the neurons located at the various sites: $s_x = +1$ if the neuron at site x is sending electric pulses, $s_x = -1$ if it is not. When varying the number of memorized patterns, the behavior can range from a ferromagnetic type to a spin glass type.

For an overview of the expanding panorama of spin glasses up to 1998, see Bovier and Picco [5].

It gradually became clear – more through failures than through positive results – that completely new ideas were needed to make significant progress in the comprehension of replica symmetry breaking. It is only in the last few years that we are witnessing a rapid and unexpected boost in the mathematical understanding of the key questions. Surprisingly, the missing new ideas turned out to be relatively simple, although they were quite hard to find. The first steps in this breakthrough were taken in 2000-2002 by the Italian mathematical physicist Francesco Guerra [10], together with Fabio Toninelli [11], building on earlier work by Ghirlanda and Guerra [9]. As a result, some of the mathematical questions that had been tackled in vain in the preceding 20 years could finally be solved. One important result is the existence of the "thermodynamic limit" for the Sherrington-Kirkpatrick model. This means that physical quantities, like the energy of the ground states divided by the volume of the system, converge to a well defined limit when the volume of the system tends to infinity. The proof of this fact is quite standard in statistical physics for models with "short range" interactions, but it is not for mean-field models, especially not for disordered ones. Another important result is that with the help of certain rigorous comparison identities – so-called *sum rules* – the thermodynamic properties of the Sherrington-Kirkpatrick model can be compared with the corresponding expressions given by Parisi's theory. These sum rules concern the *free energy* $f(T,|\Lambda|)$ as a function of the temperature T and the volume $|\Lambda|$, a quantity of central importance in statistical physics, from which all thermodynamic properties of the system can be deduced. This free energy is related to the Gibbs distribution μ_T via the relation $f(T,|\Lambda|) = -kT \log Z_T$. The result is that $f(T,|\Lambda|)$ can be related to the free energy predicted by Parisi's theory via an identity of the type

$$f(T,|\Lambda|) = f^{Parisi}(T,|\Lambda|) + R(T,|\Lambda|),$$

where $R(T,|\Lambda|)$ is an "error term". Proving the validity of Parisi's theory is equivalent to showing that

$R(T,|\Lambda|)/|\Lambda|$ tends to zero in the thermodynamic limit $|\Lambda|\to\infty$. A particularly important fact is that $R(T,|\Lambda|)$ turns out to be non-negative, so that Parisi's free energy at least is a lower bound for $f(T,|\Lambda|)$, a fact that itself is rich in physical implications (see Toninelli [19]). Subsequently, Aizenman, Sims and Starr [1] obtained Guerra's sum rules through a general variational principle and showed that Parisi's free energy arises from a restriction of this variational principle to "ultrametric structures". This restriction is optimal precisely when replica symmetry breaking theory correctly describes the Sherrington-Kirkpatrick model.

These new ideas provoked great excitement in the scientific community, and new feverish work began. The last part of this story is still in progress and is keeping the excitement high. In July 2003 the French mathematician Michel Talagrand, who has been working on the problem intensively and who has introduced many new ideas in this field since the mid 1990's (see [16]), has announced (see [17]) that he was able to complete the mathematical proof of Parisi's solution, extending the method of sum rules invented by Guerra. The details of the proof have not yet been made public only in April 2004. It is not hard to imagine the impression this proof has produced on the experts. It seems that the full mathematical justification of Parisi's theory, explaining the mysterious features of the Sherrington-Kirkpatrick model, is finally at hand.

Currently, research in this rapidly evolving field is being carried out by a number of groups, including the Interacting Stochastic Systems group at EURANDOM, the European institute for research on stochastic phenomena located at the Technical University of Eindhoven, The Netherlands. Fabio Toninelli works as a postdoc in the ISS-group. Frank den Hollander is supervisor of the ISS-group and scientific director of EURANDOM.

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5. PUBLICATIONS

5.1. Papers in journals and proceedings

(For the EURANDOM Report series, see 5.2)

Interacting Stochastic Systems

*** Federico Camia**

F. Camia, C.M. Newman and V. Sidoravicius. A Particular Bit of Universality: Scaling Limits for some Dependent Percolation Models. To appear in: *Comm. Math. Phys*.

F. Camia and C.M. Newman. The Percolation Transition in the Zero-Temperature Domany Model. To appear in*: J. Stat. Phys*.

F. Camia and C.M. Newman. Continuum Nonsimple Loops and 2D Critical Percolation. To appear in: *J. Stat. Phys*.

*** Remco van der Hofstad**

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R. van der Hofstad, F. den Hollander and W. König. Weak interaction limits for one-dimensional random polymers. *Probab. Theory Related Fields* **125**, no. 4 (2003), 483-521.

R. van der Hofstad and G. Slade. Convergence of critical oriented percolation to super-Brownian motion above $4+1$ dimensions. *Ann. Inst. H. Poincaré Probab. Statist.* **39**, no. 3 (2003), 413-485.

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*** Arnaud Le Ny**
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*** Akira Sakai**
M. Holmes, A. Jarai, A. Sakai and G. Slade, High-dimensional graphical networks of self-avoiding walks. To appear in: *Canadian Journal of Mathematics.*

*** Fabio Toninelli**
F. Guerra and F.L. Toninelli. The high temperature region of the Viana-Bray diluted spin glass model. To appear in: *Journal of Statistical Physics*.

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5.2. EURANDOM Report series

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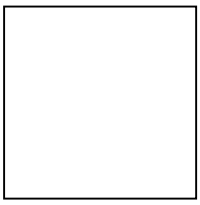

6. ACTIVITIES

6.1. Workshops and Conferences

January 15-18, 2003 SIM
Statistical learning in classification and model selection.

The goal of this workshop was to bring together researchers working on similar problems but within different disciplines and with different backgrounds. The invited speakers (18) were all world-class researchers. This and the fact that talks were -on request- very accessible, made the workshop highly successful.

The workshop started in the morning of January 15th with a very clear tutorial introduction by Thore Graepel about Kernel Methods and PAC-Bayesian error bounds. Both topics continued to play an important role in many of the talks. For example, the second talk by Olivier Catoni was about some exciting new developments in the PAC-Bayesian field, improving and relating PAC-Bayesian bounds to those obtainable within Vapnik's structural risk minimization framework. The third talk by Jean-Paul Vert was about applications of kernel methods to discrete data as arising in, for example, DNA sequence analysis. Several of the talks gave high-level introductions to quite different concepts in model selection and classification. We mention Paul Vitanyi's entertaining talk about 'algorithmic statistics', advocating a potential new approach to statistics (basically invented, but never published, by Kolmogorov in the 1970s) that is fundamentally different from other existing approaches, in that it is built on finite combinatorial principles rather than the assumption of a 'true' distribution. Another highlight was Volodya Vovk's talk on 'On-line classification with confidence', proposing yet a fundamentally different approach to classification based on Vapnik's idea of 'transduction' and Martin-Löf's 'repetitive structures'. Frequentist performance guarantees of Bayesian methods were also a repetitive theme, witness Yoav Freund's (the inventor of the 'boosting' method for classification) talk 'How to be a Bayesian without believing'. The talk prompted a member of the audience to remark that 'I believe that if I were a Bayesian, I would not believe that what you are doing is being Bayesian'. The only disappointment was the cancellation of Frederick Jelinek's talk. Professor Jelinek had become ill while traveling and had to return to the United States prematurely.

There were 48 participants.
The workshop was organized by R.D. Gill (Universiteit Utrecht/EURANDOM), P. Grünwald (CWI/EURANDOM), A.W. van der Vaart (Vrije Universiteit Amsterdam/EURANDOM) and J. Lember (EURANDOM). This workshop was co-funded by NWO and KNAW.

January 23-25, 2003 SERA
Dependence in Extreme Value Theory.

The statistical theory of extremes from cross-sectional or time dependent data is a fairly recent but 'hot' topic. The newly developed nonparametric procedures can address several important cases, but also still leave a lot to be desired. For example, the combination of cross-sectional and time dependency is a largely unexplored topic, which is nevertheless very important in applied fields as finance and insurance. It is well known that the volatility of equity returns is time dependent, but at the same time different stock returns move in tandem. Therefore we initiated a conference on the topic of dependence (temporal and/or spatial) in extreme value theory. We brought together statisticians, probabilists and scientists from economics, finance, and insurance, who are familiar with and actively apply extreme value theory. The

participants felt that the workshop was needed and organized at the right moment. Clearly it will generate new, substantial research in the area.

At the workshop 19 lectures were presented and two vivid round table discussions were held. In general the lectures were of very high quality and well presented. About 50 participants, from many countries, attended the workshop. The majority of the participants is active in the area and many leading scientists were present.

Organizing Committee:
Prof.dr. J.H.J. Einmahl, Universiteit van Tilburg/EURANDOM, Prof.dr. C.G. de Vries, Erasmus Universiteit Rotterdam/EURANDOM, Prof.dr. L. de Haan, Erasmus Universiteit Rotterdam.
The workshop was co-funded by NWO.

February 12 and 13, 2003 SERA
Tutorial Reinsurance: Actuarial Aspects
J. Teugels, KU Leuven, Belgium and EURANDOM, The Netherlands.

Reinsurance is one of the main procedures, used by insurance industries, to safeguard themselves against excessively large and catastrophic claims. As reinsurance is in the first place insurance, it has been necessary to first deal with classical concepts from insurance mathematics like claim number processes, claim size processes, premium schemes and ruin theory. Especially finite time ruin problems are studied under the hypotheses of either light or heavy claim sizes.

But reinsurance adds something to insurance. For this reason, the second part of the tutorial contains a number of topics, specifically important in reinsurance. Why would an insurer take reinsurance? What kind of reinsurance should he choose and what are the main elements from the portfolio that can influence his choice? How will the premiums have to be split between first line insurer and reinsurer? Would it be wise to a reinsurer to take an additional reinsurance on his own portfolio?

We provide partial answers to most of the questions above. We also offer a vast set of possible research topics that can be addressed. The main omission from the tutorial is the lack of issues related to finance. To help the audience, a set of lecture notes has been written out in detail. Hopefully these notes succeed in covering most of the vast literature on reinsurance, as the basic content from some 450 publications has been included.

There were 25 participants.

February 20-22, 2003 CMB
Statistical Aspects of Microarray Data
Aarhus, Denmark.
Scientific participation by EURANDOM.

Microarrays can provide a broad picture of the state of a cell by monitoring the expression level of thousands of genes at the same time. As such the technique can give valuable information on many biological processes. Presently, microarray studies are mostly used for classification and clustering. In particular in relation to tumors a precise classification is of importance for finding the optimal treatment. The analysis of microarray data poses many interesting statistical problems. The raw data consist of an image of scanned pixel values and the location of a particular signal must be identified. Often there will be outliers in the data that need to be detected. A fundamental but very difficult question is the precise translation of a pixel value to the number of molecules present. Due to the variation in the production of the chips and the variation in the preparation of the samples the data from two arrays cannot be compared before a normalization has been made. This normalization is a non-trivial task

and, unless done very carefully, may introduce systematic errors. Coming to the estimation of the actual expression level of a gene one is still lacking a systematic study delineating the part of the variance due to the measurement technique and the part due to biological variation. Underlying the above points is also the problem of designing the experiments so as best to extract the information.

With around hundred participants from many countries the workshop was very successful. Sixteen speakers (thirteen invited and three contributed) covered all topics mentioned above. In between lectures there were vivid scientific discussions.

Organizing Committee:

Jens Ledet Jensen (University of Aarhus) - Chairman, Mathisca de Gunst (EURANDOM, Eindhoven/Vrije Universiteit of Amsterdam), Mats Rudemo (Stochastic Centre, Gothenburg), Michael Sørensen (University of Copenhagen).

March 13 and 14, 2003 SN
Benelux-Workshop on Performance Analysis of Communication Systems.

Technological developments have in recent years revolutionized the way humans exchange information; prime examples are the Internet and mobile communications. These new forms of communication, in their turn, have given rise to fascinating new problems in traffic engineering, Quality-of-Service provisioning and network design. As a result, the performance analysis of communication systems is going through very exciting times. To mention just a few interesting issues:
(i) Providing Quality-of-Service to multi-media applications requires new traffic engineering and network design approaches.
(ii) Multi-service networks raise challenging issues related to the integration of services with different traffic characteristics and Quality-of-Service requirements.
(iii) The modelling and performance evaluation of network traffic with long-range dependence.
One of the hottest topics in the latter area concerns the impact of heavy-tailed input processes on network performance. Queueing theory continues to provide a key tool to study performance issues like those mentioned above. In addition, performance issues arise that concern, e.g., routing, scheduling, admission control, and pricing, requiring techniques from fields like combinatorial optimization, linear programming, control theory, stochastic geometry, and economics.

In Belgium and in The Netherlands, there are several strong groups in the field of performance analysis of communication systems. However, there is relatively little interaction between the groups of both countries. To strengthen the ties, EURANDOM has organized this Benelux workshop on Performance Analysis of Communication Systems.

There were six invited 45-minute lectures and fifteen contributed 30-minute lectures. The invited speakers were K. Laevens (Ghent University), A. da Silva Soares (Université Libre de Bruxelles, replacing G. Latouche), B. Van Houdt (University of Antwerp), M. Mandjes (CWI and Twente University), Rob van der Mei (TNO Telecom and Vrije Universiteit), P. Van Mieghem (Delft University of Technology).

The Belgian colleagues have proposed to organize a second Benelux workshop on Performance Analysis of Communication Systems in Belgium, in 2004.

There were 57 participants.

Organizing committee: Chris Blondia (University of Antwerp), Sem Borst (CWI), Onno Boxma (TU/e and EURANDOM).

April 23 - 26, 2003 SIM
Joint Workshop on Statistical Data Mining and Pro-ENBIS meeting.

EURANDOM has had a long relationship to the ENBIS network and as work package leader is able to draw on its own experience in the area of statistical data mining and related areas. Indeed, EURANDOM has run two previous workshops in this area and was able to draw on its experience to put on a successful workshop as a Pro-ENBIS partner. EURANDOM has, fortuitously, also made this area its leading area within the statistical programme of EURANDOM. For example, there were parallel grant applications in the area. In particular, EURANDOM is a partner on the EU 6th Framework Programme Network of Excellence, PASCAL.

Another beneficial aspect of the involvement with data mining is the wider heading of computational and statistical learning. The subject is probably the fastest moving area of statistics. It is driven by the need to perform data analysis and modelling on very large data sets. The activity can range from relatively standard clustering methodologies to sophisticated use of kernel-based methods which are able, in addition to more standard curve fitting styles, to detect unforeseen patterns in the data. A brief summary of a current review of the area is that data can be split broadly into model plus patterns plus noise.

The meeting divided broadly into general theoretical and conceptual sessions on the first day and more practical and hands on talks on the second day, although theory and application were mixed throughout the workshop.

The most attractive feature of the workshop was the coming together of leading members of the statistical and the computer science community. Thus, the statistical community was very well represented by David Hand, Jerry Friedman and Alan Carr, each of whom described the challenges of the subject and why these were non-standard from a statistical point of view. Jacqueline Meulman gave an interesting talk from a more social science perspective, while Petra Perner and Arno Siebes spoke more from a computer science perspective.

It had always been the intention to include a practical session, and Andrea Ahlemeyer-Stubbe and Elsa Jordaan represented this area well; the first in relation to marketing and the second in relation to statistical process control. Elsa works for Dow Chemical and had just completed her PhD in the area. Other notable industrial participation was from Philips Research.

In conclusion, this was a very well received workshop and the useful items can be listed as follows:
1) Helping to establish data mining at a high technical level within the Pro-ENBIS framework.
2) Establishing good links between Pro-ENBIS and the US, particularly to the National Institute of Statistics (Director Alan Carr).
3) Involvement of Industry.
4) The contacts with Dow and Phillips should be built upon enhancing of networking for Pro-ENBIS via EURANDOM (e.g. to Pascal).

Participants: 46 to the workshop and 28 to the meeting.
The workshop was funded through The EC Thematic Network Pro-ENBIS.

June 23-27, 2003 ISS
Dutch-Hungarian Workshop (Budapest) on Randomness in Space and Time.

The workshop presented a broad scope of recent subjects in probability and mathematical statistical mechanics. The covered subjects included:

- Random walks in random and non-random environment
- Gibbs measures
- Zeros of Gaussian power series and determinantal point processes
- Self-organized criticality
- Ergodic properties and decay of correlations in billiards
- Hydrodynamic limits and fluctuations
- Quantum dynamics of many degrees of freedom.

On the last day of the conference special attention was paid to the work of Joszef Fritz (whose birthday was celebrated) on hydrodynamic limits of stochastic many particle system. In particular, the seminal work of Fritz and Toth on hydrodynamic limits under eulerian scaling beyond shocks was presented.

Besides many interesting lectures, the workshop provided ample time for meeting and interesting discussions between the participants. The presence of both excellent young researchers and world-top senior researchers contributed to the stimulating and inspiring climate of the workshop.

Participants: 35.
The workshop was largely funded through NWO/OTKA funds.

September 8-11, 2003 SN
Heavy Traffic Analysis and Process Limits of Stochastic Networks.

Stochastic networks are used to model complex manufacturing, telecommunications and computer systems. The stochastic processes, which are central to these models, are typically difficult to analyze exactly. However, the underlying systems often operate in "heavy traffic", meaning that the nominal load on the system is approximately equal to the system's capacity. In this regime, it is sometimes possible to approximate the stochastic processes of interest by processes which are easier to analyze, such as diffusion processes, Levy processes or deterministic "fluid models". Heavy traffic analysis can provide conditions under which such approximations are mathematically justified. This area of research has a strong tradition, going back to Kingman, Borovkov and Iglehart in the 1960's, and has reached a considerable level of mathematical maturity.

The goal of this workshop was to introduce the topic to those who are unacquainted with it and to stimulate further research in the area. The first day of the workshop consisted of tutorials given by Avi Mandelbaum and Ruth Williams. The remaining days consisted of a mix of five 60-minute invited lectures and nine 45-minute contributed talks.

The full list of speakers was:
R. Atar (Technion), M. Bramson (Minnesota), M. Harrison (Stanford), D. Korshunov (Novosibirsk), L. Kruk (Lublin), S. Kumar (Stanford), A. Mandelbaum (Technion), K. Ramanan (Carnegie-Mellon), M. Reiman (Bell Labs), P. Robert (INRIA Rocquencourt), D. Shah (Stanford), S. Shreve (Carnegie-Mellon), A. Stolyar (Bell Labs), G. Weiss (Haifa), R. Williams (UC San Diego), D. Wischik (Cambridge).

Approximately 50 researchers and students, from various countries, attended the workshop. Many leading researchers in the field were present. Participants felt that the lectures were of high quality and that the workshop provided a valuable stimulus to further research in this area.

Organizing committee:
Onno Boxma (TU/e and EURANDOM), Christian Gromoll (EURANDOM), Bert Zwart (TU/e and EURANDOM).

September 18 and 19, 2003 SERA
AON Re Europe Science Team Meeting "Statistical Issues in Actuarial Risk Modelling: Dependence Modelling and Detrending".

The AON Re Europe Science Team used the premises of EURANDOM to hold its 2003 Fall meeting. The Team consists of Dietmar Pfeifer (Universität Oldenburg, Germany), Jan Beirlant (Katholieke Universiteit Leuven, Belgium), Paul Deheuvels (Université Paris VI, France), Rolf Hüsler (Universität Bern, Switzerland) and Juan L. Vilar Zanon (Universitate Complutense Madrid, Spain). The team focuses on actuarial statistical research originating from or related to problems encountered at different branches of AoN Re Europe. During the workshop members of the team, invited international experts on detrending and/or dependence modelling, and technical experts from the AoN branches exchanged views on these subjects. The morning sessions contained 45-minutes presentations with discussion by the invited experts. In the afternoon, round table discussions highlighted real life problems and data sets from the AoN branches.

The modelling of dependent risks recently has received a lot of attention. More specifically, copulas are being fitted to insurance data as the actuarial community has become aware of the impact of dependence in actuarial and financial computations. In the reinsurance world, extreme value copulas receive a lot of attention when describing the joint occurrence of large claims. On the other hand, detrending exercises often appear in actuarial risk management. Besides economic trends, the increase in number as well as in severity with respect to claims due to natural catastrophes are considered, particularly windstorm, hailstorm or flooding.

Valerie Chevez-Demoulin (ETHZ, Zürich, Switzerland) described smooth non-stationary generalized additive models for sample extremes, in which spline smoothers are incorporated into models for exceedances over high thresholds. Fitting was done by maximum penalized likelihood estimation with uncertainty by differences of deviances and by bootstrap simulation. The approach in the insurance context was illustrated on simulated data. Dietmar Pfeifer showed how modern Integrated Risk Management (IRM) and Dynamic Financial Analysis (DFA) rely heavily on an appropriate modelling of stochastic behaviour of the various risky assets and on processes that influence the performance of the company under consideration. He showed that a major challenge was the substantial and realistic description and modelling of the various complex dependence structures between such risks, showing up on all scales. Illustrations of risk processes in collective risk theory were given. Yuri Goegebeur (Katholieke Universiteit Leuven, Belgium) treated extremal problems using the methodology of regression. Building on univariate and bivariate extreme value theory, he showed how second order extreme value theory could be employed to partially parametrize covariates. Illustrations from fire and automobile insurance were given as well.

Nader Tajvidi (Lund Institute of Technology, Sweden) spoke on the distribution and dependence-function estimation for bivariate extreme value distributions. Two new methods were proposed, the first based on a multiplicative modification of a technique of Pickands, the other based on spline smoothing under constraints. Both methods produce estimators satisfying the conditions of dependency functions. Applications of the dependence function estimators were given to es-

timate the bivariate distribution, its density as well as predictors. Arthur Charpentier (ENSAE-CREST, Université Paris 9, France) discussed specific properties of copulas and their relationship to specific actuarial activities. More specifically, copulas emphasizing correlations among large losses are crucial in property and casualty insurance. The lecturer focused on tail conditional copulas, restricting himself later to Archimedian copulas. Functional measures based on Spearman's rho or Kendall's tau illustrated tail dependence modelling. Also Paul Deheuvels discussed copulas and their estimation. He discussed some of the most useful families of copulas that have been introduced in the literature. Apart from their theoretical properties and estimation, he illustrated the use of copulas with some practical data.

The workshop was attended by some 30 participants. Apart from the AoN Re Europe Science Team and the speakers, participants came from EURANDOM, from universities in The Netherlands and Belgium. The presence of practitioners of Aon branches from Belgium, France, Germany and The Netherlands greatly enhanced the relevance of the workshop. This was particularly clear during the discussion meetings on the afternoons of Thursday and Friday.

Organizing committee: Jef L. Teugels, with J. Beirlant and D. Pfeifer

October 16, 2003,
"STIELTJES AFTERNOON".
Two lectures were given:
Stieltjes Professor G. Slade (University of British Colombia, Vancouver, Canada) talked about scaling limits and super-Brownian motion. Brownian motion is well known as the scaling limit of random walks. For random walks that undergo critical branching, the appropriate generalization is super-Brownian motion. The talk gave an introduction to super-Brownian motion, and described how it arises as the scaling limit of lattice trees and critical percolation clusters in high dimensions.

Professor B. Nienhuis (University of Amsterdam, The Netherlands) showed applications of Loewner's equation to critical phenomena. In the early 20th century Loewner found a differential equation to describe conformal maps from the disk with an increasing slit onto the unslit disk. At the end of the 20th century Schramm was able to apply this equation to conformally invariant processes in the plane. Since then it has developed into an approach by which a number of universal properties of critical phenomena can be calculated rigorously.

Professor W.R. van Zwet (Chair of the Advisory Committee for the "Stieltjesprijs") explained the report of the jury and professor R.A. van Santen (Rector Magnificus of the TU/e) awarded the "Stieltjesprijs" to Dr. Nelly Litvak, former EURANDOM postdoc and currently assistant professor at Twente University. Each year the "Stieltjesprijs" (Stieltjes Prize) is given to the Stieltjes student with the best Ph.D. thesis.

Participants: 35.
Sponsored by the Thomas Stieltjes Institute.

December 8-10, 2003 **ISS**
Gibbs vs. non-Gibbs in Statistical Mechanics and Related Fields.

Non-Gibbsian measures have originally been detected in the context of renormalization group pathologies, by R.B. Griffiths, P.A. Pearce and R.B. Israel. They typically are obtained by renormalizing Gibbs measures which describe low-temperature or critical phases. They were identified as such and more systematically studied by van Enter, Fernandez and Sokal in the early

nineties. Since then they have been shown to occur also in the description of non-equilibrium measures (both in the steady-state and in the transient regimes) in disordered systems (the Morita formalism), and in non-uniformly hyperbolic dynamical systems. Related developments and questions occurred in the study of (non-Feller) interacting particle systems and in the theory of infinitely many interacting diffusions. Inspired by R.L. Dobrushin, a more refined classification into almost and weakly Gibbsian measures was developed, and the corresponding extension of the thermodynamic formalism to such generalized Gibbs measures was studied.

The workshop brought together people working on these various developments. Several of these topics were reviewed and also a number of new results were presented. Contact between the representatives of these different streams of research proved to be very fertile. A particular highlight of the meeting was the up to now unpublished proof by R. Israel of the result that Gibbs measures are exceptional among all probability measures in the topological generic sense. About 25 participants attended the workshop and lectures were given by:

R. Israel, University of British Colombia, Vancouver; R. Kühn, King's College, London; O. Haggstrom, Chalmers University of Technology, Gothenburg; C. Külske, WIAS, Berlin; R. Lefevere, Université Catholique de Louvain; S. Pigorov, Institute for Problems of Information Transmission, Moscow; R. Fernandez, Université de Rouen; E. Olivieri, Università Degli Studi Di Roma 'Tor Vergata'; E. Verbitskiy, Philips Research, Eindhoven; J.R. Chazottes, CNRS, Paris; M. Yuri, Sapporo University; S. Roelly, University of Potsdam; H. Guiol, École Polytechnique Féderale de Lausanne; F. den Hollander, EURANDOM; C. Maes, Katholieke Universiteit Leuven.
Proceedings of the workshop will appear in a special volume of the journal Markov Processes and Related Fields.

Organisers: A.C.D. van Enter (Groningen), F. Redig (Eindhoven), and A. Le Ny (Orsay).
This workshop was sponsored by the ESF-Programme "Phase Transitions and Fluctuation Phenomena for Random Dynamics in Spatially Extended Systems" (RDSES).

Summary of the workshops

ISS: 2
SERA: 3
SIM: 2
SN: 2
CMB: 1
Stieltjes afternoon: 1
In total 11 workshops and/or other scientific events were (co)-organised.
Furthermore, EURANDOM co-sponsored the "Nederlands Mathematisch Congres 2003" in Nijmegen.

6.2. Lectures and Seminars

EURANDOM organises, on a regular basis, the following seminars:

EURANDOM Seminar Interacting Stochastic Systems:

On the variety of critical thresholds in the Bak-Sneppen evolution model
D. Znamenski, Vrije Universiteit Amsterdam, The Netherlands
January 9, 2003

Almost Sure Limit Theorems for Expanding Maps of the Interval
J. Chazottes, CNRS-École Polytechnique, Palaiseau, France
February 6, 2003

Distributed algorithms with dynamical random transitions
N. Guillotin-Plantard, Université Claude Bernard Lyon I, France
February 27, 2003

Subexponential behaviour of the Dirichlet heat kernel
M.van den Berg, School of Mathematics, University of Bristol, UK
March 4, 2003

Large deviations results for coupled map lattices
J. Bardet, Paris X, France
April 15, 2003

Random subgraphs of high-dimensional tori
R.van der Hofstad, TU Eindhoven/ EURANDOM, The Netherlands
April 29, 2003

An introduction to abelian sandpiles
F. Redig, TU Eindhoven/EURANDOM, The Netherlands
May 13, 2003

Mean field spin glasses: an introduction and some rigorous results - part I
F. Toninelli, EURANDOM, The Netherlands
May 20, 2003

Mean field spin glasses: an introduction and some rigorous results - part II
F. Toninelli, EURANDOM, The Netherlands
May 27, 2003

The finite system scheme for state-dependent multitype branching processes
P. Pfaffelhuber, University of Erlangen, Germany
June 3, 2003

Localization-delocalization phenomena for random interfaces
E. Bolthausen, Institut für Mathematik, Universität Zürich, Switzerland
June 6, 2003

Mixing properties of polygonal Markov fields on the plane
Th. Schreiber, University of Torun, Poland
June 17, 2003

Power-law distributions in natural and social systems
B. D. Hughes, University of Melbourne, Australia
September 9, 2003

Short Type Asymptotic for fractal spaces
A. Telcs, Budapest University, Hungary
September 9, 2003

Chains with complete connections and one-dimensional Gibbs measures
G. Maillard, University of Rouen, France
September 30, 2003

Stieltjes professor

The lace expansion and its applications
G. Slade, University of British Columbia, Canada
October 8, 15, 22, 29 and November 5 and 12, 2003

Mark Kac Seminar

The lace expansion for percolation
G. Slade, University of British Columbia, Canada
and
Triviality of the hierarchical Ising model in four dimensions
Takashi Hara, Nagoya University, Japan
October 10, 2003

Probabilistic extensions of dynamical systems and their applications to limit theorems
M. Gordin, Steklov Institute of Mathematics, Saint Petersburg, Russia
October 20, 2003

Long-lived lattice trees for d>8
M. Holmes, University of British Colombia, Canada
November 10, 2003

Simulations of charge transport in disordered polymers
F. Pasveer, Eindhoven University of Technology, The Netherlands
November 11, 2003

Invariant measures of some random iterated function systems which are contracting on average and their dimension
K. Simon, Technical University of Budapest, Hungary
December 11, 2003

EURANDOM Seminar Stochastics of Extremes and Risk Analysis:

Some model extensions in ruin theory
H. Albrecher, Graz University of Technology, Austria
February 20, 2003

Precise Estimates for the Ruin Probability in Finite Horizon in a Discrete-time Model with Heavy-tailed Insurance and Financial Risks
Q. Tang, University of Amsterdam, The Netherlands
May 22, 2003

Forecasting with artificial neural network models
G. Rech, Stockholm School of Economics, Sweden
June 17, 2003

Empirical likelihood methods with heavy tails
L. Peng, Georgia Institute of Technology, USA
June 20, 2003

Multi-period risk estimation in Garch models
R. Brummelhuis, University of London, UK
October 6, 2003

Approximations to the tail empirical distribution function with application to testing extreme value conditions
D. Li, Erasmus Universiteit, The Netherlands
November 10, 2003

Long Memory Processes: Forecasting and Extreme Values
J. Collet, Université de Reims, France
November 10, 2003

EURANDOM Seminar Statistical Information and Modelling:

Locally Stationary Wavelet Processes
P. Fryzlewich, University of Bristol Department of Mathematics, UK
January 23, 2003

Change point problems in the model of logistic regression. Estimating transition probability by logistic regression
A. Vexler, Hebrew University, Department of Statistics, Israel
February 4, 2003

Learning on Manifolds
M. Belkin, University of Chicago, USA
February 4, 2003

Nonparametric amoc changepoint tests for stochastically ordered alternatives
G. Gurevich, Technion, Institute of Technology, Israel
March 11, 2003

Two sample tests for current status data
V. Kulikov, University of Technology Delft, The Netherlands
March 11, 2003

An invitation to quantum tomography
M. Guta, EURANDOM, The Netherlands
March 25, 2003

What does pharmacokinetics model?
J.K. Lindsey, University of Liege, Belgium
April 29, 2003

Testing conditional independence with a continuous control variable
W. Bergsma, Universiteit Tilburg, The Netherlands
May 19, 2003

"Zero-Point" in the Evaluation of Martens Hardness Uncertainty
G. Brondino, Politecnico di Torino, Italy
May 20, 2003

Algebraic Aspects of Statistical Modeling
A. Koloidenko, EURANDOM, The Netherlands
May 20, 2003

Universal Modeling: introduction to "modern MDL"
P. Grünwald, CWI and EURANDOM, The Netherlands
September 23, 2003

Adjusted Viterbi Training
A. Koloidenko, EURANDOM, The Netherlands
October 10, 2003

Short Introduction to Graphical Models
W. Bergsma, EURANDOM, The Netherlands
November 3, 2003

Updating Probabilities
P. Grünwald, CWI and EURANDOM, The Netherlands
November 7, 2003

Testing nullity in regression framework
Y. Rozenholc, Paris Jussieu, France
November 7, 2003

Kernel Based Algorithms and Statistical Learning Theory
D. Herrmann, The Bosch Group, Germany
November 14, 2003

Problems in Quantum Statistical Information
R. Gill, University of Utrecht and EURANDOM, The Netherlands
November 21, 2003

Modeling the Li-ion rechargeable batteries
D. Danilov, EURANDOM, The Netherlands
December 5, 2003

On the Equivalence of Algorithms for Computing Effects in Factorial Designs
P. v.d. Ven, EURANDOM, The Netherlands
December 12, 2003

Qrandom seminars

Qubits from Number States and Bell Inequalities for Number Measurements
J.-A. Larsson, Linköping University, Sweden
February 6, 2003

Covariance: CP-maps, POVM's, Instruments... Optimal covariant measurements
M. Guta, EURANDOM, The Netherlands
April 16, 2003

An ergodic theorem for quantum trajectories
H. Maassen, Katholieke Universiteit Nijmegen, The Netherlands
April 16, 2003

The subadditivity of the quantum entropy
D. Petz, Budapest University, Hungary
May 28, 2003

Continuous time limit of repeated measurement
H. Maassen, University of Nijmegen, The Netherlands
July 16 2003

Estimation of unitary quantum operations
M. Ballester, University of Utrecht, The Netherlands
July 16, 2003

Quantum trajectories in QED cavities
D. Spehner, University of Essen, Germany
October 30, 2003

Quantum Theory of Measurement and Macroscopic Observables
B. Janssens, University of Nijmegen, The Netherlands
November 14, 2003

Joint SOR/EURANDOM Stochastic Networks Seminar: (jointly organised with the Stochastic Operations Research group of TU/e)

A two priority stochastic fluid model
I. Adan, Eindhoven University of Technology, The Netherlands
January 21, 2003

Limits of on/off hierarchical product models for data transmission
S. Resnick, Cornell University, USA
January 22, 2003

Singular perturbation of Markov chains: a survey
M. Haviv, Hebrew University of Jerusalem, Israel
February 4, 2003

Sample path large deviation asymptotics for occupancy problems
P. Whiting, Bell Labs, USA
March 4, 2003

Heterogeneous finite-source retrial queues
J. Sztrik, University of Debrecen, Hungary
April 15, 2003

Tail asymptotics for the supremum of a random walk when the mean is not finite
D. Denisov, Heriot-Watt University, UK
May 23, 2003

Asymptotic Analysis of Communication Networks
O. Ozturk, Purdue Universtiy, USA
June 3, 2003

Capacity of multiservice WCDMA Networks with variable GoS
N. Hegde, CWI, Amsterdam, The Netherlands
June 10, 2003

On measuring fairness in queues
H. Levy, University of Tel-Aviv, Israel
October 9, 2003

Perturbation analysis for denumerable Markov chains with applications to queueing models
R. Nunez-Queija, CWI and Eindhoven University of Technology, The Netherlands
October 21, 2003

2-dimensional Quasi-Birth-and-Death process with special transition structure.
A. Sleptchenko, EURANDOM, The Netherlands
November 4, 2003

The first Laurent series coefficients for singularly perturbed stochastic matrices
K. Avrachenko, INRIA, France
November 21, 2003

Heavy traffic analysis of a closed queueing system with Gated Random Order of Service
D. Denteneer, Philips Research, The Netherlands
December 2, 2003

Throughput analysis of two carousels
M. Vlasiou, EURANDOM, The Netherlands
December 16, 2003

EURANDOM Computational Molecular Biology Seminar:

Steady and casual partners as sources of HIV infection among homosexual men in Amsterdam
M. Xiridou, GGD Amsterdam, The Netherlands
March 6, 2003

Phylogenetic inference under a statistical model of sequence evolution
G. Lunter, Oxford University, UK
May 8, 2003

Statistical Issues in the Clustering of Gene Expression Data
D. Goldstein, ISREC, Switzerland
June 5, 2003

Estimation of the offspring mean for a size-dependent branching process
N. Lalam, Université Paris Sud 11, France
October 9, 2003

Semi-Markov model versus Competing risk model
A. Afchain, Université Paris Sud 11, France
October 9, 2003

EURANDOM Postdoc Seminar:

Walking on random trees, looking for ancestors and open problems
B. Basrak, EURANDOM
January 31, 2003

A technique for exponential change of measure for Markov processes
Z. Palmowski, EURANDOM
February 13, 2003

Perturbations of covering algorithms
P. van der Wal, EURANDOM
February 27, 2003

A leisure problem with urns
M. Vlasiou, EURANDOM
February 28, 2003

Effect of the model selection in regression analysis
D. Danilov, EURANDOM
March 20, 2003

Local Statistics and Coding of Natural Images
A. Koloidenko, EURANDOM,
March 27, 2003

Mean field spin glasses: an introduction
F. Toninelli, EURANDOM
April 10, 2003

Longest queue priority systems
A. Sleptchenko, EURANDOM
May 1, 2003

Critical phenomena for infection spreading
A. Sakai, EURANDOM
May 15, 2003

On Statistics of Gene Mapping
B. Basrak, EURANDOM
May 22, 2003

Bayesian Adaptation
J. Lember, EURANDOM
June 5, 2003

Some ideas for a conjecture of Nussbaum
B. Lemmens, EURANDOM
July 10, 2003

Two-dimensional critical percolation and its continuum scaling limit
F. Camia, EURANDOM
October 9, 2003

Minimax estimation of fractional derivatives
F. Enikeeva, EURANDOM
October 23, 2003

Measuring market risk with "Value-at-Risk"
M. Sarma, EURANDOM
November 6, 2003

Risk measures of non-linear processes
S. Ladoucette, EURANDOM
December 4, 2003

- Interacting Stochastic Systems Seminar (ISS) including Mark Kac Seminar: 26
- Stochastics of Extremes and Risk Analysis Seminar (SERA): 7
- EURANDOM Seminar Statistical Information Modelling (SIM): including Qrandom Seminar 27
- Joint SOR / EURANDOM Stochastics Networks Seminar (SN): 14
- Computational Molecular Biology Seminar (CMB): 5
- EURANDOM Postdoc Seminar and Problem Session: 16

In total there were 95 lectures in 2003

6.3. EURANDOM visitors in 2003

	January	
F. Nardi (Università degli Studi di Roma, I)	Jan. 1-15, 2003	ISS
E. Scoppola (Università degli Studi "Roma Tre", I)	Jan. 20-22, 2003	ISS
S. Resnick (Cornell University, USA)	Jan. 21-26, 2003	SN
A. Greven (Friedrich-Alexander-Universität Erlangen-Nürnberg, D)	Jan. 28-30, 2003	ISS
	February	
G.M. D'Ariano (Università di Pavia, I)	Feb. 1-8, 2003	CSM
M. Haviv (Hebrew University of Jerusalem. Israel)	Feb. 3-5, 2003	SN
J. Gaertner (Technische Universität Berlin, D)	Feb. 3-9, 2003	ISS
M. Belkin (University of Chicago, USA)	Feb. 3-7, 2003	CSM
J.A. Larsson (Linkjoping University, S)	Feb. 3-9, 2003	CSM
U. Yechiali (Tel Aviv University, IL)	Feb. 8-14, 2003	SN
H. Albrecher (Universität Graz, A)	Febr. 9-March 1, 2003	SERA
N. Guillotin-Plantard (Université Claude Bernard Lyon I, Fr)	Feb. 15-March 1, 2003	ISS
P. Clement (TU Delft, NL)	Feb. 17, 18, 24 & 25, 2003	ISS
W. Desch, (Universität Graz, A)	Feb. 17-28, 2003	ISS
	March	
M. v.d. Berg (University of Bristol, UK)	March 2-14, 2003	ISS
J. Gaertner (Technische Universität Berlin, D)	March 16-22, 2003	ISS
	April	
J. Sztrik (University of Debrecen, HU)	April 12-17, 2003	SN
J.P. Bardet (Université de Paris X, F, and EPFL, Lausanne, Ch)	April 13-15, 2003	ISS
	May	
G. Lunter (University of Oxford, UK)	May 7-9, 2003	CMB
D. Denisov (Heriot-Watt University, UK)	May 20-24, 2003	SN
D. Petz (Budapest University of Technology and Economics, HU)	May 28-31, 2003	CSM

	June	
O. Ozturk (Purdue University, USA)	June 2-5, 2003	SN
F. Nardi (Università degli Studi di Roma La Sapienza, I)	June 2-26, 2003	ISS
L. Peng (Georgia Institute of Technology, USA)	June 2 - July 13, 2003	SERA
P. Pfaffelhuber (Universität Erlangen-Nürnberg, D)	June 2-6, 2003	ISS
D. Goldstein (ISREC, CH)	June 5&6, 2003	CMB
B. Brzezniak (University of Hull, UK)	June 9-22, 2003	ISS
T. Schreiber (University Torun, PL)	June 15-20, 2003	ISS
M. Huskova (Charles University, Prague, CZ)	June 16-30, 2003	AS
	July	
D. Perry (University of Haifa, IL)	July 13-18, 2003	SN
O. Kella (Hebrew University of Jerusalem, IL)	July 13-18, 2003	SN
K. Simon (Technical University Budapest, HU)	July 28-Aug. 9, 2003	ISS
	September	
G. Slade (University of British Columbia, CA)	Sept. 1-Nov. 30, 2003	Stieltjes Professor
M. Holmes (University of British Columbia, CA)	Sept. 1-Nov. 30, 2003	ISS
A. Telcs (CEU Graduate School of Business, HU)	Sept. 3-12, 2003	ISS
B. Hughes (University of Melbourne, AU)	Sept. 7-19, 2003	ISS
A. Greven (Friedrich-Alexander-Universität Erlangen-Nürnberg, D)	Sept. 14-19, 2003	ISS
T. Hara (Nagoya University, Japan)	Sept. 14-Oct. 13, 2003	ISS
H. Albrecher (Catholic University Leuven, Be)	Since September 2003: every 2 weeks a 2 day visit	SERA
	October	
H. Levy (Tel Aviv University, IL)	Oct. 7-10, 2003	SN
J. Gaertner (Technische Universität Berlin, D)	Oct. 7-16, 2003	ISS
R. Brummelhuis (University of London, UK)	Oct. 10, 2003	SERA
M. Gordin (Steklov University of Mathematics, Saint Petersburg, Russia)	Oct. 19-23, 2003	ISS
	November	
J. Collet (Université de Reims, Fr)	Nov. 10-14, 2003	SERA
D. Herrmann (The Bosch Group, D)	Nov. 14&15, 2003	SIM

	December	
K. Simon (Technical University Budapest, HU)	Dec. 11, 2003	ISS
W. König (TU Berlin, D)	Dec. 16-19, 2003	ISS

In total 46 researchers visited EURANDOM in 2003 (from several days up to 3 months). Total residence time: 75,5 weeks.

Distribution over the programmes:

ISS	24 researchers - 42 weeks
SERA	5 researchers - 7 weeks
SIM	5 researchers - 6 weeks
SN	9 researchers 6 weeks
CMB	2 researchers 1 week
Stieltjes Chair:	13,5 weeks (3 months)

7. INTERNATIONAL COOPERATION and FUNDING

7.1. International Cooperation

As the previous sections show, international cooperation is flourishing through a.o. workshops and the visitors programme. Joint workshops, like the Benelux-Workshop together with FWO (which is expected to get a continuation next year in Belgium) and the workshop "Statistical Aspects of Microarray Data" in Aarhus, are examples. Many international organisations are supporting activities of EURANDOM by sending their researchers to attend workshops or to spend time as a visitor.

During 2003 EURANDOM continued to integrate workshops with visits of senior and junior scientists for a period before or after the workshop (e.g. Redig in Budapest). Many researchers from EURANDOM went to work with colleagues abroad (e.g. Camia in New York; Toninelli in Rome; Lemmens in Berlin).

EURANDOM is member of ERCOM, the European Research Centres on Mathematics, a committee under EMS (European Mathematical Society) consisting of mathematical institutes that host visitors and workshops. Through members of the Scientific Council and members of the Steering Committees, as well as scientists active at EURANDOM and postdocs who left the institute, many contact lines continue to tie EURANDOM to mathematical institutes and universities all over the world.

EURANDOM organised its first activity for EURANDOM-Alumni in January 2004 and for that reason set up a database with current addresses and positions of former EURANDOM postdocs.

EURANDOM chairs the ESF Scientific Programme on "Random Dynamics in Spatially Extended Systems" involving 13 European countries. EURANDOM is involved in a Thematic Network under the EC, Pro-ENBIS (European Network for Promoting Business and Industrial Statistics). These networks will strengthen our contacts in this area. EURANDOM participates in a Network of Excellence, PASCAL (start December 1, 2003), "to build a Europe-wide Distributed Institute that will pioneer principled methods of pattern analysis, statistical modelling and computational learning as core enabling technologies for multimodal interfaces that are capable of natural and seamless interaction with and among individual human users".

EURANDOM joined an application for an Integrated Project, BITOPIA-FUGE. "The objective of the Integrated Project is to provide a comprehensive bioinformatics software suite for optimal integration of computational analysis and prediction techniques for sequence, expression and functional genomics data, in order to streamline and accelerate biotechnological, pharmaceutical and medical discovery projects. Rather than coupling and integrating databases, typically achieved through the development of interface software and general query systems, the IP aims to deliver a toolkit that integrates information from the included data sources at a higher level, through a tools-directed and thus interpretation-based approach with an additional emphasis on integrating expert knowledge. The ultimate aim is to provide a functional genomics software suite that is able to go beyond the analysis skills of human experts aided by traditional bioinformatics techniques".

EURANDOM cooperates with German scientists through the DFG Schwerpunkt 1033 "Interagierende stochas-

tische Systeme hoher Komplexität" and through a Dutch-German Bilateral Research Group on Mathematics of Random Spatial Models from Physics and Biology.

7.2. Cooperation in The Netherlands

There are formal agreements of cooperation with EIDMA (the Euler Institute for Discrete Mathematics), the Thomas Stieltjes Institute for Mathematics and the Mathematical Research Institute.

Some postdocs were involved in teaching activities; this year only at Eindhoven University of Technology (TU/e).

There are intensive links with the Department of Mathematics in Eindhoven through joint seminars, visitors, researchers working together, etc., and, on a less intensive level, with the Departments of Technology Management, Chemical Engineering and Chemistry and Biomedical Technology.

7.2 Funding

On the national level, financial support of EURANDOM was provided by NWO (up to 2007) and TU/e (up to 2006) based on the "EURANDOM Business Plan 2003-2007".

EURANDOM continued activities in the area of funding agreements between NWO and European research councils. With DFG and FWO there is intensive cooperation through co-funding of workshops and visitors at EURANDOM. Most science organisations are willing to finance postdoc and/or visitor positions based on personal applications with the respective science organisations.

In 2003, 11 postdocs and PhD students were paid via external funds, among which grants from FWO (1), NWO (2), NSF (part of 2003), EC/Marie Curie Fellowship (part of 2003) and TU/e funding (2). Furthermore, KNAW and NWO co-financed workshops in 2003. Philips Electronics Nederland BV funded one PhD position for cooperation in the area of cable access networks. The project with Philips on "Modelling and Management of Batteries", which started in 2000, was extended in 2001 and continued to receive funding through the EET-programme of the Ministry of Economic Affairs (1 postdoc, 1 PhD position and additional support for scientific guidance). The research project on 'Signature Analysis' was continued with Flextronics (after the take over of the Dutch Xerox organisation by Flextronics) and was also EET-funded (1 postdoc, 1 PhD student and additional support for scientific guidance).

One longterm visitor was sponsored through the NWO visitor programme; several German scientists visited EURANDOM on DFG sponsoring; the NWO/OTKA programme financed the Budapest workshop in June, and also several visits of Hungarian scientists to EURANDOM and elsewhere in The Netherlands. Another long term visitor, the Stieltjes professor, Gordon Slade, was partly funded by the Thomas Stieltjes institute (2 out of 3 months)

The joint NWO-OTKA project networking and exchange of scientists with Hungary ran successfully in 2003.

An INTAS programme "The Mathematics of Stochastic Networks" is coordinated by Boxma (until July 1, 2003). Another INTAS programme "Complex Stochastic Models: Structures, Asymptotics and Estimations" runs since Summer 2003, coordinated by Friedrich Götze, Bielefeld.

On the European level (ESF and EU), EURANDOM continues investing in the concept of a 'European Research Area'.

8. FACILITIES

8.1. Computing and Communication

EURANDOM has ample computing facilities. Desktop equipment consists of personal computers that offer access to the Windows / NT and the Unix servers. The personal computers are connected through a high-speed network to these servers and to the Internet. EURANDOM has its own Unix computing server with 4 processors (SGI 200) and uses the NT servers of TU/e. If needed, computing time can be bought on the supercomputing facilities of NCF. The available mathematical software consisted of Mathematica, Maple, TE*x*, S-plus, Matlab, R, and programming languages such as C++, C and Visual Basic.

8.2. Library

A modest in-house library is available. As with computing power and software, EURANDOM follows the policy to acquire books and journals, when they are needed. EURANDOM has a working library, not a complete coverage of journals in the field of stochastics. Full-scale libraries are available for EURANDOM staff at TU/e, especially at the Department of Mathematics and access is given to the Dutch academic library system.

8.3. Housing

EURANDOM provides well-equipped office space, meeting and seminar rooms, a common room, and lunch facilities for its staff in its own building.

All other facilities of TU/e may be used; this includes a sports centre on campus, where staff can participate in various kinds of sports.

8. EXPENDITURE

The financial report for 2003 was approved in an audit by Deloitte & Touche. From this audited report we provide a summary of the expenditure.

Expenditure (in kilo euros)

Staff	1521
Advisors	121
Travel	45
Visitors	33
Housing	121
Workshops, Seminars	68
Books, Journals, Software	15
Depreciation costs	39
General costs	46
ICT Support	36
Software	5
TOTAL	2050