MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 20/1985

Angewandte stochastische Prozesse

28.4. bis 4.5.1985

Die Tagung fand unter der Leitung von Herrn Prof. Dr. M. Schäl (Bonn) und Herrn Prof. Dr. R. Schaßberger (Berlin) statt. An der Planung und den Vorbereitungen hatte darüberhinaus Herr Dr. W. Whitt (Holmdel,USA) einen besonderen Anteil.

Im Mittelpunkt des Interesses standen stochastische Prozesse, deren Anwendungsbezug offensichtlich ist. Damit wurde ein Gebiet behandelt, auf dem in der Bundesrepublik Deutschland bisher verhältnismäßig wenig gearbeitet wurde. Die Statistik der Vorträge zeigt, daß mehr als drei Viertel von ihnen von ausländischen Wissenschaftlern gehalten wurde. Die Qualität der Vorträge mit einigen aufsehenerregenden Resultaten und die auffallende Intensität der Diskussionen sollten sich stimmulierend und richtungweisend auf die Forschung auswirken und auch dazu beitragen, die in der Bundesrepublik noch teilweise bestehende Lücke zwischen Theorie und Anwendungen stochastischer Prozesse zu füllen.

Gefördert durch DFG Deutsche Forschungsgemeinschaft

Der Schwerpunkt bei den untersuchten Prozessen lag auf Erneuerungsprozessen und Irrfahrten, Markoff-Ketten, -Prozessen und -Feldern sowie Verallgemeinerungen. Die Forschung zielte dabei auf Anwendungen bei Bedienungsmodellen, Warteschlangennetzen, Ersetzungs-, Instandhaltungs- und Speichermodellen und Modellen der Versicherungsmathematik. Es zeigte sich deutlich der Einfluß der stürmischen Entwicklung im EDV-Bereich.

Die Forschungsergebnisse betrafen dabei die Modellierung, Kontrolle und Planung von stochastischen Systemabläufen und die theoretische Berechnung sowie die Erstellung von Algorithmen und Schranken für charakteristische Kenngrößen.

Vortragsauszüge

A.A. Borovkov:

Ergodicity and some asymptotic results for queueing networks with general independent servers

First we consider closed network consisting of N stations and n customers. The path of a customer's progress throughout the network is controlled by a transition matrix and N independent sequences of i.i.d.r.v.'s $\{\tau_j^k\}_{k=1}^{\infty}$, $j = 1,\dots,N$, where $\{\tau_j^k\}_{k=1}^{\infty}$ are service times at station j . The ergodicity of such networks is proved under some conditions and the equation for steady-state distribution is obtained. The limit behaviour of these networks is investigated when $n\to\infty$. To this end some open networks are constructed and the weak convergence of corresponding distributions is proved. We consider also the situation with several "slow" stations and prove in this case convergence of the normalized queue lengths to diffusion process with reflection.

O. J. Boxma:

Response time distributions in cyclic queues

Recently, exact results for response time and cycle time distributions in closed cyclic queueing systems have been obtained. Using those results, we perform an asymptotic analysis of response times and cycle times for N, the number of customers in the system, growing to infinity. This asymptotic analysis demonstrates that, for large values of N, the slowest queue almost exclusively determines the behaviour of the cyclic system. Numerical results are presented which show that, even for moderate values of N, the slowest queue makes a dominating contribution to the cycle time.

E. Çinlar:

Random circles and cylinders

The problem is to model the exact shapes that result when we try to manufacture a disk or a cylinder. In the case of random circles, assuming that a 'center' is given, we are interested in a stochastic process $R(\theta)$, $0 \leq \theta \leq 2\pi$, where $R(\theta)$ is the 'radius' when the angle is θ. This process should be continuous, stationary, reversible and Markov, that is, the probability law should be invariant under rotations, reversals, and be that of a continuous Markov random field. Subtracting the mean radius, we obtain something easier to work with: a process (X_p) indexed by the points p of a circle C. Supposing C has radius one, letting W be a Wiener process on $[0,2\pi]$, and letting $\alpha(p,q)$ be the arclength from p to q going counterclockwise , we define

$$X_p = \int_C \alpha(p,q)\,dW_q \ , \quad p \in C \ .$$

The result is a process X that is continuous, stationary, reversible, and is a Gaussian Markov random field on C. In fact, it has the form $X_p = X_0 + W_p - pW_1$, namely a Brownian bridge plus an initial value X_0 , but $X_0 = \int_0^{2\pi} q\,dW_q$ depends on all of W. This differs slightly from a process of Lévy's by a random constant, the constant making X markov (whereas Lévy's process is not). It is easy to construct a random cylinder by taking this circle and extend it like an Ornstein-Uhlenbeck process along an axis.

H. Daduna:

Sojourn time distributions in networks of queues (Burke's theorem)

I report on joint work with R. Schaßberger, Berlin, concerning sojourn times in networks with product-form steady state distribution. We have proved that in open, closed, and mixed networks the Laplace-Stieltjes transform of the limiting joint distribution of the successive sojourn times has simple product-form, if the following holds:

i) the path under consideration is overtake-free
ii) the first and the last node are multiservers, the other nodes of the path are single servers
iii) the service discipline is first-come-first-served for all path-nodes
iv) the service time distributions of the path-nodes are exponential and node specific.

If the network is totally open this implies independence of the successive sojourn time distribution (Burke's theorem).

G. Fayolle:

Analytic methods and stability conditions for random walk

Starting from peculiar examples, we show how analytic and probabilistic methods blend fruitfully in the proof of stability theorems for random walks with n-dimensional state space:

i) One-dimensional case: The stability of a stack-algorithm (belonging to the "Capetanakis-Tsybakov Mikailov" class) is analysed using mainly analytic methods.
ii) Two-dimensional case: A wide variety of models - described by random walks with state space the lattice in the positive quarter plane of R^2 - can be solved by reduction to Riemann-Hilbert boundary value problems. The stability conditions are directly related to the index of these problems.

iii) A case in N^N: The exponential back-off algorithm. Partial results for the unstability are shown - using martingales arguments.

R. D. Foley:

Sojourn times in generalized semi-Markov processes

For a class of stochastic processes, the generalized semi-Markov processes, conditions are known which imply that the stationary distribution of the process, when it exists, depends only on the means and not the shape of life time distributions of certain components of the process. We show that this insensitivity is intimately linked with stationarity of a certain transformed process. Furthermore, if T_x is the random length of time needed for components s to reach internal age x, $\{T_x, x \geq o\}$ possesses stationary increments.

U. Herkenrath:

On the estimation of the adjustment coefficient in risk theory by means of a stochastic approximation procedure

One essential branch of insurance mathematics is risk theory. Within risk theory one is mainly interested in the study of the so-called surplus process (surplus of the insurance company which is necessary to compensate random fluctuations in claims evolution). In particular one is interested in ruin probabilities for the surplus process, in order to control the security of the business.
In this context there exists a so-called adjustment coefficient which was introduced by Cramer. It plays an important role in formulas and estimates for ruin probabilities. Moreover, often this coefficient itself is taken as a measure of security for the business.

We propose a method for estimating this coefficient by means of observed (= reported) individual claims. This method is based on the well-known Robbins-Monro-procedure of stochastic approximation. Convergence results for the sequence of estimators are available. Numerical simulations were done in order to improve the empirical speed of convergence of the estimators in a range of 100 - 200 approximation steps (= observations).

K. Hinderer:

On the joint distribution of residual, spent and total lifetime in renewal theory

Let Y_t, Z_t and L_t denote the residual, spent and total life time, respectively, of an ordinary renewal process with life time distribution Q and renewal measure ν. A natural starting point for the investigation of the joint distribution of any two of the r.v's Y_t, Z_t, L_t (without using the renewal equation technique) is the distribution of (S_{N_t}, L_t), which is the restriction of $\nu \times Q$ to $\{(s,x) : o \leq s \leq t < s+x]$. From this one obtains easily old and new representations of d.f.'s (e.g. for Y_t/L_t), of densities and of moments. Moreover, under a rather general condition the limit of $Ef(Y_t, Z_t, L_t)$ for $t \to \infty$ is reduced to the Key Renewal Theorem. As applications, the weak limit of some distributions (e.g. for Y_t/L_t) is identified and convergence of densities and of moments towards the corresponding quantity of the limit distribution is shown.

M. Hofri:

Analysis of the algorithm NFD for Bin Packing

The problem of Bin Packing will be described as well as the need for heuristic algorithms to handle it.
The Next Fit algorithm will be given as an example of algorithm with simple recurrence properties - and hence simple to analyze. The Next Fit Decreasing algorithm does not have such nice properties and we show an asymptotic analysis of its behaviour.

G. Hooghiemstra:

Calculation of the equilibrium distribution of a simple solar energy model

The study of a simple energy storage model leads to the question of analyzing the equilibrium distribution of a Markov chain, for which the state at epoch (n+1) (i.e. the temperature of the storage tank) depends on the state at epoch n and on a controlled input, acceptance of which entails a further decrease of the temperature level. Here we study the model where the input is exponentially distributed. For all values of the parameters involved, an explicit expression for the equilibrium distribution of the Markov chain is derived, and from this the exact values of the mean of this equilibrium distribution.

A. Hordijk:

Insensitive bounds on the blocking probability in a simple queueing model

In this talk a simple queueing model with blocking was discussed to make a first step in approximating weakly sensitive by insensitive systems.

A method was given to obtain upper and lower bounds for the stationary blocking probabilities. These bounds only depend on the service time distributions through their means. It was pointed out that the bounds could be proven for phase-type distributions with a monotone uniformized transition matrix.

G. Hübner:

Algorithms for constrained or multi-objective Markov decision processes

In applied inventory it is difficult to fix shortage costs, so only the other costs are minimized while the expected total amount of shortage has to obey a constraint.

This situation is modelled by a Markov decision process with two-dimensional rewards structure such that the first dimension (objective) is to be minimized under a constraint for the second. Three methods of solution are discussed:

1) the usual linear programming method,
2) the search along the edge of the convex set of feasible values. This is done by some adapted form of policy iteration where only one action per step is exchanged,
3) a Lagrangean search method which works well even in an approximative version.

We conclude with a remark on methods for the case where the problem is viewed as a multi-objective one.

U. Jensen

Optimal inspection and replacement policies

Consider a system which is subject to failure. The state of the system is described by a continuous time Markov process.
In the first part a solution of the maintenance problem is given in which preventive replacements are possible at any stopping time.

The second part deals with the following inspection model:
The true state of the system cannot be observed continuously. Only partial information is available which contains at least the age of the system and occurence of system failure. These informations are used to determine an inspection time at which the true state can be observed. Depending on the system state at inspection two decisions are possible: perform a preventive replacement or continue and replace at failure. The problem is to specify a decision rule which minimizes long run average cost per unit time.

D. Kadelka:

On sufficient conditions for the existence of optimal control limit policies in a harvesting model

We investigate a stochastic model of optimal harvesting. At each time point n the value s of some biological asset is known to the decision maker. He has to decide whether to let the asset mature one more time period or to harvest it completely and to plant another asset of the same kind. The growth of the asset is governed by an arbitrary stochastic law, dependent on s. The problem is to maximize the expected discounted value of the cash flow stream generated by the growth and harvesting process for finite and infinite horizon. Now:

(i) Assuming that the expectation of the growth is a decreasing function of s there always exists an optimal control limit policy for the model with infinite horizon and discount factor $\beta<1$.

(ii) If the growth has negative binomial distribution (or logarithmic series distribution) then the same holds for the model with finite horizon under weak conditions.

P. C. Kiessler (R. L. Disney):

Reversibility of point processes and their applications to traffic processes in queueing networks

The idea of reversing a stationary random process and whether a random process is reversible is not new. These ideas are extended to point processes and to marked point processes when considered as random counting measures. The definitions for reversing a stationary marked point process, its synchronous version and its interval process are shown to be equivalent. It is then shown that if the marked point process $(\hat{X},\hat{D})$ is the reverse process of the marked point process (X,D) then the point process $\hat{D}$ is the reverse process of the point process D.

The idea are then used to relate flow processes in Jackson queueing networks. For example, when the queue length process is reversible the input process is the reverse process of the output process at a node. An example is given to show that the result does not extend to all Jackson networks .

W.A. Massey:

Lattice Bessel Functions

Modified Bessel functions play a key role in the transient analysis of the M/M/1 system for quantities such as queue length distribution and exit times to the zero state (busy period). By creating a new class of functions called lattice Bessel functions, we can do a similar transient analysis for series networks with an arbitrary number of nodes. We can then investigate queueing network models where we can explicitly determine their relaxation parameter, and even create a system with a non-product form steady state distribution.

Stochastic orderings for Markov processes on partially ordered spaces

The purpose of this paper is to develop a unified theory of stochastic ordering for Markov processes on countable partially ordered state spaces. When such a space is not totally ordered, it can induce a wide range of stochastic orderings, none of which are equivalent to sample path comparisons. Such alternative orderings are essential to developing tools for the transient analysis of multi-dimensional stochastic models such as queueing networks.

S. R. Pliska (joint with K. Back):

Martingale characterization of shadow prices for continuous time stochastic control problems

We consider a general class of continuous time stochastic control problems where one seeks to minimize a convex functional over the space of bounded predictable processes. We provide conditions under which a natural dual problem is to maximize the conjugate functional over a space of martingale. This is done by embedding the primal problem's variables in an L^{∞} space of adapted, cadlag processes; characterization of the dual space; using convex analysis to formulate the standard dual problem; and showing that if there exists a dual solution, then one can find a solution whose singular component is null and whose continuous component corresponds to a martingale. This result has significance for computational purposes, for the economic interpretation of optimal dual variables as shadow prices, and for the comparison of predictable versus adapted controls in economic applications. Two examples are presented: the optimal control of a portfolio and the optimal sale of a resource when confronted by an exogenous price process.

T. Rolski:

Queues with doubly stochastic Poisson arrivals

In this lecture I will discuss some results concerning DSP/GI/1 queues. Arrivals at such queues are generated according to a doubly stochastic Poisson process with a random arrival rate function $\{\lambda(t)\}$. Service times are i.i.d. and independent of the input process. Two characteristics are considered; that is the stationary delay W^{o} and the stationary work-load Z^{*}. I will show how to define these characteristics and then give bounds for them.

A subclass of DSP/GI/1 queues of interest are so called Periodic Poisson queues. In this case arrivals are generated according to a Poisson process with a deterministic periodic arrival-rate function $\{b(t)\}$. We show how periodic queues can be approximated by Markov modulated Poisson queues; that is queues with random arrival-rate $\{\lambda(t)\}$ of form $\lambda_{X(t)}$, where $\lambda_1,\dots,\lambda_N \geq 0$ and $\{X(t)\}$ is a continuous time, finite state Markov process.

S.M. Ross:

Simulation in statistical tests

We show how simulation can be used to test statistical hypothesis even in cases where the null hypothesis does not completely determine the distribution function of the test statistic. The method is applied to the Behrens-Fisher problem.

R.F. Serfozo:

Partitions of point processes: Poisson approximations

We show that when a point process is partitioned into certain uniformly sparse subprocesses, then the subprocesses are asymptotically multivariate Poisson or compound Poisson. Bounds are given for the total-variaton distance between the subprocesses and their limits. Our key lemma is a compound Poisson approximation for a sum of dependent random variables.

J. H. A.de Smit:

The single server semi-Markov queue

We consider a general model for the single server semi-Markov queue. Its solution is reduced to a Wiener-Hopf matrix factorization problem. Given this factorization, results are obtained for the distribution of actual and virtual waiting times and queue lengths both at arrival epochs and in continuous time. Two examples are discussed for which explicit factorizations have been obtained, viz. a generalization of the GI/M/1 queue and the M/G/1 queue with Markov modulated arrivals and services. The latter model may serve as an approximation for the periodic M/G/1 queue.

J.L. Teugels:

Stochastic models in insurance mathematics

We start from a homogeneous portfolio of claims $X_1, X_2, \ldots$ that arrive at an insurance firm at times $T_1, T_2, \ldots$. We assume that the times of claim arrivals form a renewal process and that independently the claim sizes are i.i.d. with distribution F on $\mathbb{R}_+$. We restrict attention to three questions from the rich arsenal of problems from insurance mathematics.

(i) The total claim amount $X(t) = \Sigma_1^{N(t)} X_i$ where $\{N(t), t \geq o\}$ is the renewal counting process is an important quantity; let its distribution be $G_t(x)$. We give two examples on how to estimate $1-G_t(x)$ for large x but fixed t; one example relates to small claims while the other allows large claims.

(ii) Once $G_t(x)$ is known, determine the solution of $1-G_t(x_\varepsilon) \leq \varepsilon$ for a small $\varepsilon > o$. If at time t the insurer has received premium income P(t) starting with initial reserve u, then $P(t) + u > x_\varepsilon$ guarantees a probability less than ε of bankrupcy at time t. The two examples show how we get explicit forms for premium calculations.

(iii) In fighting the influence of large claims the company can buy reinsurance. We give 5 examples of reinsurance treaties that are used in practice pointing out their defects and virtues. For treaties involving largest claims, asymptotic results are available.

H.C. Tijms:

Heuristics and algorithms for queueing systems

This lecture shows for stochastic service systems the wide applicability of a two-moment approximation based on a linear interpolation on the squared coefficient of variation of the service time. Applications are given both to buffer design with blocking and to delay systems with Poisson input and general service times. For the latter systems an extremely accurate approximation to the waiting time percentites is discussed.

J. van der Wal:

Iterative approximation of the equilibrium distribution in a finite state Markov chain

Consider a Markov chain with states 0,1,...,N and irreducible transition matrix P with elements p_{ij} . The equilibrium distribution π satisfies $\pi P = \pi$, $\Sigma \pi_i = 1$. Define $z_i = \pi_i / \pi_o$, then z satisfies $z_o = 1$, $z_1 = p_{oi} + \Sigma_j \, p_{ji} z_j$, which with $r_i = p_{oi}$ and $q_{ij} = p_{ji}$ can be rewritten as $z_i = r_i + \Sigma_j \, q_{ij} \, z_j$. In vector notation $z = r + Qz$. z_i is the expected number of visits to state i between two visits to state o. Since P is irreducible Q has spectral radius less than 1. Thus z can be iterated according to $z^o = o$, $z^{n+1} = r + Qz^n$. From this bounds on z can be obtained as follows. Define $\alpha_n = \min_i (z^{n+1} - z^n)_i / (z^n - z^{n-1})_i$ and $\beta_n = \max_i (z^{n+1} - z^n)_i / (z^n - z^{n-1})_i$. If Q is irreducible and aperiodic then α_n and β_n converge to the spectral radius of Q and one has, once $\beta_n < 1$, $z^{n+1} + \alpha_n / (1 - \alpha_n) \cdot (z^{n+1} - z^n) \leq z \leq z^{n+1} + \beta_n / (1 - \beta_n) \cdot (z^{n+1} - z^n)$. These bounds on z easily lead to bounds on π.

J. Walrand:

Remarks on Insensitivity

We indicate that the insensitivity results for GSMP's (generalized semi-Markov processes) can be seen as particular results on product-forms. This observation explains the similarity between the conditions for insensitivity and those for product form; it also leads to elementary derivations. The basic idea is to represent the insensitive GSMP clocks by $M/G/\infty$ queues.

G. Weiss:

Stochastic scheduling problems

We discuss 4 problems.

1) A single server job scheduling problem: to minimize the sum of completion times, $\sum_1^n C_m$, of n jobs with random independent different processing times, by a single machine or server, using pre-emptions. The solution is by a Gittins index.

2) Branching bandit processes: jobs of types 1,...,L, where type i requires processing V_i, obtains reward R_i, and generates descendants $N_{i_1},\dots,N_{i_L}$ of types 1,...,L, with state $n_1,\dots,n_L$ counting number of jobs of each type are processed by a single server. A Gittins index is derived, which provides a priority policy that maximizes expected discounted rewards.

3) A simple two server scheduling problem: n jobs require processing 1 w.p.p or k+1 w.p. 1-p. Two servers wish to minimize $E(\Sigma C_m)$, by deciding if and when to pre-empt jobs after processing time 1. Applying Gittins policy for each server, while not optimal is shown to be "almost optimal".

4) Parallel servers, no pre-emptions: We mention a recent result of Varaiya, Walrand and Weber: for $X_1 \leq_{ST} \cdots \leq_{ST} X_n$, SEPT (shortest expected processing time first) minimizes $E(\Sigma C_m)$. For $E(X_1)=\ldots=E(X_n)$ we discuss the LVF (largest variance first) policy.

Uri Yechiali and Offer Kella:

Priorities in M/G/1 queue with server's vacations and extension to the non-preemptive M/M/c system

The M/G/1 queue with server's vacations is studied under both the preemptive and non-preemptive regimes. We derive the Laplace-Stieltjes Transform (LST) and the first two moments of the waiting time, W(k), of a class-k customer for the two models of server's vacations analyzed by Levy and Yechiali (1975). Using a probabilistic equivalence between the M/G/1 queue with multiple vacations and the non-preemptive priority M/M/c system, we derive the LST and first two moments of W(k) in the M/M/c queue where all customers habe the same mean service time.

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