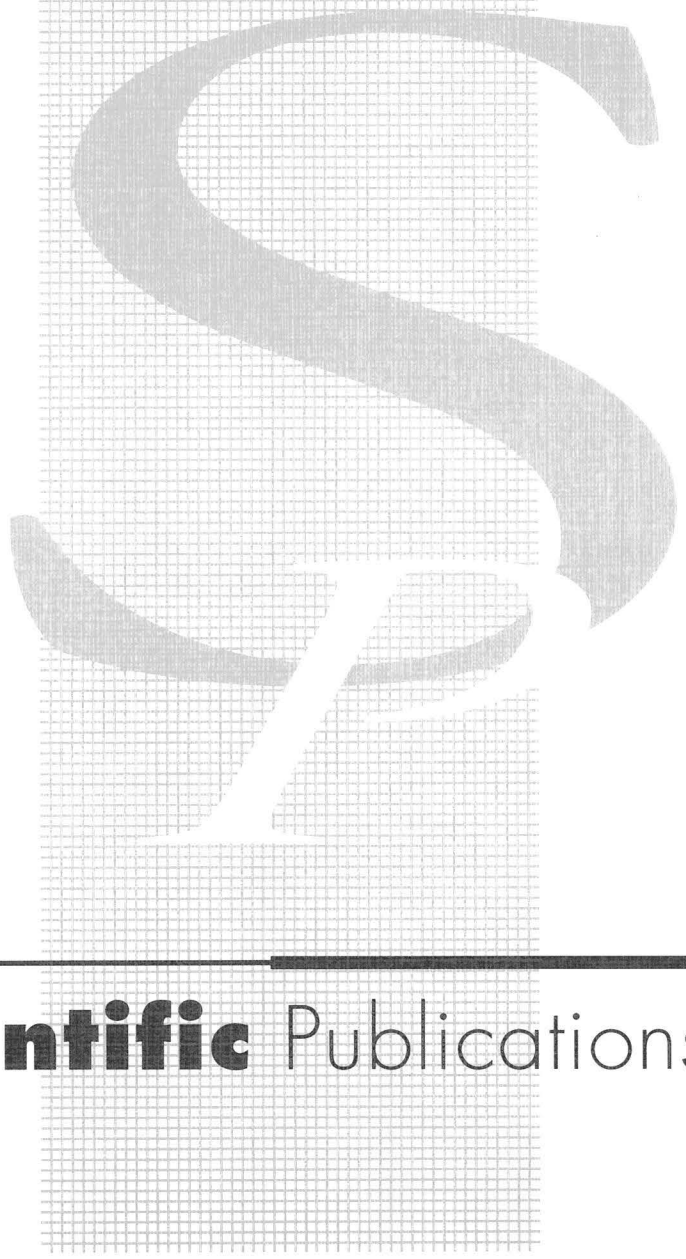

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Centrum voor Wiskunde en Informatica

CWI Scientific Publications

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Introduction

CWI is the National Research Institute for Mathematics and Computer Science. CWI is administrated by the Stichting Mathematisch Centrum (SMC), the Dutch foundation for promotion of mathematics and computer science and their applications. SMC is sponsored by the Netherlands Organization for Scientific Research (NWO). At present about 150 researchers are employed at CWI. CWI publishes, apart from the scientific reports, two series of publications through its own publication department: the Tracts and the Syllabi.

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This booklet contains information on the titles published in these series, as well as on some other publications. The abstracts are given for the Tracts and Syllabi published since 1991. On the back cover you will find ordering information and an order form. For further information contact our Sales Department: Mrs. D. Amende, telephone +31 20 592 4128, e-mail `tamende@cwi.nl`

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by M.W.P. Savelsbergh
Distribution management presents a variety of decision making problems at the three levels of strategic, tactical and operational planning. Decisions relating to the location of facilities may be viewed as strategic, while problems of fleet size and fleet mix determination can be termed

tactical. On the operational level, two problems prevail: the routing of capacitated vehicles through a collection of customers to pickup or deliver goods, the vehicle routing problem, and the scheduling of vehicles to meet time or precedence constraints imposed upon their routes, the vehicle scheduling problem. Only during the last decade, researchers started to emphasize the development of methods to solve real-life distribution problems. Before that, most effort has been put in methods that solve the basic theoretical models, especially for pure routing problems. To obtain methods that are able to solve practical problems the following two steps are taken. In part I of this book, the links between theory and practice are strengthened by the introduction of various side constraints into the theoretical models and the development of algorithms to solve these extended models. Three important classes of side constraints are emphasized: time windows at customers, combinations of pickups and deliveries, and precedence relations between customers. In part II of this book the application of a new tool provided by computer engineering called interaction is discussed. Solution approaches that are not purely algorithmic but that integrate algorithms and human problem solving capabilities via man-machine interaction are investigated. Part III is a report on efforts to design a model and algorithm management system for vehicle routing and scheduling problems.

1992 134 pages
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76. STABILITY, DUALITY AND DECOMPOSITION IN GENERAL MATHEMATICAL PROGRAMMING
by O.E. Flippo

In this tract, the notions of stability, duality and decomposition in General Mathematical Programming are analysed. New results are presented on each topic individually as well as on the interrelations between them. Known results on stability are presented in a single unifying framework, and some of them are extended. With respect to duality theory, it is proven that under a stability condition, strong duality is preserved if in the dual solution space only additively separable solutions are taken into consideration. Finally, extensions of the well-known Benders and Danzig-Wolfe Decomposition procedures to general mathematical programmes are presented. It is proven that both methods, even in their full generality, are dual to one another, and it is demonstrated that both methods converge asymptotically if a stability condition is met.

1991 228 pages
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77. ASPECTS OF NONPARAMETRIC DENSITY ESTIMATION
by A.J. van Es

The main part of this tract concerns the likelihood cross-validation method for bandwidth selection for nonparametric kernel density estimators. After a review of the history of the method we derive the almost sure rates of convergence to zero and the asymptotic normality of bandwidths obtained by this method. These results are compared with related results for least squares cross-validation. Special attention is paid to the performance of likelihood cross-validation in cases where the unknown density which we want to estimate is non-smooth. Properties of kernel estimators in such cases, where we allow a finite number of jumps and kinks in the density, are investigated in detail. We derive expansions of the bias and variance of kernel estimators. These results are used to derive asymptotically optimal bandwidths with respect to the mean squared error criterion and the supremum distance. A classical problem of stereology, Wicksell's corpuscle problem, serves

as an example of a situation where non-smooth densities occur naturally in a practical situation. The relatively poor performance of kernel type estimators in this problem inspired us to consider nonparametric maximum likelihood estimation. The final chapter is devoted to the Wicksell problem and the related deconvolution problem. Special attention is paid to specific uniform deconvolution problems, where the nonparametric maximum likelihood estimator of the unknown distribution function is known explicitly, as well as its asymptotic distribution. We also derive a local asymptotic minimax lower bound for deconvolution which we relate to the performance of the nonparametric maximum likelihood estimator in the uniform deconvolution case, and to other minimax results for deconvolution.

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78. EXERCISES IN PARALLEL COMBINATORIAL COMPUTING
by G.A.P. Kindervater

Operations research is one of the areas that are likely to benefit from advances in parallel computing. With respect to sequential computing, many operations research problems appear to be practically intractable, and for other problems a shorter solution time would be preferable. In this tract, we discuss some aspects of the impact of parallel computing on combinatorial operations research. First we deal with the classification of parallel computers according to processor autonomy, interprocessor communication, and model of operation. Next, we investigate what one can and cannot expect from parallelism on a theoretical basis. Within the class $\mathcal{P}$ of problems which are solvable in polynomial time, this leads to a distinction between 'very easy' problems, which are solvable in polylogarithmic parallel time, and the 'not so easy' ones, which are $\mathcal{P}$-complete. Then, we describe the implementation of standard algorithms for well-known combinatorial problems on existing parallel architectures. In these experiments, we encounter techniques such as divide and conquer, dynamic programming, and branch and bound. For branch and bound, we design and analyse a queueing network model that resembles the experiments performed in a master-slave environment. Finally, we address issues that withstand a real breakthrough of parallel computing: the diversity among existing parallel architectures as well as the wide gap between theoretical models and available computers.

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79. TOWARDS A SYMMETRICAL THEORY OF GENERALISED FUNCTIONS
by J.J. Lodder

This tract presents a program and a simple model for a new theory, the symmetrical theory of generalised functions. This theory is logically independent of other theories of generalised functions, such as distribution theory. The characteristic difference with distribution theory is the existence of a symmetrical inner product, in which generalised functions and test functions are treated on an equal footing. Every generalised function also serves as a test function. In particular the Dirac δ-function is treated as an ordinary function, and not just as a linear functional. The theory combines the symmetry of a Hilbert space with the availability of δ-functions. The theory allows and requires the multiplication and convolution of generalised functions. The product is not associative, so the well-known impossibility result of Schwartz does not apply. This book gives the construction of a simple model, which shows that a symmetrical theory of generalised functions is possible. The need to consider generalised functions and ordinary functions on the

same footing suggests the need for a reconsideration of the function concept, and therefore of the foundations of analysis. A first step in this direction is presented. The only prerequisite for following the construction is standard analytic function theory. An index to formulae makes it possible to use the book also as a reference for obtaining the action of operators and the products of generalised functions.

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80. CONTROL OF FREEWAY TRAFFIC FLOW

by S.A. Smulders

In this tract a freeway traffic control problem has been addressed and solved. The control problem consists of designing an optimal policy for the Dutch Motorway Control and Signalling System. The aim is to reduce the instabilities of traffic flow that occur when demand is high, and thereby to reduce the probability of congestion. As a first step towards solving the control problem we presented a mathematical model for freeway traffic. This model was investigated by means of stochastic simulation, which resulted in a modified model that shows reasonable behaviour in various traffic situations. An estimation algorithm, called *filter*, was developed next. It continuously estimates the state of traffic using the above-mentioned model and using on-line measurements from several freeway locations. The actual control problem is addressed last. A control policy is developed for the so-called homogenization measure. This measure was used in practice on several freeways in The Netherlands in 1983, using the Motorway Control and Signalling System. The optimal policy turns out to consist of switching on or off the measure whenever the traffic density crosses specific limits.

1996 158 pages
ISBN 90-6196-451-2 NLG 40.00

81. A PARALLEL OBJECT-ORIENTED LANGUAGE: DESIGN AND SEMANTIC FOUNDATIONS

by P. America and J.J.M.M. Rutten

The work described in this tract has been inspired by the parallel object-oriented language POOL. The tract describes the design of the language itself and the techniques that have been used to give it a formal semantics. Two styles of formal semantics are discussed: operational and denotational. The first describes the execution of a POOL program in terms of a sequence of transitions between states. The denotational semantics is defined compositionally. The mathematical domain used for the latter is a complete metric space, which is obtained as a solution of a reflexive domain equation. A method for solving such equations in a category of complete metric spaces is presented. A general technique is described for relating operational and denotational semantics, which is next applied to establish the correctness of the semantics for POOL.

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82. OPTIMALITY AND EQUILIBRIA IN STOCHASTIC GAMES

by F. Thuijsman

In this tract infinite horizon two-person stochastic games, with finite state and action spaces, are being considered. In such non-cooperative games play evolves as a stochastic process, controlled by the players, along a finite set of states, at each of which players receive payoffs according to their actions selected. Thus, players receive payoffs at each of an infinite number of stages and

in choosing their actions each of them is aiming to maximize his overall reward. There are three major ways to evaluate the sequences of stage payoffs as overall rewards for each of the players. These are referred to as discounted rewards, limiting average rewards and total rewards. Here total rewards are a generalization of summation of all payoffs, and one chapter is devoted to study properties of this criterion. In this tract however, the main emphasis is on limiting average rewards. Sufficient conditions are presented for the existence of limiting average epsilon-equilibria, while for the zero-sum case results are derived with respect to existence of stationary limiting average epsilon-optimal strategies. The strength of these results is being exposed by showing their impact on several structured classes of stochastic games, i.e. classes determined by ergodicity properties of the transition law (unichain stochastic games, stochastic games with state independent transitions and repeated games with absorbing states). Furthermore, characterizations for the existence of solutions in stationary strategies, as well as their relations with mathematical programs, are being exposed. This is done for solutions with respect to any of the three evaluation criteria. Many examples are given to illustrate the topics of discussion.

1992 107 pages
ISBN 90-6196-406-7 NLG 40.00

83. Convergence Properties of Recurrence Sequences
by R.J. Kooman

The aim of the work is the investigation of the asymptotic behaviour of solutions of homogeneous linear recurrences, whose coefficients converge. Grossly, the work consists of four parts. In the first part, which is of an algebraic nature, linear recurrences with rational coefficients are studied. It is shown that the set of numbers that are limits of quotients u_n/v_n, where $(u_n)_{n=1}^{\infty}$ and $(v_n)_{n=1}^{\infty}$ are two solutions of such a linear recurrence, is a field, containing the real algebraic numbers as a subfield. In the second part, linear recurrences of arbitrary order are studied, together with their matrix equivalents $M_n x_n = x_{n+1}$, where $(M_n)_{n=1}^{\infty}$ is some converging sequence of non-singular matrices. It is proved that in general, such a matrix recurrence can be decomposed into matrix recurrences of smaller order such that their limit matrices each have only eigenvalues with equal moduli. The theorem of Poincaré and Perron follows as a special case. In the third part, linear recurrences with fast converging coefficients are studied, and an upper bound for the speed of convergence is given in order that the solutions behave asymptotically like the solutions of a linear recurrence with constant coefficients. The last part of the work is devoted to a more detailed study of second-order recurrences. It appears that, for recurrences with regularly behaving coefficients, two main types occur: A first type, called hyperbolic, for which the recurrence has a subdominant solution, i.e. a non-zero solution $(v_n)_{n=1}^{\infty}$ such that $\lim u_n/v_n = 0$ for all solutions $(u_n)_{n=1}^{\infty}$ linearly independent with $(v_n)_{n=1}^{\infty}$, and such that for every non-zero $(u_n)_{n=1}^{\infty}$ that is a solution of the recurrence, $\lim u_{n+1}/u_n$ exists. The second type, called elliptic, contains recurrences having no subdominant solutions, whereas there exist solutions $(u_n)_{n=1}^{\infty}$ and $(v_n)_{n=1}^{\infty}$ for which both $\lim u_{n+1}/u_n$ and $\lim v_{n+1}/v_n$ exist and such that $\lim |u_n/v_n| = 1$. In the final chapter of the work, these results are applied to the solution of a problem posed by O. Perron, concerning the convergence of continued fractions whose coefficients are rational functions.

1991 111 pages
ISBN 90-6196-401-6 NLG 39.00

84. COMPUTATIONAL ASPECTS OF LIE GROUP REPRESENTATIONS AND RELATED TOPICS
edited by A.M. Cohen

The Spring 1990 sessions of the Computational Algebra Seminar at CWI, Amsterdam, have been mainly devoted to computational aspects of Lie group representations. This tract consists of the proceedings of that seminar. On one hand, better ways are brought forward to satisfy the physicists' demands to collect explicit data about representations, tensor product decompositions etc., while, on the other hand, new impulses are given to effective computations of invariants of groups acting on given spaces and even invariants of elements pertaining to these groups. The contributions by Bram Broer, Arjeh Cohen & Bert Ruitenburg, Marc van Leeuwen and Peter Littelmann reflect these activities. Omar Foda and Jan Sanders exploited the use of Lie group notions and techniques in computations for statistical mechanics and differential equations, respectively. The remaining two contributions are somewhat further away from the theory of Lie groups. Both cover topics of very general interest to computational algebra. Wim Ruitenburg focuses on the fundamental theorem of algebra from a constructive point of view: how to find (or, better, construct) roots of polynomials. He stresses that a solution in constructive algebra leads to the existence of an (admittedly, possibly highly impractical) algorithm providing that solution. Van den Essen elaborates on the Jacobian Conjecture. He shows that it is related to various branches of mathematics and how various forms of the conjecture have computational interpretations.

1991 142 pages
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85. ONE-DEPENDENT PROCESSES – TWO-BLOCK-FACTORS AND NON-TWO-BLOCK-FACTORS
by V. de Valk

This monograph consists of six articles on one-dependent processes. Therefore, the subject is in the first place probability theory, although the methods and applications not only appear in probability theory, but also in statistical physics, analysis, functional analysis, dynamical systems, variational problems, matrix theory and combinatorics. One-dependent processes are stationary, discrete time processes $(X_N)_{N\in\mathbb{Z}}$ with the property that at each time t the future $(X_N)_{N>t}$ is independent of the past $(X_N)_{N<t}$. Such processes can be constructed as a two-block-factor of an independent, identically distributed (i.i.d.) sequence $(Y_N)_{N\in\mathbb{Z}}$ by defining $X_N := f(Y_N, Y_{N+1})$ for some function f. Although it was conjectured for quite a long time that each one-dependent process is a two-block-factor, in the second article of this monograph we construct a continuum number of counterexamples of $0-1$ valued one-dependent processes that are not two-block-factors. In section 6 of the introduction we show a counterexample (by Aaronson, Gilat and Keane) of a one-dependent Markov process (assuming only 5 values) that is not a two-block-factor. In the third article of this monograph is proved that under certain extremal conditions on the two-correlations (the probability of a run of two ones) a $0-1$ valued one-dependent process is a two-block-factor. The third article is a simplification and a generalization of M. Katz (1971): Rearrangements of $(0-1)$ matrices, *Israel J. Math.* *9*, 53-72, where the maximal two-correlation over the class of $0-1$ valued two-block-factors is computed (for fixed probability of a one). In the first article the minimal two-correlation over the class of $0-1$ valued two-block-factors is computed (for fixed probability of a one). In the fourth article the maximal and minimal value of $\|M^2\|$ is computed over the class of $0-1$ valued $N\times N$ matrices M with K ones

(for fixed N and K). In the fifth article the construction of counterexamples of one-dependent processes that are not two-block-factors is generalized by a representation in terms of Hilbert spaces, vectors and bounded linear operators on Hilbert spaces. In the sixth article for an arbitrary process $(X_n)_{n\in\mathbb{N}}$ a nonlinear autoregression representation $X_n = f_n(X_1, \ldots, X_{n-1}, U_n)$ and a representation $X_n = g_n(U_1, \ldots, U_n)$ are constructed, where $(U_n)_{n\in\mathbb{N}}$ is an i.i.d. sequence with the property that U_n and $(X_1, \ldots, X_{n-1})$ are independent. For a special class of processes this provides a method to check whether a process is an m-block-factor of an i.i.d. process.

1994 178 pages
ISBN 90-6196-437-7 NLG 50.00

86. ON TOPOLOGICAL AND LINEAR EQUIVALENCE OF CERTAIN FUNCTION SPACES

by J.A. Baars and J.A.M. de Groot

For a completely regular space $X, C_p(X)$ is the set of all real-valued continuous functions on X endowed with the topology of pointwise convergence. The function space $C_p(X)$ is a dense linear subspace of $\mathbb{R}^X$ with the product-topology. In 1949, J. Nagata proved that $C_p(X)$ and $C_p(Y)$ are isomorphic as topological rings iff X and Y are homeomorphic. In this tract we consider $C_p(X)$ as a topological vector space or just as a topological space. More specifically we consider the following problems: 1) Under what conditions on X and Y are $C_p(X)$ and $C_p(Y)$ (linearly) homeomorphic. 2) Which topological properties of spaces X are preserved under (linear) homeomorphisms of spaces $C_p(X)$. In Chapter 1 we develop tools that will be important throughout the tract and we also present some new results. We prove that if $C_p(X)$ and $C_p(Y)$ are linearly homeomorphic, then $X^{(1)}$ (=the set of accumulation points of X) is countably compact iff $Y^{(1)}$ is. For metric spaces X and Y we prove that if $C_p(X)$ and $C_p(Y)$ are linearly homeomorphic, then X is completely metrizable iff Y is. In Chapter 2 we classify function spaces $C_p(X)$ up to linear homeomorphisms for spaces X from one of the following classes: compact zero-dimensional metric spaces, compact ordinals, σ-compact ordinals and separable metric zero-dimensional locally compact spaces. For countable spaces, $C_p(X)$ is a subspace of the Hilbert cube. In Chapter 3 we give a topological classification of the function spaces $C_p(X)$ for non-locally compact countable metric spaces X and in Chapter 4 we classify function spaces $C_p(X)$ up to linear homeomorphisms for countable metric spaces X with scattered height less than or equal to ω. In this tract we also study $C_p^*(X)$ the subspace of bounded elements of $C_p(X)$ and $C_0(X)$ the set of all real-valued continuous functions endowed with the compact-open topology. Chapter 4 contains an example of locally compact countable metric spaces X and Y such that $C_p(X)$ and $C_p(Y)$ are linearly homeomorphic but $C_p^*(X)$ and $C_p^*(Y)$ are not.

1992 201 pages
ISBN 90-6196-411-3 NLG 60.00

87. THE WAY OF MATHEMATICS AND MATHEMATICIANS – FROM REALITY TOWARDS FICTION

by A.F. Monna

Half a century ago modern mathematics was still in its early years and in any case university programmes were mainly classical. Just mathematicians of these generations have observed a gigantic development. They have experienced the transition from the old phase into the modern

one. This development raised the question what the sense of this all would be and what mathematics is after all. This essay is not mathematics, it is a writing about mathematics. Special emphasis is laid on the influence and various forms of creativity in mathematics.

1992 81 pages
ISBN 90-6196-415-6 NLG 30.00

88. NUMERICAL METHODS FOR THE THREE-DIMENSIONAL SHALLOW WATER EQUATIONS ON SUPERCOMPUTERS
by E.D. de Goede

The shallow water equations describe a mathematical model for flows in rivers and shallow seas. The application of three-dimensional models requires a great computational effort. It is therefore of great importance to construct numerical methods that are able to fully exploit the potential of vector and parallel facilities of fast computers. By order of Rijkswaterstaat an efficient method on vector and parallel computers has been developed. Apart from the computational efficiency, properties such as accuracy and stability have also been taken into account. A large number of methods has been constructed. The unconditionally stable two-stage time splitting method turns out to be an accurate and a very efficient one. For realistic test problems such as for the IJsselmeer and the Continental Shelf, its computational efficiency has been shown on a Alliant FX/4 and on CRAY supercomputers.

1993 124 pages
ISBN 90-6196-417-2 NLG 40.00

89. MOMENT PROBLEMS IN HILBERT SPACE WITH APPLICATIONS TO MAGNETIC RESONANCE IMAGING
by M. Zwaan

This tract is concerned with mathematical and computational aspects of reconstruction techniques by means of magnetic resonance imaging, in particular for the time-dependent case, referred to as dynamic Magnetic Resonance Imaging (MRI). The main subjects are: a mathematical framework for dynamic MRI reconstruction, analytic solutions, numerical algorithms and development of reconstruction techniques, stability analysis of the reconstruction algorithms, comparison between these algorithms. The tract consists of two parts. The first part covers the mathematics of dynamic MRI, giving a Hilbert space setting for the reconstruction problem, finding solution reconstruction techniques, and proving stability of the solutions under perturbation of the data and time markers. The second part can be read independently of the first part. It covers the physical aspects of MRI, presents simulations for reconstruction from test-data and MR-data, and states conclusions about the performance of the different reconstruction methods.

1993 136 pages
ISBN 90-6196-418-0 NLG 40.00

90. THE SOLUTION OF A ONE-DIMENSIONAL STEFAN PROBLEM
by C. Vuik

In this monograph we study some classes of Stefan problems. An example of a Stefan problem is the melting of ice in water. In a mathematical model the temperature of water satisfies the heat equation. Remark that initially the configuration of water is known. However after some time part of the ice is melted and so the domain whereon the heat equation should be satisfied, is transformed. The domain can be found using the assumption that the heat disappeared from the water has been used to melt the ice. More generally a Stefan problem is a problem where

the domain, on which a parabolic partial differential equation should be satisfied, is unknown and must be found as part of the solution. The main differences of the results given in the monograph and known results given in the literature are the following. The diffusion equation is posed on an unbounded domain. In the literature the Stefan condition is a differential equation. In the Stefan problem specified in the tract, the Stefan condition is a functional integral equation. So the Stefan condition considered here can be used to describe a general class of Stefan conditions. In contrast with the existence results given in the literature we prove existence in a constructive way. So our existence proof suggests a numerical solution method. In a numerical simulation properties of the numerical iterates are in agreement with those of the analytical iterates as given in the theory. Another difference is that our conditions are such that the solution exists for every $T > 0$.

It is known that on an unbounded domain the solution of the diffusion equation is unique only if it is an element of a certain function class. In order to prove uniqueness we will assume that the function C is bounded and that S is a continuous function.

1993 134 pages
ISBN 90-6196-419-9 NLG 40.00

91. MULTIMEDIANS IN METRIC AND NORMED SPACES
by E.R. Verheul

A point b in a metric space (X, d) is said to be *metrically* between points a, c provided $d(a, b) + d(b, c) = d(a, c)$. In this tract we study metric spaces in which every triple of points x, y, z admits a point metrically between x, y, x, z and y, z. Among other things we obtain new characterizations of Banach spaces of type L_1, and we present an application in the theory of "rectilinear" Steiner networks.

1993 136 pages
ISBN 90-6196-420-2 NLG 40.00

92. ITERATIVE METHODS FOR NON-LINEAR PARTIAL DIFFERENTIAL EQUATIONS
by J.M.L. Maubach

Over the past decades, much attention has been paid to the use of *preconditioned iterative methods* for the solution of self-adjoint elliptic boundary value problems. A thorough investigation has shown that these iterative methods are eminently applicable for the solution of most frequently occuring elliptic problems. However, elliptic boundary value problems are relatively simple, and the increase of the computational capacity of the large computer mainframes nowadays creates a growing need to investigate more complex physical problems, such as those found in the oil recovery, airplane and semiconductor industry. As there is a growing demand for the investigation of these – often time-dependent – physical problems, the study of the behaviour of iterative methods for this type of problems becomes of interest. In view of this development, this tract considers the use of such methods for the global finite element technique applied to initial value problems. This application, recently shown to be one of a growing interest, has been far less studied so far, the cause being undoubtedly the complexity entailed by non self-adjoint differential equations, which can for instance give rise to a solution with layers moving in time.

1994 249 pages
ISBN 90-6196-421-0 NLG 50.00

93. STATISTICAL UNCERTAINTIES IN POSTERIOR PROBABILITIES
by A.W. Ambergen

Classifying an object into one of k (≥ 2) populations can be done on the basis of the Bayes rule. The object is characterised by a vector of scores at p (≥ 1) variables. For each of the populations the simultaneous probability distribution of the variables is unknown. The posterior probabilities are composed of the prior probabilities for the various populations and the values of the simultaneous probability densities at the vector of scores of the object under classification. If the simultaneous probability densities are estimated from samples, the estimates will be afflicted with statistical uncertainties. These statistical uncertainties will be carried over via the values of the simultaneous probability densities at the vector of scores of the object under classification into the posterior probabilities. The posterior probabilities of a certain object are considered as parameters which have to be estimated. The vector of scores of the object is supposed to be constant without error. Instead of only point estimates of the posterior probabilities, interval estimates of the posterior probabilities can be considered. A simulation study, chapter 5, showed that deviations between theoretical and estimated posterior probabilities can be substantial. In chapter 2 the asymptotic distribution of the estimator of the vector of posterior probabilities is derived for a number of models. In chapter 3 the asymptotic distribution of the estimator of the vector of posterior probabilities is applied in all sorts of situations. In chapter 4 it is proven that unbiased estimators for the vector of posterior probabilities do not exist if multivariate normality of the probability distributions is assumed. In chapter 5 the theory has been applied to an investigation of the origin of a cranium of ca. 100,000 years old, found at Border Cave, South Africa. A few words are devoted to the computerprogram POSCON in which some theory of this research has been implemented.

1993 129 pages
ISBN 90-6196-422-9 NLG 40.00

94. MOVING-GRID METHODS FOR TIME-DEPENDENT PARTIAL DIFFERENTIAL EQUATIONS
by P.A. Zegeling

In recent years, several sophisticated packages based on the method of lines have been developed for the automatic numerical integration of time-dependent problems in partial differential equations (PDEs) on fixed uniform grids. These packages greatly benefit from the successful developments of automatic stiff ordinary differential equation solvers. However, from the PDE point of view, they integrate only in a semi-automatic way in the sense that they automatically adjust the time-step sizes, but use just a fixed space grid, chosen a priori, for the entire calculation. For PDE solutions possessing moving sharp spatial transitions, a fixed grid is computationally inefficient, since for an accurate solution this grid often must contain a very large number of nodes. In such cases methods which automatically adjust the size of both the space and the time steps are likely to be more successful in efficiently resolving critical regions of high spatial and temporal activity. Methods and codes that operate this way belong to the realm of adaptive or moving-grid methods. Following the method of lines approach, this tract is devoted to an evaluation and comparison, supported by extensive numerical tests, of several moving-grid methods in one and two space dimensions. The examination of the treated methods is aimed at assessing which is the most suitable from the point of view of retaining the acknowledged features of reliability, robustness, and efficiency of the conventional method of lines approach. Considerable attention is paid to the temporal performance of the methods, when applied to many different kinds of

parabolic and hyperbolic PDEs involving fine scale structures such as steep moving fronts and emerging steep layers.

1993 169 pages
ISBN 90-6196-424-5 NLG 50.00

95. STATISTICAL ANALYSIS OF SOFTWARE RELIABILITY MODELS
by M.C.J. van Pul

The past two decades have witnessed an enormous growth of literature on software reliability theory. The preoccupation with model-building has resulted in a large number of theoretical models which seem to lack immediate appeal from a statistical point of view. The aim of this tract is to attempt to reduce the gap between statistical theory and applications in the area of software reliability. The tract has been divided into three parts. Part I gives a general introduction to software reliability and provides most of the mathematical framework. Part II provides the statistical theory and analysis of software reliability models. In Part III the results of two software reliability case studies at Philips Medical Systems and Ericsson Telecommunications are presented.

1993 186 pages
ISBN 90-6196-425-3 NLG 50.00

96. A LIE ALGEBRAIC STUDY OF SOME INTEGRABLE SYSTEMS ASSOCIATED WITH ROOT SYSTEMS
by J.K. Scholma

In this tract finite-dimensional Hamiltonian systems with pairwise interaction are studied from a Lie algebraic point of view. They include the Calogero-Moser model, the Sutherland model and their generalizations to other root systems and to the more general case where the potential is the Weierstrass $\wp$-function. It is shown how these systems can be viewed as Hamiltonian systems on real semisimple Lie algebras. A condition is formulated for a certain constant element μ in the Lie algebra (the moment) which is sufficient to prove integrability and this is translated in a condition on the dimension of the centralizer of μ in the compact subalgebra. Using this condition the Lax pair is derived and a Lie algebraic proof of the involutivity of the Ad-invariant functions is given. For the quasi-split Lie algebras and for the root systems of exceptional type the possible candidates for the moment are classified. It is shown that such an element does not exist for root systems of type E and G_2. The examples corresponding to the classical root systems, all related to quasi-split Lie algebras, are described in detail and a Lie algebraic explanation of the restriction on the coupling constants is given. The Poisson structure is analysed and it is shown that it cannot be "explained" from an underlying double Lie algebra structure.

1993 92 pages
ISBN 90-6196-426-1 NLG 30.00

97. SOJOURN TIMES IN FEEDBACK AND PROCESSOR SHARING QUEUES
by J.L. van den Berg

The subject of this tract is the analysis of sojourn times in queueing models where customers may repeatedly return to some service facility to obtain several phases of service before they finally depart from the system. Such *feedback* phenomena occur in a wide variety of processes arising in computer communication and production networks. The central model investigated in the tract is an $M/M/1$ system with a quite general feedback mechanism: immediately after his service completion a customer returns to the end of the queue with probability $p(i)$ or leaves the system with probability $1 - p(i)$, where i denotes the number of times the customer has

already been served. The main result of the analysis of this model is a complete description of the joint distribution of the sojourn times during a customer's successive passes through the system. Further it is shown how, via a limiting procedure, the results for the $M/M/1$ feedback queue can be used to derive (partially new) sojourn time results for the $M/G/1$ Processor Sharing (PS) queue. Using this new approach some asymptotic results and simple approximations are derived for the second moment of the sojourn time distribution. The last chapter of the tract is concerned with the analysis of some single-queue single-server models in which, next to the 'ordinary' customer streams, also a fixed number of additional *'permanent'* customers are served, i.e. customers who are fed back after each service. Results are derived which show the influence of the presence of the permanent customers on the sojourn time distribution of the other customers.

1993 123 pages
ISBN 90-6196-427-X NLG 40.00

98. STOCHASTIC INTEGRALS AND GOODNESS-OF-FIT TESTS
by A.J. Koning

Stochastic integrals with respect to the basic martingale are used for assessing goodness-of-fit of a statistical model. Main tools in the study of the resulting tests are KMT-type probability inequalities governing the approximation of the stochastic integrals by means of mean zero Gaussian processes. Test statistics for the simple null hypothesis are assumed to be sublinear Lipschitz functionals of stochastic integrals. Special cases of the resulting tests are generalized rank and supremum type tests. The KMT-type inequalities for the simple null hypothesis are derived by means of empirical process theory. Together with the sublinearity and the Lipschitz property of the functional, they lead to a number of limiting results which are subsequently used in various efficiency computations. The optimal choice of the weight process with respect to some specific alternative is established for generalized rank and supremum type tests. The test statistics for the simple null hypothesis are adapted to the composite null hypothesis by plugging in M-estimators. The KMT-type inequalities for the composite null hypothesis are of a lesser quality than their counterparts developed for the simple null hypothesis. This leads to less far stretching limiting results. Still a method of constructing optimal generalized rank and supremum type tests can be given.

1993 163 pages
ISBN 90-6196-428-8 NLG 50.00

99. PARALLELISM IN THE NUMERICAL INTEGRATION OF INITIAL VALUE PROBLEMS
by B.P. Sommeijer

Since many numerical algorithms were designed for traditional sequential computers, the existing methods are not necessarily the best to exploit the facilities offered by modern computer architectures. This is particularly true in the field of numerical methods for ordinary differential equations (ODEs), since there the traditional approach is to follow the step-by-step process which is sequential in nature. Therefore, the main topic of this tract is the construction and analysis of new methods which possess inherent parallelism. Part I, consisting of two chapters, deals with the construction of parallel methods for nonstiff ODEs; the next four chapters, collected in Part II, treat the stiff case. Chapter I discusses parallel, explicit Runge-Kutta (RK) methods with the main property that the number of 'stages' (which is a measure for the amount of work) can be

chosen equal to the order of accuracy, for arbitrary order. This property is principally impossible for 'sequential' RK methods. The parallel Blockmethods discussed in Chapter II have the nice property that order $2s$ can be obtained; methods have been constructed for $s = 2, 3, 4$. In Chapter III we study implicit Blockmethods for stiff ODEs and integro-differential equations. We found A-stable, parallel methods of orders ≥ 4. Diagonally implicit iteration of implicit RK methods is discussed in the next two chapters. In Chapter IV, emphasis is placed on the stability of the resulting method, choosing a fixed number of iterations. In Chapter V, the freedom in the iteration process is used to obtain fast convergence towards the solution of the underlying RK method. In both approaches the role of parallelism is to reduce the amount of linear algebra involved in solving the implicit relations defined by the RK method. Finally, Chapter VI presents a more thorough analysis of the iteration method discussed in the preceding chapters. On the basis of a linear, homogeneous test equation we give an error analysis of these techniques.

1993 195 pages
ISBN 90-6196-431-8 NLG 50.00

100. MULTIGRID METHODS FOR SEMICONDUCTOR DEVICE SIMULATION
by J. Molenaar

In the development of new semiconductor devices increasing use has been made of simulations. As the costs of computer resources are going down these simulations have become much cheaper than experimental investigations. Moreover, simulations are more flexible, so the use of simulations may yield a better end product, because it is feasible to consider many more options. In order to reduce the computing time for accurate and complex simulations the author considers the solution of the stationary two-dimensional semiconductor equations by the nonlinear multigrid method. The major advantage of multigrid over other solution methods is that it has optimal complexity with respect to both the amount of computational work and to the memory usage. As the semiconductor equations are strongly nonlinear and badly scaled, it is not at all straightforward to apply the multigrid method for these equations. It is shown that it is indeed possible to use multigrid for practical semiconductor device simulation.

1994 134 pages
ISBN 90-6196-433-4 NLG 40.00

101. DYNAMIC FEEDBACK IN NONLINEAR SYNTHESIS PROBLEMS
by H.J.C. Huijberts

The purpose of this tract is to explain the role that is played by dynamic (and static) state feedback in the solution of synthesis problems for nonlinear control systems. In particular attention is paid to the disturbance decoupling problem, the model matching problem and the input-output decoupling problem. In linear systems theory, the geometric approach has proved to be a powerful tool for solving synthesis problems. Motivated by this success, various authors have tried to generalize the concepts from the linear geometric theory to the nonlinear context using differential geometric tools. To a great extent, these attempts have been very successful. Examples of this are provided by the aforementioned problems.

1994 164 pages
ISBN 90-6196-435-0 NLG 50.00

102. STOCHASTIC PROCESSES AND POINT PROCESSES OF EXCURSIONS
by J.A.M. van der Weide

The tract gives a self-contained presentation of Itô's theory of excursions of a Markov process

from some state a. The subject is treated from the point of view of point processes. For the description, a generalization of the notion of locally finiteness is developed. Local time comes in as a time-scaling. In the second part the author treats the construction of stochastic processes from point processes of excursions. For the derivation of the Markov property and the calculation of the resolvent, techniques from point process theory (conditioning, Palm measures) are used. Some explicit constructions are given of processes which behave outside some given state a as Brownian motion.

1994 108 pages
ISBN 90-6196-438-5 NLG 40.00

103. CONTRIBUTIONS TO MULTIGRID
edited by P.W. Hemker and P. Wesseling

This tract contains a selection from the papers presented at the Fourth European Multigrid Conference, held in Amsterdam, July 6-9, 1993. Another selection, including the contributions by the invited speakers, appears as the proceedings of the Fourth European Multigrid Conference and is published by Birkhäuser Verlag, Basel. Multigrid has much impact on Computational Fluid Dynamics (CFD). This influence is much reflected in the present selection of contributions: more than 10 of the 17 contributions are devoted to CFD.

1994 220 pages
ISBN 90-6196-439-3 NLG 60.00

104. A COMPENSATION APPROACH FOR QUEUEING PROBLEMS
by I.J.B.F. Adan

The main objective of the present tract is to contribute to the development of techniques for the analysis of the equilibrium behaviour of Markov-processes with a two-dimensional state space. The research was initiated with the analysis of the symmetric shortest queue problem. For this queueing problem an approach to the characterization and calculation of the equilibrium probabilities is developed. The essence of this approach is to characterize the set of product form solutions satisfying the equations in the interior points and then to use the solutions in this set to construct a linear combination of product form solutions which also satisfies the boundary conditions. This construction is based on a compensation idea: after introducing the first term, terms are added so as to alternately compensate for errors on the two boundaries. This explains the name compensation approach. This approach leads to an explicit characterization of the equilibrium probabilities. The results can easily be exploited for numerical analysis and lead to efficient algorithms with the advantage of tight error bounds.

1994 183 pages
ISBN 90-6196-442-3 NLG 50.00

105. PERFORMANCE EVALUATION OF PARALLEL AND DISTRIBUTED SYSTEMS SOLUTION METHODS – PROCEEDINGS OF THE THIRD QMIPS WORKSHOP, PART 1
edited by O.J. Boxma and G.M. Koole

These are the proceedings of the third QMIPS workshop, held in Torino, Italy, on September 25 and 26, 1993. The QMIPS project is a collaborative research project supported by the European Union, and it is carried out by 8 organizations from 6 different European countries. It is concerned with quantitative modeling in parallel and distributed systems. Three steps can be distinguished in the analysis of parallel and distributed systems. The first is modeling, using one of the available

formalisms. Depending on the formalism used, a solution method is employed to obtain performance measures for the system. This second step is the subject of these proceedings. The third step is the optimization of the system. Research in this area was presented at the fourth QMIPS workshop in London, on April 14 and 15, 1994.

1994 155 pages
ISBN 90-6196-444-X NLG 50.00

106. PERFORMANCE EVALUATION OF PARALLEL AND DISTRIBUTED SYSTEMS SOLUTION METHODS – PROCEEDINGS OF THE THIRD QMIPS WORKSHOP, PART 2

edited by O.J. Boxma and G.M. Koole

See CWI Tract 105.

1994 221 pages
ISBN 90-6196-445-8 NLG 60.00

107. LOCAL UNIFORM GRID REFINEMENT FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATIONS

by R.A. Trompert

This is tract is based on five papers which have appeared in the literature. The Chapters 2 and 6 are applied in nature while the Chapters 3, 4 and 5 are more fundamental. The latter chapters form the kernel of this tract. In these chapters strategies for grid refinement based on an error estimates are developed from error analyses. In general, a refinement strategy based on heuristic criteria like the slope or the curvature of the solution is computationally cheaper than an error-estimate-based strategy. However, a strategy based on error estimates will in many cases give more accurate results than a strategy based on heuristic error monitors. This is due to the fact that heuristic error monitors bear no relationship with the true numerical error. Because of this, the situation can occur that a strategy based on heuristics does not refine a grid cell which ought to be refined considering the numerical error and vice versa. Hence, a strategy based on error estimates can generate better subgrids than a heuristic strategy. A brief description of the contents of this tract is given below.

Chapter 2 discusses the local uniform grid refinement methods applied to parabolic PDEs. The explicit Runge-Kutta-Chebyshev (RKC) method of Van der Houwen and Sommeijer: *On the internal stability of explicit m-stage Runge-Kutta methods for large m-values*, ZAMM 60 (1980) 479-485, is used for time stepping, and the grid refinement process and time step selection are based on heuristic error monitors.

In Chapter 3 a refinement strategy, controlling the generation of subgrids, is developed based on an error analysis. The error analysis is carried out for the local uniform grid refinement method applied to time-dependent PDEs which after spatial discretization yield a system of ODEs, and where the implicit Euler method is used for time stepping. Further, it is assumed here that the grid spacing of the finest subgrid is fixed in time.

Chapter 4 is in many respects similar to Chapter 3, except that a general Runge-Kutta scheme is used for time stepping. The case of a variable grid spacing in time of the finest subgrid is also discussed in this chapter.

In Chapter 5, a refinement strategy is developed in case PDEs are solved which after spatial discretization result in a system of differential algebraic equations (DAEs). This refinement strategy is based on an error analysis carried out for this case. A backward differentiation formula method

(BDF) is used for time stepping.

Chapter 6 discusses the application of the local uniform grid refinement method to a model for unsteady groundwater flow coupled with transport of solute in heterogeneous porous media. The local uniform grid refinement method proves to be useful for this application, since it frequently occurs that the variations of the concentration of solute over the spatial domain are only large at a small part of this domain. This work is carried out as a part of contract research in behalf of the RIVM - the Dutch National Institute of Public Health and Environmental Protection. In the scope of this project, the local uniform grid refinement method is implemented in a code called MOORKOP. This code is developed for solving a rather general class of PDEs defined on a rectangular domain, including transport problems in heterogeneous porous media.

1995 160 pages
ISBN 90-6196-452-0 NLG 40.00

108. STOCHASTIC GEOMETRY MODELS IN IMAGE ANALYSIS AND SPATIAL STATISTICS

by M.N.M. van Lieshout

The pioneering work by Geman & Geman: ***Stochastic relaxation, Gibbs distribution and the Bayesian restoration of images***, IEEE Trans. PAMI, 6 (1984) 721-741, and Besag: ***On the statistical analysis of dirty pictures***, J. Royal Stat. Soc. B 48 (1986) 259-302, stimulated a surge of interest in statistical approaches to image analysis. Until recently, most attention has been given to segmentation or classification tasks, i.e. dividing an image into relatively homogeneous regions of different type. Following the above mentioned pioneers, a Bayesian approach is usually taken in which a Markov random field model is used as a prior distribution to impose smoothness on segmentations. Computational problems due to the high dimensionality of images are overcome by iterative algorithms relying only on the local characteristics of the probabilistic model. An efficient deterministic technique to find a locally optimal segmentation is Besag's Iterated Conditional Mode (ICM) algorithm. Realisations of the posterior distribution can be obtained by a Gibbs sampler, and a simulated annealing schedule to approximate a globally optimal classification can be designed.

The goal of this tract is to argue that the (continuous) Markov or Gibbs processes studied in stochastic geometry, spatial statistics and statistical physics provide a rich collection of models usable in a broad range of problems involving the higher-level interpretation of spatial and image data.

1996 172 pages
ISBN 90-6196-453-9 NLG 40.00

109. COMPARATIVE CONCURRENCY SEMANTICS AND REFINEMENT OF ACTIONS

by R.J. van Glabbeek

This book consists of seven chapters which are all based on separate papers and have their own introduction. This general introduction is only meant to give an indication of their contents and their role in the book.

In the first chapter several semantic equivalences for concrete sequential systems are presented, and motivated in terms of the observable behaviour of systems, according to some testing scenario. Here *concrete* means that no internal actions or internal choice are considered. These semantics are partially ordered by the relation 'makes strictly more identifications than', thus constituting a

complete lattice. For ten of these semantic equivalences complete axiomatizations are provided. As in the rest of the book, stochastic and real-time aspects of concurrent systems are completely neglected. Chapter I serves partly to give an overview of the literature on semantic equivalences for concrete sequential processes. The various notions that can be found elsewhere can easily be compared, since they are all presented in the same style, and using the same formalism. In order for the semantics of this chapter to be applicable for design and verification purposes, they have to be generalized to a setting with internal moves, and with parallelism. This can be done in many ways. In the last two chapters the two extreme points on the semantic lattice, trace semantics and bisimulation semantics, are generalized to a setting with parallelism and in Chapter III, bisimulation semantics is generalized to a setting with internal moves.

In the second chapter it is shown how semantic notions can be used in protocol verification and other applications. This chapter is entirely algebraic in style and employs axiom systems of which only classes of models are considered, rather than a particular model. It is based on the *Algebra of Communicating Processes* by Bergstra & Klop as written in two articles (Information and Computation 60 (1984) and Lecture Notes in Computer Science 354). In order to combine axiom systems representing semantic notions that are difficult to combine a new notion of 'proof' is developed.

The third chapter is devoted to the generalization of bisimulation equivalence to a setting with silent moves. It is argued that the solution of Milner in *A Calculus of Communicating Systems* (Springer, 1980) (observation equivalence) does not respect the branching structure of processes and hence lacks an important feature of bisimulation semantics without internal moves. A finer equivalence is proposed which indeed respects branching structure. This new ***branching bisimulation equivalence*** turns out to have some practical advantages as well. In particular, we show that in a setting without parallelism it is preserved under refinement of actions, whereas observation equivalence is not.

In the fourth chapter an operator for refinement of actions is defined on four causality based models for concurrent systems, namely on three kinds of event structures and on Petri nets, and in the remaining three chapters it is investigated which of the 'linear time' and 'branching time' semantic equivalences proposed in the literature are preserved under refinement of actions and which are not. Chapter V can be regarded as an informal summary of the Chapters VI and VII. It uses Petri nets rather than event structures and contains no technicalities like definitions and proofs. Instead more attention has been paid to the examples.

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110. Probability and Lattices

edited by W. Vervaat (†) and H. Holwerda

This tract consists of six papers. The first, fourth and fifth paper have been revised. The third paper is followed by a supplement of comments and corrections.

1. W. Vervaat (1988): Random upper semicontinuous functions and extremal processes.
2. T. Norberg (1990): On the convergence of probability measures on continuous posets.
3. G. Gerritse (1985): Lattice-valued semicontinuous functions.
4. W. Vervaat (1988): Spaces with vaguely upper semicontinuous intersection.

5. T. NORBERG & W. VERVAAT (1989): Capacities on non-Hausdorff spaces.
6. H. HOLWERDA (1993): A note on Fell- and epicompactness.

These papers were written in two streams of research. The first sprang from the need for a general qualitative theory of extremal processes in the 1980 research. For extremal processes, since long a topic of active research, an abstract definition surprisingly did not exist. The first paper in this tract provides one, and its formalism has been adopted in the field soon after its prepublication in 1988.
The second stream started with work of Norberg on random capacities in the spirit of the theory of random measures as developed by his thesis advisor Olav Kallenberg). The fifth paper in this tract generalizes the topic to non-Hausdorff spaces, a generality demanded by developments in the first stream.
An extremal process now is regarded as a random variable with values in a topological space of sup measures, or equivalently, of upper semicontinuous functions. They are topological lattices, an area of active research since the 70s. In fact, if the time domain is locally compact (but not necessarily Hausdorff), they are a major example of continuous lattices.
This connection is already present in the first and third paper in a fresh and rudimentary form, but more prominently and digested in the second, fifth and sixth. For a uniform theory with many isomorphisms it is essential to regard the Hausdorff property as incidental and to consider unprohibitedly t_0 spaces. The editor discovered this in the first paper, and the resulting attitude permeates all other papers in this tract, in particular the fifth and sixth. The second paper extends the values of random varables to the more general continuous partially ordered sets, the third paper the values of semicontinuous function to lattices. The fourth paper explores the separation condition (satisfied by all Hausdorff spaces) that renders the intersection of closed sets upper semicontinuous, and consequently also the infimum of upper semicontinuous functions. The sixth paper places the compactness of the spaces of closed sets and semicontinuous functions in the context of the best related results for continuous lattices.
Capacities appear at the end of the first paper and dominate the fifth. There are two reasons for this. On the one hand, capacities can be regarded as upper semicontinuous functions on the space of open sets provided with a non-Hausdorff topology. That is how they appear in the first paper, and are studied again in part of the fifth. On the other hand, the space of capacities contains all kinds of interesting subspaces, as the measures, the upper semicontinuous functions and the closed sets.

1997 154 pages
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111. COVARIANT FORMAL GROUP THEORY AND SOME APPLICATIONS
by I. Helsloot

Much has been written on commutative formal group theory and undoubtedly much more will be written. This work is another contribution to the theory of commutative formal groups. The main body of this work consists of a) a more or less self-contained presentation of commutative formal group theory in a covariant way, b) a theorem on the classification up to isomorphism of commutative formal groups defined over an algebraically closed field of positive characteristic. In the last chapter various applications are given.

In the first chapter the concept of DPS-Hopf algebras is introduced. The category DPS-cHopf of DPS-Hopf algebras will turn out to be equivalent to the category of commutative formal group laws. Classical concepts as curvilinearity and S-typicality have well defined counterparts in DPS-cHopf. Within one chapter we will develop most of the classical theory. New is the emphasis on the universal object $C(A)$, whose group structure seems to reflect the menagerie of integrality lemmas necessary in the theory of commutative formal group laws. Witt and Hilbert rings will be seen to arise naturally in this setting.

The second chapter deals with f-types. We will show that the Witt and Hilbert (if they exist) F-types of a curvilinear commutative formal group law G fully describe the formal group law G. In the process we will construct a universal DPS-Hopf algebra over a polynomial ring L, and thus give a new proof of the fact that the Lazard ring is a polynomial ring. We proceed to give connections with the theory of Dieudonné and Honda. We adapt a lemma of Dieudonné in order to obtain a very computable algorithm for finding the isogeny type of a commutative formal group law given by its F-type.

In the third chapter we prove our main result: A commutative formal group law defined over an algebraically closed field k of positive characteristic of finite height is isomorphic to a commutative formal group law having a finite F-type. This finite F-type is described by a new set of invariants, called the jump data. Thus as a corollary we obtain: there is a catalogue of finite dimension over k of commutative formal group laws defined over k with bounded height.

In this chapter we also prove a theorem on the reduction of formal group laws defined over $W(k)$ given by their Hilbert F-types. This theorem will then be used to lift the problem of classification up to isomorphism over k to a well-described classification problem over $W(k)$.

The last chapter then gives several applications: We give a complete classification in the 2-dimensional case. In the 2- and 3-dimensional case we give the isogeny types as function of the parameters in the finite F-type. In the 2-dimensional case this has been already done by Kneppers, but this is new in the 3-dimensional case. Moreover using our theory there is now no obstruction for doing the same in any dimension. The chapter ends by treating a problem suggested by N. Yui: describe the structure (of the isomorphism classes) of the formal Brauer groups of Fermat hypersurfaces defined over an algebraically closed field k of positive characteristic. Again the solution of this problem lies in lifting the problem to a problem over $W(k)$, solving that problem using the theory of Hilbert F-types (and the Serre-Witt cohomology, and then reducing the solution using a reduction theorem from chapter II.

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ISBN 90-6196-455-5 NLG 35.00

112. Loop Checking and Logic Programming

by R.N. Bol

A definition of logic programs and their logical meaning is given in chapter 1. This chapter also formalizes the process called *SLD-resolution*: the construction of an *SLD-tree*, the search space of a top-down interpreter for logic programs. It recalls an important result: the soundness and strong completeness of SLD-resolution. Completeness means that every 'desirable result' is achieved: every correct solution is present in every SLD-tree. A loop check is a mechanism that prunes SLD-trees.

In chapter 2 a formal definition on loop check is given and we introduce notions of soundness and completeness for loop checks. In addition non-simple loop checks are discussed.

The simple loop checks defined in chapter 3 have in common that they are based on making

comparisons between goals and their ancestors in the SLD-tree. A goal is pruned if it is 'sufficiently similar' to one of its ancestors. Based on their notions of 'sufficiently similar', these loop checks are divided into three groups, called *equality checks, subsumption checks* and *context checks* respectively. Each group contains weakly sound and sound versions.

Both chapter 4 and chapter 5 contain generalizations of the elementary framework of loop checking outlined so far; however, the nature of these generalizations is quite different. Chapter 4 focusses solely on the completeness of loop checks. Its central theorem, the Generalization Theorem, allows us to generalize certain completeness results. The theorem is applied on the results for the subsumption and context checks mentioned before; stronger completeness results for these loop checks are thus obtained.

Chapter 5 introduces loop checks for a broader class of programs, namely programs with negative literals in their clauses. The declarative and procedural semantics for logic programs with negation are considerably more complicated than for programs without negation. As a result the effect of applying a loop check is also more complex. Nevertheless we show that loop checks for programs without negation can easily be extended to loop checks for *locally stratified* programs, for which satisfactory semantics have been defined.

Chapter 6 introduces an alternative application of loop checks, namely in partial deduction. In chapter 7 we pay attention to the implementation of loop checking. In chapter 8 we discuss work by others related to several subjects discussed in this tract.

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113. Stochastic Scheduling and Dynamic Programming

by G.M. Koole

The title of this tract consists of two parts, *stochastic scheduling* and *dynamic programming*. The former refers to a class of models, the latter refers to the method used to find optimal policies for these models. The models studied here can be divided in two classes: those in which customers at arrival are to be assigned to one of a number of queues and those in which one or more servers are to be assigned to different customer classes or queues. Of great importance is the way in which customers arrive at the stations. Models with independent arrival streams are studied in chapter 1. Then we allow the arrival stream to depend on the numbers of customers in the queues in such a way that controllable networks can be modelled with it. These and other network results can be found in chapter 2. In chapter 3 we generalize the arrival process even more, for example to include finite source models. Many results of chapter 1 and 2 are special cases of the results of chapter 3. Chapter 4 contains the proofs of the dynamic programming results. Chapter 5 considers methods by which we can translate the discrete-time results of the chapters 1 to 3 to continuous-time results. We conclude with four appendices, respectively on weak convergence of arrival streams, on phase-type distributions with a monotone failure rate, on majorization, and on algorithms to compute optimal policies.

Summarizing, chapter 1 can be seen as an introduction, chapter 2 contains the network results, and in chapter 3 the dynamic programming results are handled in their greatest generality.

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114. Efficient and Inefficient Estimation in Semiparametric Models

by M.J. van der Laan

This tract starts with an introduction to existing relevant theory which forms a basis for this tract: *weak convergence theory, empirical process theory, efficiency theory* and some multivariate techniques. The rest of the tract consists of two parts: chapter 2, 3, 4 and 5 form the first part and chapter 6, 7 the second part.

The first part covers general efficiency theory for maximum likelihood estimators (MLE) and applies this theory to a general class of missing data models and two interesting applications. In chapter 2 we present a method for proving efficiency of MLE. The method is applicable to all models. In this theory a lot of significance occurs if the model is *convex*, which means that if one moves along a straight line from one element to another element of the model, then one does not leave the model. Using this convexity we establish a useful *identity* for MLE which in a straightforward manner provides us with consistency, efficiency and validity of the bootstrap under minimal conditions. The theorem can be trivially extended to all kinds of modifications of MLE.

Many *semiparametric models* are convex. In chapter 3 we apply this efficiency theory for convex models to MLE in a general class of *missing data models* and illustrate it with several examples. Moreover, in chapter 4 and 5 we successfully apply this theory to the *bivariate censoring* and *line segment* model, which are models where the standard approaches based on the self-consistency equation require too strong conditions. For the bivariate censoring model we propose and prove efficiency of an MLE which is based on a slight reduction of the data.

For reading chapter 2 one only needs to read the empirical process theory section and efficiency theory section of chapter 1. The general structure of the efficiency proofs in chapter 3, 4 and 5 are applications of the main theorems presented in chapter 2, but except for this the three chapters are self-contained and can be read independently of each other.

In the second part of the tract we study the construction of interesting *inefficient estimators* in the *bivariate censoring model* and analyze them by considering the estimators as functionals of the empirical distribution and establishing the required differentiability of these functionals. These estimators are especially interesting because they are easy to compute, have a good practical performance, and are very robust to changes of the distribution where we sample from so that the bootstrap works well. In chapter 6 we use the generally applicable *functional delta-method* in order to give full analyses of three explicit estimators. This chapter is joint work with Richard Gill and Jon Wellner. In chapter 7 an ad hoc modification of a MLE (a so called *M*-estimator) for the bivariate censoring model, using density estimators, is analyzed by applying the *implicit function theorem* and a refinement of the usual *functional delta-method* as used in chapter 6.

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115. Polling Systems

by S.C. Borst

This monograph is devoted to the mathematical analysis of polling systems. The classical polling model consists of a number of queues attended by a single server visiting the queues in a cyclic manner. The routing discipline specifies in which order the server should visit the queues, while the service discipline indicates which customers the server should serve during a visit. Over the years, polling systems have found a wide range of applications in the performance evaluation of communication systems, computer networks, and manufacturing systems.

First, we describe the classical polling model, together with some of the main variants, and review the state-of-the-art in the analysis and optimization of polling systems. We then elaborate on the use of decomposition properties in the analysis of polling models, in particular discussing the existence of pseudo-conservation laws for the mean waiting times.

Next, we consider two different polling models: (i) a model with *zero* switch-over times, and (ii) a model with *non-zero* switch-over times where the server keeps cycling when the system is empty. We expose a strong relationship between both the queue length and the waiting-time distribution in the two models.

In the next two chapters, we consider polling systems in which the server may be allowed to make a halt at a queue when the system is empty. We derive a pseudo-conservation law for a general model, permitting a variety of service disciplines. Then we focus on a globally gated polling system in which the server makes a halt at its home base when the system is empty.

The next two chapters are devoted to various optimization issues in polling systems. We study the problem of optimizing polling systems with the k-limited service discipline. We also address a similar optimization problem for polling systems operated with a fixed-time polling scheme.

The final three chapters are devoted to systems with multiple queues and multiple servers. First, we characterize the structure of an optimal probabilistic allocation in a system consisting of multiple customer classes attended by multiple parallel servers. We then explore the class of polling systems with multiple *coupled* servers that allow an exact analysis. In the final chapter, we derive waiting-time approximations for polling systems with multiple *independent* servers and either the exhaustive or gated service discipline.

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116. Statistical Test Limits in Quality Control

by G.D. Otten

For certain types of products requirement as to their quality are formulated by fixing specification limits for a number of characteristics. If one of the characteristics does not satisfy the specification, the producer should not deliver that part to the customer. In complicated production processes it often occurs that a (small) fraction of the manufactured parts does not satisfy the specifications, despite efforts to reduce the variability within the production process. To ensure that this fraction is not shipped to the customer, the products are inspected on the characteristics specified. A typical example is the manufacturing of Integrated Circuits (IC`s), for which specification limits are agreed on for a large number of characteristics and each part is tested before delivery.

In general, the measurements will not give the true value of the characteristic. Due to measurement errors the measurement could wrongly suggest that the characteristic is conforming. To prevent accepting too many nonconforming products in this way, a somewhat more stringent test limit is set by the producer. The more stringent this test limit, the smaller the number of accepted nonconforming products, but, at the same time, the larger the number of products that are needlessly rejected. It is common practice to agree with the customer on a bound on the probability of wrongly accepting a product, denoted by γ, together with a specification limit.

So, given a specification limit and a value of γ, a test limit has to be determined. Besides by the value of γ, the distance between test limit and specification limit is determined by two more factors.

Although the problem has been given some attention in the literature, in practice test limits are

determined mainly in an informal way. Often the test limit is taken somewhat stricter, in which somewhat is not specified. The so-called 3σ-limit is often applied as well.
In this book procedures are derived to determine accurate test limits. This means that procedures are derived for which the obtained test limit gives the largest yield feasible, while the value of γ (the bound on the probability of a product being both nonconforming and accepted) is observed. In particular, if products are manufactured in very large numbers, a slightly less strict test limit already leads to important improvement in the yield.
To determine test limits, the inspected characteristic and the measurement error are considered random variables. In the literature appeared so far attention has been paid only to the situation in which both the characteristic and the measurement error are normally distributed. The first practical complication, which has not yet been studied, is that even if the assumption of normality is satisfied, the corresponding parameters (mean, variance) will be unknown. Estimation itself of the parameters is not a problem, however, the accuracy of the test limit depends on the accuracy of the estimators. In chapter 3 of this book ample attention is paid to the complication when for the determination of the test limit estimators of the parameters have to be used. Test limits which allow for the fact that they are based on estimators are derived.
In many situations in practice the assumption of normality of the measurement error and/or the characteristic is not justified. In chapter 4 test limits are derived for the situation in which the measurement errors can still be assumed to be normally distributed, but in which the characteristic is not necessarily normally distributed. Chapter 5 is dedicated to a specific part of the determination of test limits. To obtain an accurate test limit, it is essential to estimate the density of the characteristic at the specification limit correctly. In chapter 5 several ways to estimate the density in one point are discussed and compared. In chapter 6 test limits are derived for the general situation: normality for the measurement error is no longer assumed either.
In chapter 2 the results are summarized for application in practice. The test limits for the different situations are presented in the form of a manual.
1996 143 pages
ISBN 90-6196-469-5 NLG 35.00

117. Graph Reduction on Shared-memory Multiprocessors
by K.G. Langendoen

The EIT Reduction Machine project is a joint effort of the University of Amsterdam (UvA) and the University of Nijmegen (KUN) aimed at the development of an efficient functional language implementation on large scalable parallel computers. The project tackles some of the fundamental and practical problems of functional languages on parallel machines like graph consistency/distribution, and builds on the experience gained within the Dutch Parallel Reduction Machine project. The proposed parallel machine consists of a (scalable) number of clusters interconnected by a high speed network, where each cluster itself is a multiprocessor that consists of a few processors connected to a shared memory.
The inclusion of shared-memory multiprocessors in the architecture raises issues that had not been surveyed by the DPRM project. The most important aspect of parallel functional language implementation is how to enforce consistency of shared graph structures that represent delayed computations. For efficiency these graph nodes must be updated once their result has been evaluated, so node access has to be controlled to avoid the readding of partially updated nodes. The usual approach is to lock individual graph nodes to enforce mutual exclusive access, but this implies overheads for all node accesses even though only a small number of nodes is actually shared.

It is, however, possible to avoid the existence of shared updatable graph nodes by forcing the evaluation of shared expressions before sparking parallel tasks. This approach results in a set of independently executing tasks that need no synchronisation at the graph access level. In addition the runtime support system can take advantage of the independence as well for task scheduling and storage management (garbage collection).

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118. NONLINEAR $\mathcal{H}_\infty$ CONTROL: THE SINGULAR CASE
by W.C.A. Maas

A standing assumption in most of the literature on the state space approach to linear or nonlinear $\mathcal{H}_\infty$ theory is a certain regularity condition. When this regularity assumption is violated the problem generalizes to the singular $\mathcal{H}_\infty$ problem. In this tract we present two methods to solve the singular $\mathcal{H}_\infty$ problem for nonlinear systems. These methods are extensions of approaches to the singular linear $\mathcal{H}_\infty$ problem derived at the end of the eighties. The first method is related to a regularization of the linear system. Using this method the solvability of the singular state feedback $\mathcal{H}_\infty$ problem is characterized by the solvability of a parameterized Hamilton-Jacobi inequality which generalizes the parameterized Riccati equality from the linear theory. Also the singular nonlinear measurement feedback $\mathcal{H}_\infty$ problem has been studied using the worst case certainty equivalence principle.

The second method uses results from geometric system theory and is therefore referred to as the geometric approach. The main feature of this method is a decomposition of the system into two subsystems by means of a transformation of the states and the inputs. This decomposition leads to several sets of conditions for the solvability of the state feedback $\mathcal{H}_\infty$ problem. These conditions are in terms of the solvability of a regular $\mathcal{H}_\infty$ control problem for a subsystem of the original system and an almost disturbance decoupling problem for a complementary subsystem.

Finally the two methods are compared and illustrated using several examples being the tracking of the orientation of a rigid body, the parameter robustness of the inverted pendulum on a cart and robust stabilization under gain-bounded perturbations.

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119. PROBABILISTIC AND ANALYTICAL ASPECTS OF THE UMBRAL CALCULUS
by A. Di Bucchianico

The subject of this tract is a class of sequences of polynomials $(q_n)_{n\in\mathbb{N}}$ defined by the following functional equations

$$(1) \qquad q_n(x+y) = \sum_{k=0}^{n} q_k(x)\, q_{n-k}(y) \qquad (n = 0, 1, \ldots)$$

A sequence of polynomials that satisfies (1) is called a sequence of polynomials of convolution type. These sequences are closely related to the sequences of polynomials of binomial type:

$$(2) \qquad q_n(x+y) = \sum_{k=0}^{n} \binom{n}{k} q_k(x)\, q_{n-k}(y) \qquad (n = 0, 1, \ldots)$$

Obviously, $(q_n)_{n\in\mathbb{N}}$ is of convolution type if and only if $(n\,q_n)_{n\in\mathbb{N}}$ is of binomial type. In this tract sequences of polynomials of convolution type are studied instead of sequences of polynomials of binomial type because convolution is a fundamental operation in analysis and probability theory. The binomial convolution appearing in (2) has advantages when dealing with certain combinatorial problems.

An extension of the class of sequences of polynomials of binomial/convolution type is the class of Sheffer sequences $(s_n)_{n\in\mathbb{N}}$, whose convolution type version is defined by

$$(3) \qquad s_n(x+y) = \sum_{k=0}^{n} s_k(x)\, q_{n-k}(y) \qquad\qquad (n = 0, 1, \ldots)$$

for some fixed sequence $(q_n)_{n\in\mathbb{N}}$ of convolution type. The class of Sheffer sequences includes (amongst others) the Hermite, Bernoulli and Laguerre polynomials.

A survey of the Umbral Calculus with over 400 references can be obtained in electronic form through the Electronic Journal of Combinatorics:

http://ejc.math.gatech.edu:8080/Journal/Surveys/index.html

Chapter 1 is an introduction to the Rota Umbral Calculus. It is shown that if $(q_n)_{n\in\mathbb{N}}$ is a sequence of polynomials of convolution type, then $q_n(x) = \sum_{k=0}^{n} g_n^{k*}\ \frac{x^k}{k!}$ for some sequence $(g_n)_{n\in\mathbb{N}}$ with $g_0 = 0$.

Chapter 2 contains a miscellany of applications of the Umbral Calculus. Topics covered include finite probability distributions, combinatorial identities, exponential families, approximation operators, orthogonal polynomials, semigroups of probability measures, and integral representations of shift-invariant operators.

Chapter 3 starts with some general Banach algebra theory. This theory is used to obtain a new, unified treatment of existence problems for logarithms. This treatment is applied to polynomials of convolution type and yields analytic results on the generating function of sequences of polynomials of convolution type. Moreover, a two-sided analogue of polynomials of convolution type is introduced and studied.

The first sections of chapter 4 consider central limit theorems for the coefficients of polynomials of convolution type.

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120. Numerical Methods in Smog Prediction

by M. van Loon

The project EUSMOG, of which this book is one of the scientific results, had a twofold purpose. The first purpose was the extension of the existing winter smog model EUROS to a summer smog model. Most important aspects of the model extension consist of the increased number of modeled species (from 5 to 15) and the much more complex chemical mechanism. In addition, new emission data were used, that also contain point source information. The consequence of these adjustments is that the computation time for one model run drastically increases. In view of the on-line application, the total computation time on a workstation needs to be restricted to 3 or 4 hours.

This lead to the second goal: the development of fast and efficient numerical methods for application in the smog model, as well as the implementation of a local grid refinement technique. Because operator splitting is applied, it is possible to choose a suitable numerical technique for each physical process separately. In the research, attention is paid to

- *local uniform grid refinement:* A finite-volume grid refinement technique has been developed from a grid point implementation. Finite volumes turn out to be necessary for a consistent treatment of point source emissions.
- *numerical methods for advection:* Starting point for selecting an advection scheme is positivity, i.e. no under- and overshoot, and accuracy. The method of lines approach is followed: the limited $k = \frac{1}{3}$ space discretization is combined with Runge-Kutta time integration. It is also investigated whether flux corrected transport could be an alternative for limiting the space discretization. This however turns out to be computationally more expensive and not easy to implement on refined grids.
- *fast and efficient solvers for the chemical equations:* Standard use of stiff ODE solvers would lead to an unproportional amount of computation time and can therefore not be applied. However, owing to the relatively low accuracy requirement it is possible to use special purpose solvers since they turn out to be more efficient for low accuracies.

Apart from the chapters on numerical algorithms, the book contains a detailed model description and a comparison of model computations with measurements for a winter and a summer smog episode. The comparison shows relatively good agreement between measurements and computations, in particular for the summer episode considered.

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121. Nonparametric Estimation for a Windowed Line-segment Process

by B.J. Wijers

In this book we investigate the (sieved) nonparametric maximum likelihood estimator (NPMLE) of the distribution function of the length of line segments. Roughly speaking nonparametric means that we put no restriction on the distribution function we want to estimate and the maximum likelihood estimator is that estimator that gives the highest probability of occurrence to the data. We observe line segments within some window. Some of the lengths of the line segments are totally observed (uncensored observations), others partially (censored observations). A line segment that hits the edge of the window is partially observed. The real length of the line segment is beyond our visual field. The line segments in the window will be interpreted as a line segment process observed through a window.

The uncensored and censored observations will be used to construct an NPMLE of the length distribution of the line segments. The EM-algorithm will be used to calculate the NPMLE from the so-called self-consistency equations. The existence and uniqueness of the NPMLE will be shown. Not using the censored observations is throwing away valuable information. A censored observation does not give us the true length of the line segment, but nevertheless it includes information about the probability of being a line segment greater or equal to the observed length. In the line segment processes studied in this book we show that the NPMLE based on the uncensored and censored data, is in some sense the best estimator among all the other estimators (efficiency).

In the two-dimensional case the data for each line segment in the window consists of its (possibly censored) length, its direction and its position in the window. In order to understand the two-dimensional case we start by analysing a simpler special case: a one-dimensional line segment process observed in an interval. If we consider a rectangular window and all line segments are horizontal, then one obtains the one-dimensional case.

In our models the window is convex. Convexity ensures that two censored line segments hitting the edge of the window, do not belong to the same underlying line segment. This prevents dependence problems in the data. Another aspect next to censoring that plays a non-trivial role in the line segment processes observed through a window is the so-called length bias: longer line segments have a bigger chance of getting (possibly partially) into the window and being observed. The observed line segments are thus not a random sample from the distribution of interest, but from the length distribution of the observed line segments.

The length bias problem can be taken account of by estimating this length distribution of the observed line segments and because of a reparametrization we can always turn back to our parameter of interest: the length distribution of the underlying line segments. Another reason why we will use a reparametrization of the models is the fact that we turn the cases into a special nonparametric missing data problem: missing data models where the parameter space is convex and the distribution of the data is linear in the parameter. Now we can use powerful special methods to prove consistency and efficiency of the NPMLE. Only for the one-dimensional case and the two-dimensional case where the window is a circle, we give in this book all proofs in detail. For the circle-case calculations get less complicated and the distribution of the direction (angle) of the line segments plays no role in the problem. For the case that the window is arbitrary convex and the distribution function of the angle is known, one can copy with more effort most of the proofs. (In the case that the angle distribution is unknown one has to study the joint NPMLE of the length distribution and the angle distribution).

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122. TEN YEARS LNMB – PH.D. RESEARCH AND GRADUATE COURSES OF THE DUTCH NETWORK OF OPERATIONS RESEARCH

edited by W.K. Klein Haneveld, O.J. Vrieze, and L.C.M. Kallenberg

The Dutch network of Operations Research (in Dutch LNMB) is an interuniversity organization, in which all universities in the Netherlands and CWI (Centre for Mathematics and Computer Science) participate. The LNMB was founded on July 1, 1987. On the occasion of the tenth anniversary of the network, this book was published. The book contains five review papers, written by senior researchers, and over forty contributions of former Ph.D. students. After an introduction on the origin of the network, by Klein Haneveld, the first part is devoted to Combinatorial Optimization and Discrete Mathematics, with a review paper by Aardal, Van Hoesel, Lenstra and Stougie. The second part, on Stochastic Operations Research, starts with a retrospective view, composed by Tijms. The third part, concerns Game Theory; Tijs and Vrieze wrote a paper on the contribution during the last decade in game theory by Dutch researchers. The book also covers some papers on applications. A review on this subject was written by Dekker. In part five some other contributions are collected with a survey on semidefinite programming by de Klerk, Roos, and Terlaky. The book is concluded with a review of the activities of the LNMB during these ten years.

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1990 169 pages
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1990 120 pages
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28. VAKANTIECURSUS 1991 MEETKUNDIGE STRUCTUREN
This course (for high-school teachers of mathematics), the 45th in succession was entitled Geometric structures. Topics: Euclides' Elementa'; the s formula; geometry and groups; configurations and computers; puzzles; the fourth dimension; symmetric problems. The syllabus is written in Dutch.
1991 104 pages
ISBN 90-6196-399-0 NLG 39.00

29. HOEKEN EN HUN MAAT
by A.G. van Asch and F. van der Blij
Some views on definition, introduction and measurement of angles are exposed. The syllabus

confines itself to angles in two-dimensional Euclidean space, but the contents is not restricted to angles between straight lines. Goniometrical functions are also treated.

1992 93 pages
ISBN 90-6196-407-5 NLG 30.00

30. PROCEEDINGS SEMINAR 1986-1987 LECTURES ON KAC-MOODY ALGEBRAS

by M.J. Bergvelt and A.P.E. ten Kroode

This syllabus covers a series of lectures presented by Maarten Bergvelt and Fons ten Kroode in the seminar 'Mathematical Structures in Field Theories' during the academic year 1986-1987. Starting with finite dimensional semisimple Lie algebras and ending with infinite dimensional matrix algebras, all fundamental concepts needed to fully understand the structure of Kac-Moody algebras and the integrable highest weight representations were covered. All this richly illustrated by the homogeneous and principal realization of the basic module $L(\Lambda_0)$ of the Kac-Moody algebra $A_1^{(1)}$.

1992 97 pages
ISBN 90-6196-408-3 NLG 30.00

31. VAKANTIECURSUS 1992 SYSTEEMTHEORIE

This course (for high-school teachers of mathematics) was entitled System theory. Contents: Introduction to mathematical system theory (G.J. Olsder); Tools from linear algebra (A.W. Grootendorst); Introduction ordinary differential equations (H.J.C. Huijberts); Stochastics (J.Th.M. Wijnen); Control and observation (J.W. van der Woude); Time-optimal control of linear systems (M.L.J. Hautus); Kalman filtering (A.W. Heemink); Recent developments in mathematical system theory (G.J. Olsder). The book is written in Dutch, except for the two articles by Olsder which are in English.

1992 209 pages
ISBN 90-6196-409-1 NLG 60.00

32. MARK KAC SEMINAR ON PROBABILITY AND PHYSICS
SYLLABUS 1987-1992

edited by F. den Hollander and H. Maassen

This syllabus contains a selection of reports of lectures at the Mark Kac Seminar on probability and physics during the academic years 1987-1992. This seminar is a monthly meeting between probabilists and statistical physicists. Each year a foreign speaker is invited to give a sequence of seminars on a subject chosen for its current interest. The following researchers have accepted an invitation in the forementioned period: B. Souillard (The mathematics and physics of electron and wave propagation in disordered media), B. Kümmerer (Non-commutative probability theory), H. Spohn (Large scale dynamics of interacting particle systems), C. Maes (Stochastic cellular automata), E. Bolthausen (Large deviations with applications).

1992 197 pages
ISBN 90-6196-414-8 NLG 60.00

33. MEETKUNDE, VAN KUNST TOT KUNDE

edited by P.W.H. Lemmens

Reprint of the MC course from 1978. Added are articles on 'Constructions by ruler and compass',

'Plane crystallographical groups' and 'Polyhedra'. The aspect of proving in geometry is emphasized.
1993 177 pages
ISBN 90-6196-410-5 NLG 50.00

34. TOEGEPASTE WISKUNDE OP EEN PC
ALGORITHMEN IN QBASIC TOEPASSINGEN
by J.H. Kruizinga

QBasic is a real language and disposes of a good compiler and library manager. In this syllabus the development of algorithms is emphasized and the algorithms are used to solve partial differential equations which occur frequently in science and technology. The syllabus is written in Dutch.
1992 170 pages
ISBN 90-6196-416-4 NLG 50.00

35. VAKANTIECURSUS 1993 HET REËLE GETAL

This course (for high-school teachers of mathematics) highlights some aspects of the real numbers. Among others, attention has been paid to first principles in Greek antiquity, the exact formulation with Dedekind's construction, the continuum hypothesis, an intuitionistic view. Besides, p-adic numbers are treated. The syllabus is written in Dutch.
1993 125 pages
ISBN 90-6196-423-7 NLG 40.00

36. VAKANTIECURSUS 1994 COMPUTERALGEBRA

This course (for high-school teachers of mathematics) highlights some mathematical aspects of computer algebra, for instance the algorithmic character and the absence of ad hoc methods. Furthermore, attention has been paid to applications of computer algebra in analysis and geometry. The syllabus is written in Dutch.
1994 113 pages
ISBN 90-6196-443-1 NLG 40.00

37. WISKUNDE EN PRAKTIJK IN HISTORISCH PERSPECTIEF (SYLLABUS)
by G. Alberts

This syllabus (written in Dutch) will give the initial impetus to a real historical exposure of applied mathematics. For this purpose the idea of applying mathematics is not accepted as an established fact, but the idea is placed in time itself. The starting-point is the relation between mathematics and practice. Firstly, within that relation it is possible to make evident the variability of opinions about mathematics and of applying mathematics. Secondly, with the changing of applied mathematics by mathematical modeling the relation between mathematics and practice showed an essential turn. To this syllabus belongs a reader published as CWI Syllabus 38.
1994 87 pages
ISBN 90-6196-446-6 NLG 30.00

38. WISKUNDE EN PRAKTIJK IN HISTORISCH PERSPECTIEF (READER)
edited by G. Alberts and J. Schut

This reader belongs to CWI Syllabus 37. The texts of this reader mostly emerged as inaugural lecture or preface. The authors expose their own views of history, particularly their own previous history. In this Reader texts of the following mathematicians are put together: Stevin, Monge,

De Gelder, Klein, White, Biezeno, Von Mises, Van Dantzig, Timman, Veltkamp, Benders, Zandbergen and Seidel.

1994 222 pages
ISBN 90-6196-447-4 NLG 60.00

39. PROCEEDINGS SEMINAR 1989-1990 MATHEMATICAL STRUCTURES IN FIELD THEORY

edited by E.A. de Kerf and H.G.J. Pijls

These proceedings contain a selection of the lectures given in the seminar 'Mathematical Structures in Field Theories', held at the University of Amsterdam during the last few years.

Chapter 1 by G.M. Tuynman explains the ideas of prequantization and is intended as a general introduction for the non-specialist.

In the second chapter P.G. Vroegindeweij introduces the space-time algebra, which is the Clifford algebra associated to Minkowski space. The main goal is to give a description of the Dirac equation in terms of this space-time algebra.

Chapter 3 by C. Dullemond deals with quark confinement. The author introduces a classical model with induced metric in order to describe this phenomenon.

The fourth chapter by G.G.A. Baüerle is devoted to the Frenkel-Kac-Segal mechanism, which provides a way to introduce gauge fields. After a review of the bosonic string in Minkowski space the author treats a special case of toroidal compactification, which gives rise to two possible affine Kac-Moody algebras as spectrum generating algebras.

The next chapter by N. van Eck gives an introduction to the theory of Hopf algebras. It may serve as first step in the study of quantum groups.

The last chapter by N.P. Landsman deals again with quantization and presents an introduction to an analytic version of deformation quantization. The central point is to study degenerate Poisson algebras and their quantization by non-simple Jordan-Lie algebras.

1996 163 pages
ISBN 90-6196-448-2 NLG 40.00

40. VAKANTIECURSUS 1995 KEGELSNEDEN EN KWADRATISCHE VORMEN

This course (for high-school teachers) was entitled *Conic sections and quadratic forms.*

Contents: Conic sections in Greek antiquity (J.P. Hogendijk), Johan de Witt's conic sections (A.W. Grootendorst), Quadrics of dimension two and higher (J.M. Aarts), Quadratic forms and metrics (A.G. van Asch), Grids and quadratic forms (P. Stevenhagen), Curves generated by recursive procedures (C.W.A.M. van Overveld), Sums of squares (F. van der Blij).

1995 151 pages
ISBN 90-6196-459-8 NLG 40.00

41. VAKANTIECURSUS 1996 CHAOS

This book (in Dutch) contains the courseware of the 50th annual course for mathematics teachers, this time dealing with *chaos* with contributions by: J.M. Aarts, J. van de Craats, A.W. Grootendorst, I. Hoveijn, C. de Pater, J.A. van Ruler, F. Selten, F. Verhulst. The subject matter is introduced with an article on Descartes' theory of vortices followed by Newton's improvements on this theory in the famous "Philosophiae Naturalis Principia Mathematica". Chaos comes into the picture of this stable and predictable world with the works of Henri Poincare in the 19th century on the three-body-problem. The mathematical treatment of chaos is the subject of the remaining articles. Bifurcation is introduced and defined; the application of bifurcation in mathematical

models of population growth; the relations between chaos and fractals; and finally the application of Lorenz's theory of chaos in weather forecasting.

1996 122 pages
ISBN 90-6196-464-4 NLG 35.00

42. WIJZER IN WISKUNDE –
EEN INLEIDING VIA LOGICA EN VERZAMELINGEN
by H.C. Doets

This book (in Dutch) is written to accompany mathematics students mainly in their first year, but also later on. Its first aim is related to the sad circumstance that pre-university mathematics education no longer pays attention to what is the essence of mathematics: the notion of a *mathematical proof*. It is explained what a proof looks like and the notion is illustrated in a few simple contexts. A second aim is to present the set-theoretic basis of mathematics, including the notions of function and relation. Next to that, there are the basic facts concerning the different magnitudes of infinity and the construction of the continuum. Finally, there is a treatment of the notion of a (partial) ordering that may be useful in later years; in particular, the standard orderings of the number systems are reviewed and an introduction to well-orderings and ordinal numbers is provided.

1996 166 pages
ISBN 90-6196-466-0 NLG 40.00

43. VAKANTIECURSUS 1997 REKENEN OP HET TOEVAL

This book (in Dutch) contains the courseware of the 51st annual course for mathematics teachers, this time dealing with *statistics* and *probability*.

The first lecture by *I.H. Stamhuis* outlines the development of statistics from a purely verbal, qualitative discipline to modern statistics (descriptive statistics and mathematical statistics). Ms. Stamhuis lets her story start in the early nineteenth century with the person of Adriaan Kluit (the first Dutch professor in statistics) and continues until the early twentieth century with Galton and Pearson.

W. Kleijne describes the earliest beginnings of probability theory, i.e. the work of Christiaan Huygens (*De Ratiociniis in Ludo Aleae*, 1657), translated in 1660 by him into Dutch as *Van Rekeningh in Spelen van Geluck*. It analyses the discussions on dice and hazard games. Also at the same time, the rise of the actuarial mathematics is described.

A.G.M. Steerneman in a way continues *Stamhuis'* lecture. His aim is a more precise definition of the concept of estimation. According to his lecture, the essence of statistics is drawing conclusions from incomplete and inaccurate observations and approximating the level of confidence of the result.

J.H.A. de Smit introduces the basics of queueing theory, which was founded by *Agner Erlang* (1878–1929). An interesting aspect of his lecture is the significance of this discipline in the new programme for secondary education.

H. Dehling uses the classical Bernoulli experiment as a tool for the introduction of some well-known probability functions: binomial, geometric, negative binomial, exponential, gamma, etc. Also, the central limit theorem is highlighted.

The lecture of *C.A.J. Klaassen* addresses the desired size of a sample for the sampling of goods like gold. Special attention is paid to the *Bonus-Malus System*: Small samples for quality test, if the manufacturer has a good record of delivering high-quality products with few failures, larger

samples, if the record is less good.

In his lecture on classical probability theory, *J.A. van Maanen* outlines probability problems from Pascal in the seventeenth century to Poisson in the eighteenth century. Special attention is paid to the *Ars conjectandi* by Jakob Bernoulli.

J.M. Aarts concludes the course by his lecture on the relation between probability and fractals.

1997 134 pages
ISBN 90-6196-476-8 NLG 35.00

Other Publications

L.E.J. Brouwer: Over de Grondslagen der Wiskunde

edited by D. van Dalen

This book (in Dutch) contains the full text of Brouwer's famous Ph.D. thesis from 1907 about the foundations of mathematics. It is supplemented with hitherto unpublished fragments, correspondence with his thesis adviser Korteweg, and two reviews by Mannoury. The book was published on the occasion of the 100th anniversary of Brouwer's birthday, under auspices of the Dutch Mathematical Society and the Brouwer Archive.

1981 267 pages
ISBN 90-6196-214-5 NLG 68.50

Draft Proposal for the B Programming Language

by L.G.L.T. Meertens

The programming language B (nowadays called ABC), developed at CWI, is designed to be used on personal computers. Its primary aim is ease of use for the programmer. Applications range from developing games, bookkeeping, simple engineering computations and solving puzzles to learning how to program. The definition of B in this publication is semi-formal because it does not capture most of the 'static semantics' in the syntactic description. The book also contains a Quick Reference.

1981 88 pages
ISBN 90-6196-238-2 NLG 29.50

A Bibliography of Lambda-Calculi, Combinatory Logics and Related Topics

by A. Rezus

The items listed in this bibliography fall roughly into three categories: pure theory (syntax and semantics), theory related to foundations of logic and mathematics, and applications (recursion theory, computer science, proof theory, category theory).

1982 86 pages
ISBN 90-6196-234-X NLG 29.50

A Contribution to the Non-Existence of Perfect Codes

by M.R. Best

This treatise is a slightly revised edition of the author's Ph.D. thesis (supervisor J.H. van Lint). It contains a proof that unknown t-perfect codes do not exist for $t \geq 3$, unless $t = 6$ or $t = 8$.

1983 99 pages
ISBN 90-6196-253-6 NLG 29.50

Deterministic Top-Down and Bottom-Up Parsing – 433 Historical Notes and Bibliographies

by A. Nijholt

The theory of parsing, as developed in the sixties by Lewis, Stearns, Knuth, Floyd, Wirth and Weber, has led to a vast body of knowledge in the seventies. This book contains bibliographies in three fields: top-down parsing, LR-grammars and parsing, and precedence parsing. There are more than thousand references, dealing primarily with theoretical problems, but also with more application oriented issues such as compiler construction techniques.

1983 118 pages
ISBN 90-6196-245-5 NLG 39.00

ZIJ MOGEN UITERAARD DAARBIJ DE ZUIVERE WISKUNDE NIET VERWAARLOOZEN
edited by G. Alberts, F. van der Blij and J. Nuis
This book (in Dutch) highlights the foundation and early activities of the Stichting Mathematisch Centrum (SMC). The events are considered in the broader context of reconstruction after World War II. Although the book was composed on the occasion of the 40th anniversary of the SMC in 1986, its scope extends to the history of mathematics in the Netherlands during its first ten years. General considerations are complemented by interviews with mathematicians involved in the early history of the SMC, e.g. Freudenthal and Van Wijngaarden.
1987 319 pages
ISBN 90-6196-320-6 NLG 78.50

OP DE GRENS VAN TWEE WERELDEN
by A.F. Monna
This book (in Dutch) contains essays concerning the author's experience with mathematics over a period of 60 years. The central theme of these essays is the author's notion of the change from classical to modern mathematics. Reflections on this theme give way to a comparison of the situation in mathematics 60 years ago with contemporary mathematics.
1989 100 pages
ISBN 90-6196-367-2 NLG 29.50

OM DE WISKUNDE
STIMULANSEN VOOR TOEPASSINGSGERICHTE WISKUNDE ROND 1946
edited by G. Alberts, H.J.M. Bos and J. Nuis
Far from being a single event the foundation of the Stichting Mathematisch Centrum (SMC, 1946) was stimulated by external demands upon mathematics. Mathematization, application and mathematical modelling are keywords for the role mathematics, and the SMC in particular, played in response. Continuing on the scope of publication no. 6. *Zij mogen uiteraard daarbij de zuivere wiskunde niet verwaarloozen* these proceedings of a 1987 symposium offer a view of the world around mathematics, by amongst others E.H. Kossmann, J. Tinbergen and P. de Wolff.
1989 74 pages
ISBN 90-6196-381-8 NLG 25.50

LAMBERTUS ZIJL'S IN STEEN GEHOUWEN MEDAILLONS
by J. Nuis
In June 1980, the Mathematisch Centrum (from September 1983 Centrum voor Wiskunde en Informatica) moved within Amsterdam from the 2e Boerhaavestraat 49 to its present location Kruislaan 413. In the new building thirteen medallions, sculptured by Lambertus Zijl, were bricked in the walls of the hall. In this book the history of the fourteen medallions (one was lost) is described. Also a brief description of Lambertus Zijl's life is given.
1990 38 pages
ISBN 90-6196-386-9 NLG 10.50

ELEMENTA CURVARUM LINEARUM – LIBER PRIMUS *by Jan de Witt*
Dutch translation from Latin with annotations by A.W. Grootendorst
The 17th Century Dutch statesman Jan de Witt (1625 – 1672) was also an eminent mathematician, especially known for his expertise in life insurance mathematics. It is less known, however, that he also published the *first* tutorial on Analytic Geometry titled – in Latin – *Elementa Curvarum Linearum.*

This book – consisting of two parts: *Liber Primus* and *Liber Secundus* – was planned as an annex to the Latin translation by Frans van Schooten jr. (the co-author of Jan de Witt's book) of Descartes' book *Géométrie*.

Dr. A.W. Grootendorst, former Professor in Mathematics at the Delft University of Technology and also very familiar with the classic languages, has now completed a Dutch translation of the *Liber Primus*, complete with annotations, a synopsis, and two appendices. The entire book is richly illustrated by geometric figures and pictures of the authors.

A Dutch translation of the *Liber Secundus* is currently in preparation.

1990 287 pages
ISBN 90 6196 472 5 NLG 50.00

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