MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

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Statistik stochastischer Prozesse

1.12. bis 7.12.1991

Die Tagung fand unter der Leitung von H. R. Lerche (Freiburg) und M. Woodroofe (Ann Arbor) statt. Hauptthemen der Tagung waren

a) Change- Point- Probleme,
b) Sequentialstatistik,
c) asymptotische Inferenz.

Daneben gab es eine Vielzahl von Einzelthemen. Bemerkenswert war, daß es weniger Vorträge zur Survivalanalysis als zu räumlichen Punktprozessen gab, obwohl dies anders geplant war. Eine interessante Verbindung zwischen beiden Gebieten stellte R. Gill in seinem Vortrag her.

An der Tagung nahmen insgesamt 48 Wissenschaftler aus 14 Ländern teil.

Vortragsauszüge

G. ALSMEYER :

Blackwell's renewal theorem for a class of generalized random walks

Blackwell's renewal theorem is discussed for a class of generalized random walks whose increments need neither be independent nor stationary. Their intrinsic property is that the conditional increment distribution functions are bounded from below and above by integrable distribution functions. We introduce certain drift constants which then lead to bounds for the renewal measure of the considered random walk. Under further regularity assumptions, notably minorization conditions inspired by similar ones arising in the theory of Harris chains and Markov random walks, Blackwell's renewal theorem can be extended.

O. E. BARNDORFF-NIELSEN :

Parametric modelling of turbulence

Some steps are taken towards a parametric statistical model for the velocity and velocity derivative fields in stationary turbulence, building on the background of existing theoretical and empirical knowledge of such fields. While the ultimate goal is a model for the three-dimensional velocity components, and hence for the corresponding velocity derivatives, we concentrate here on the streamwise velocity component. Discrete and continuous time stochastic processes of the first-order autoregressive type and with one-dimensional marginals having log-linear tails are constructed and compared with two large data-sets. It turns out that a first-order autoregression that fits the local correlation structure well is not capable of describing the correlations over longer ranges. A good fit locally as well as at longer ranges is achieved by using a process that is the sum of two independent autoregressions. We study this type of model in some detail. We also consider a model derived from the above-mentioned autoregressions and with dependence structure on the borderline to long-range dependence. This model is obtained by means of a general method for construction of processes with long-range dependence.

M. BEIBEL :

Bayes problems in change-point models for Brownian motion

Ritov (1990) introduced random change points in a discrete time model which depend on the observations before v. Ritov's construction is related with the cusum procedures. We present a continuous time version of this approach. We consider a Brownian motion process W and a randomized stopping time v of W. Before v, W had drift 0, after v, W has drift μ. ν is unknown and μ is known. Using Girsanov's formula we obtain a probability measure under which $W_t - \mu(t - v)^+$ is a standard Brownian motion. We construct a special class of priors under which the posterior probability π_t, that a change has taken place up to time t given the observation W up to time t, is an isotonic function of a cusum statistic. We study the Bayes problems for these priors and the loss structure of Ritov. The main idea, to prove that a p^* exists and that $T^* = \inf\{t \mid \pi_t \geq p^*\}$ is a Bayes solution, is to find a function g with a unique minimum such that the expected loss is equal $Eg(\pi_T)$ for all bounded stopping times T.

H. E. DANIELS :

Nearly exact saddlepoint approximations

The saddlepoint approximations to densities or tail probabilities are often remarkably accurate for quite small sample size over the whole range of the variable. A few "exact" cases are known but otherwise there is so far no theoretical explanation for the phenomenon. In this talk a family of distributions which is essentially an infinite convolution of Gamma variables is found to have nearly exact saddlepoint approximation in the sense that even for a single observation the density $f(x)$ and distribution function $F(x)$ are reproduced with small error over the whole range of the variable by $\hat{f}(x)$ and $\hat{F}(x)$. It is stated that for a subclass of such distributions the relative error of $\hat{f}(x)$ is bounded by $e/\sqrt{2\pi} = 1,0844$. From numerical examples, renormalization would probably reduce the relative error by about half, but this has not been proved.

H. DINGES :

The small sample version of the large deviation principle (LDP) applied to first crossing of curved boundaries

Let $\{S_t: t > 0\}$ be a process with independent stationary increments, upward continuous with a Gaussian component. The process is observed until the time τ^c when it first hits the boundary of (i.e. it first leaves) $C = \{(t,x) : x \leq f(t)\}$ where $f(\cdot)$ is smoothly concave. The continuation set C is more conveniently described by $t(\nu)$, the solution of $\nu = \frac{f(t)}{t}$. We study the slope $V^C = \frac{f(\tau^C)}{\tau^C}$, at which the process leaves C under all the hypotheses generated by tilting from the original. $\beta(\vartheta,\nu) = P_\vartheta(V^C \geq \nu)$ is the probability that the hypothesis of a small drift is rejected. We are interested in a good small sample approximation of this power function. (Approximation = a clever asymptotic $(\varepsilon \to 0)$ + hope, that it works for $\varepsilon = 1$.) Our asymptotic is $\{\frac{1}{\varepsilon}C: \varepsilon \to 0\}$, i.e. enlarging C by homothetic expansion. Small sample means $\beta_\varepsilon(\vartheta,\nu) \approx 0{,}025$ or $\approx 0{,}975$. It is convenient to study the transformed power function $\Lambda(\beta_\varepsilon(\vartheta,\nu))$ where $\Lambda(p) = \frac{1}{2}[\Phi^{-1}(p)]^2$ (the name "probabilistic logarithm" seems suitable for this important elementary function).

<u>THEOREM</u> There exist functions $M_0(\vartheta,\nu), M_1(\vartheta,\nu),\ldots$ such that $\Lambda(\beta_\varepsilon(\vartheta,\nu)) = \frac{1}{\varepsilon}t(\nu)[K(\nu) - \vartheta\nu + \varphi(\vartheta)] + M_0(\vartheta,\nu) + \varepsilon M_1(\vartheta,\nu) + O(\varepsilon^2)$ uniformly for $\nu_- < \nu < \nu_+$ and $K'(\nu_-) < \vartheta < K'(\nu_+)$. These functions can (by the method of Laplace) be computed explicitly from the given

$$\varphi(\vartheta) = \frac{1}{t}\ln[E\exp(\vartheta S_t)]\ ,\ K(\nu) = \sup\{\vartheta\nu - \varphi(\vartheta)\}$$

$$\beta_\varepsilon(\vartheta,\nu) = \Phi\left[(\pm\sqrt{2}\sqrt{\tfrac{1}{\varepsilon}M(\vartheta,\nu) + M_0(\vartheta,\nu) + O(\varepsilon)}\right]$$

In the critical region "$\beta \approx 0{,}025$ or $\beta = 0{,}975$" the correction $M_0(\vartheta,\nu)$ to the classical large deviation approximation yields the additional factor $\exp(M_0(\vartheta,\nu))$, which is independent of ε.

R. DÖHLER :

<u>The Blackwell space as a basic assumption for continuous-time sequential analysis</u>

Let $\mathfrak{F}_t = \sigma(X_s; s \leq t)$, $t \geq 0$, be the natural filtration of a right-continuous random process $X = (X_t)$ which is supposed to be defined on a Blackwell space $(\Omega,\mathfrak{A})$. For any stopping time τ, the sigma-field $\mathfrak{F}_\tau = \{A \subset \Omega\ ;\ A \cap \{\tau \leq t\} \in \mathfrak{F}_t\ \forall t \geq 0\}$ is then equal to $\sigma(X_{\tau \wedge t}\ ; t \geq 0)$. After introducing a more general past, this result can be extended to arbitrary random times.

K. DZHAPARIDZE :

<u>Evaluating the brackets of a semimartingale via its periodogram</u>

The following theorem holds.

<u>Theorem</u>. Let X_t be a P-semimartingale. Then for a fixed $T > 0$

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$$\frac{1}{2L}\int_{-a}^{a} I_T(\lambda;X)d\lambda \xrightarrow{P} [X]_T \text{ as } L \to \infty$$

where

$$I_T(\lambda;X) = \left|\int_0^T e^{i\lambda t}dX_t\right|^2$$

is the periodogram of X_t, and $[X]$ the usual quadratic variation process.

(Joint work with P. Spreij, VU Amsterdam)

P. GAENSSLER :

On a Mean Glivenko-Cantelli result for certain set-indexed processes

This paper presents a Mean Glivenko-Cantelli result for set-indexed processes $S_n = (S_n(C))_{C\in\mathcal{C}}$ given by $S_n(C) := \sum_{j\leq j(n)} 1_C(\eta_j)\xi_{nj}$, $C \in \mathcal{C}$, where η_j, $j \in \mathbb{N}$, are independent and identically distributed random elements in an arbitrary sample space $X = (X,\mathfrak{X})$, where $\mathcal{C} \subset \mathfrak{X}$ is a Vapnik-Chervonenkis class of sets in X, and where $(\xi_{nj})_{1\leq j\leq j(n), n\in\mathbb{N}}$ is a triangular array of rowwise independent but not necessarily identically distributed real-valued random variables such that the whole array is independent of the sequence $(\eta_j)_{j\in\mathbb{N}}$. Assuming $\mathcal{C}$ to be countable (for simplicity) it is shown that under a certain moment condition on the ξ_{nj}'s

$$(*)\quad \lim_{n\to\infty} \mathbb{E}\left(\sup_{C\in\mathcal{C}}|S_n(C) - \mathbb{E}(S_n(C))|\right) = 0 .$$

In the i.i.d. case (that is, when $\xi_{nj} = j(n)^{-1}\xi_j$ for some i.i.d. sequence $(\xi_j)_{j\in\mathbb{N}}$ with $j(n) \to \infty$ as $n \to \infty$) it turns out that $(*)$ holds true whenever $\mathbb{E}(\xi_1^2) < \infty$; whether the latter can be weakened to assuming only the existence of first moments, is still an open problem.

(Joint work with K. Ziegler)

R. D. GILL :

Estimating the point-event distribution of a stationary point process observed through a bounded window

There is a clear analogy between estimating the survival function based on randomly censored lifetimes and estimating the point-event distribution function for a stationary point process based on observing the process through a bounded window. Distances are censored by the distance to the boundary of the window. The analogy is

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explored and a generalized Kaplan-Meier estimator shown to have interesting properties.

(Joint work with A. I. Baddeley, Amsterdam)

P. GREENWOOD :

Estimating the minimum Kullback-Leibler distance functional

A stochastic process X is observed on a time interval $[0,t]$. It is presumed that the law of the process belongs to a family of probability measures $\{P_\vartheta, \vartheta \in \Theta\}$, but in fact the law of X is P, not belonging to this family. We ask how well the maximum likelihood estimator, $\hat{\vartheta}$, estimates $\kappa \in \Theta$ where the Kullback-Leibler distance from P to the family $\{P_\vartheta\}$ is minimized as $t \to \infty$. We construct a local model around P which has the local asymptotic normality property at P and such that the Kullback-Leibler functional is differentiable at P. The convolution theorem gives an efficiency bound. We compute this bound and compare it with the limiting variance of the normalized $\hat{\vartheta}$. We find that $\hat{\vartheta}$ is not, in general, efficient as an estimator of κ.

(Joint work with W. Wefelmeyer)

J. HARDWICK :

Advantages of adaptive allocation

We study exact solutions to an allocation problem with ethical cost. Suppose patients enter a trial sequentially and are allocated to one of two treatments - T_1 or T_2. Patient outcomes are modeled so $X_i \sim B(I,P_1)$ if T_1 or $Y_i \sim B(I,P_2)$ if T_2; $i = 1,2,\ldots$ The problem is to test the hypothesis $H_0: P_2 - P_1 > 0$ vs. $H_1: P_2 - P_1 < 0$ with maximal power (MP) while incurring as few failures as possible during a trial of length n. It is known that A) optimal power may be achieved using an equal allocation strategy, and B) the rule giving the fewest expected failures (E(F)) is given by the solution to the Bernoulli two-armed bandit with finite horizon and uniform discount sequence. In principle, such rules can be computed using dynamic programming. However, until recently, this has not been feasible. Furthermore, such allocation rules induce a significant loss in power. The major contribution here is the development of a new type of rule which retains MP but offers the fewest E(F)'s of any other rule in this class. The computational work required to produce this rule is similar to that needed to solve the bandit problem. Currently we are able to provide all of these rules, along with their characteristics for samples of size 500 to 1000.

R. HÖPFNER :

Asymptotic inference for Markov step processes: observation up to a random time

Consider a Markov step process whose generator depends on an unknown one- dimensional parameter ϑ. Under a "homogenity" assumption concerning the family of information processes Π_ϑ, $\vartheta \in \Theta$, which does not require exact knowledge of the asymptotics of Π_ϑ under P_ϑ, there is an increasing sequence of stopping times U_m such that, observing X continuously over $[0,U_m]$, the sequence of resulting statistical models is LAN as $m \to \infty$, at every point $\vartheta \in \Theta$, with local scale which does not depend on ϑ.

M. HUSKOVA :

Change point problems - a nonparametric approach

Consider the following regression model:

$$X_i = \underset{\sim}{c}_i'(\underset{\sim}{\Theta}_0 + \underset{\sim}{\vartheta} I\{i > m\}) + e_i \, , \; i = 1,\dots,n \, ,$$

where $c_i = (c_{i1},\dots,c_{ip})'$, $i = 1,\dots,n$, are known regression vectors, $\underset{\sim}{\Theta}_0, \underset{\sim}{\vartheta} \neq 0$ and m are unknown parameters, $e_1,\dots,e_n$ are i.i.d. random variables, e_i is distributed according to a distribution fulfilling certain regularity conditions and unknown otherwise.

For the testing problem $H_0 : m = n$ against $H_1: 1 \leq m < n$ the test procedures based on M-estimators $\underset{\sim}{\Theta}_k(\varphi) = \underset{\sim}{\Theta}_k(\varphi,X_1,\dots,X_k)$, M-residuals $\varphi(X_k - \underset{\sim}{c}_k'\underset{\sim}{\Theta}_n(\varphi))$ and M-recursive residuals $\varphi(X_k - \underset{\sim}{c}_k'\underset{\sim}{\Theta}_{k-1}(\varphi))$, $k = p+1,\dots,n$, were discussed. The considered test statistics are, in fact, modifications of the likelihood ratio test statistics, CUSUM and MOSUM tests developed for the case when errors are distributed $N(0,\sigma^2)$.

It appears that the limit distributions (under H_0) of the proposed test statistics coincides with the respective procedures for the normally distributed errors and $\varphi(x) = x$, $x \in \mathbb{R}$.

The presented results are published in the author's papers: Asymptotics for robust MOSUM (CMUC, 31, 1990, 345-356); Some asymptotic results for robust procedures for testing constancy of regression model over time (Kybernetika, 26, 1990, 392-403).

J. JACOD :

Random sampling in estimation for diffusion processes

We consider a parametric model based on the observation of a diffusion process (of

dimension d, with non-degenerate diffusion coefficient) on the time interval $[0,1]$, where the diffusion coefficient depends on the parameter. We are allowed to observe the process at n sampling times, and we are looking for the best sampling procedures, asymptotically as n goes to infinity.
Sampling at deterministic times give the LAMN property with some variance bound depending on some function $\gamma(\Theta,x)$, of the form $\int \gamma(\Theta,x_t)\mu(dx)$, where μ depends on the sampling procedure, and a lower bound is thus $M(\Theta) = \sup_t \gamma(\Theta,x_t)$. We consider the random sampling (i.e. the i-th time $T(n,i)$ depends on the previous observed values $X_{T(n,1)},\ldots,X_{T(n,i-1)}$). We still find the same bound $M(\Theta)$ and exhibit a particular procedure achieving this bound simultaneously for all Θ.

A. JANSSEN :

Goodness of fit tests of Rényi type

In this talk the power of two sample goodness of fit tests of Rényi type (in the sense of Gill) is considered. As motivation let us consider the following example coming from survival analysis. Suppose that we have a preference for a proportional hazard rate model. Then usually the log rank (Savage) test will be applied. However, this test does not detect crossing hazards. If we are not sure that the model is true it might be convenient to substitute the log rank test by a consistent goodness of fit test. In this context we propose a Rényi type goodness of fit test which has much the same good property for proportional hazards as the log rank test. For these tests the following results are obtained:
(a) Consistency, (b) asymptotic admissibility, (c) the asymptotic power function under local alternatives, (d) a spectral decomposition of the curvature of the power funct tttttion.
In addition we adjust Rényi tests at given principal directions of alternatives.

(Joint work with H. Milbrodt)

P. JEGANATHAN :

Asymptotic expansions in functional limit theorems arising in regression models involving integrated processes

In many regression models such as autoregressive models with unit roots, the limiting distribution of various estimators and the statistics involve distributions of functionals of Brownian motions. We present a method of obtaining asymptotic expansions for the distributions of statistics involved. The method used is different from the me-

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thod of characteristic functions, which we do not know how to employ in the present context. The leading term of the expansion can be taken to be either the distribution of the limiting functional, or the distribution obtained by replacing the original sample by the sample generated by normal random variables.

J. JUREČKOVÁ :

Regression rank scores and their application in estimation and testing

Regression rank scores are dual to regression quantiles of Koenker and Bassett (1978) in the linear programming sense, but they also extend the duality of order statistics and ranks from the location to the linear regression model. We show the asymptotic approximation of the process of regression rank scores by the empirical process as well by the process of Hájek-Sidak (1967) scores. This provides, along with the uniform asymptotic linearity of the regression rank scores process, a basis for various tests and estimators in the linear regression model.

R. W. KEENER :

Fixed width interval estimation for the reciprocal drift of Brownian motion

Let $b(t)$, $0 \leq t < \infty$ denote Brownian motion with unknown positive drift μ. The problem of setting a fixed width confidence interval for $\Theta = 1/\mu$ is considered. The intervals studied are of the form $[\hat{\Theta}_\zeta - h, \hat{\Theta}_\zeta + h]$ where ζ is a stopping time and $\hat{\Theta}_\zeta = \zeta/b(\zeta)$. Stopping times τ_h are derived so that these intervals have coverage probabilities converging to a set value β as $h \to 0$. This convergence is uniform for μ near 0. Asymptotic optimality is also addressed.

G. KERSTING :

How much noise is sufficient to disturb a dynamical system?

Consider the diffusion (X_t) in $\mathbb{R}^d$, which satisfies the Ito-equation $dX_t = b(X_t)dt + \sigma(X_t)dW_t$, as a random disturbance of the dynamical system $dy = b(y)dt$. When do both systems show substantially different long-term behaviour? In the talk we will show that this question is closely connected to the problem of existence of global harmonic coordinates u on $\mathbb{R}^d$, such that $|u(x) - x| = o(|x|)$, as $|x| \to \infty$. By harmonic coordinates we mean a bijection $u: \mathbb{R}^d \to \mathbb{R}^d$ such that $Lu \equiv 0$, where L is the infinitesimal generator of the diffusion. Furthermore we discuss the question of existence of harmonic coordinates.

U. KÜCHLER :

Some one-dimensional diffusions and related exponential families

There are different ways to define exponential families of stochastic processes. One can demand a) that the last observation is a sufficient statistic, b) that the one-dimensional distributions form an exponential family for every fixed $t > 0$, c) the log-likelihood function is of the form $\gamma(\vartheta)^\tau B_t - \Phi_t(\vartheta)$. All these properties are equivalent in the case of processes with independent increments, but they are not for more general processes, e.g. for Markov processes. It will be shown that in concrete cases (here diffusions on $[0,\infty)$ with elastic killing at zero) with exponential families in the sense of a) there are connected several other exponential families: life-time distributions, hitting time distributions, exponential families of inverse local times, which form processes with independent increments. Thus, all mentioned properties a)-c) correspond to one another also in more general cases than the independent increments.

References: Küchler, U.: On life-time distributions of some one-dimensional diffusions and related exponential families, Preprint, 1991.

H. R. LERCHE :

On the influence of the overshoot on optimality in sequential testing

In the case of testing "$\vartheta = 0$" versus "$\vartheta \neq 0$" the influence of the overshoot is studied. Let $I(\vartheta) = \vartheta^2/2$ and $\varphi(\vartheta)$ denote the standard normal density function. It is shown that for iid. observations which are distributed according to a normal $N(\vartheta,1)$, the minimal Bayes risk

$$R(T_c^*) = \gamma P_0(T_c^* < \infty) + (1-\gamma)c \int_{-\infty}^{\infty} I(\vartheta) E_\vartheta T_c^* \varphi(\vartheta) d\vartheta$$

differs from that of Brownian motion by a term $K \cdot c$ as $c \to 0$. The constant K can be stated explicitly in terms of the overshoot distribution.

G. LORDEN :

A flexible method for constructing exact multistage hypothesis tests for the drift of a Wiener process

Suppose that one observes $\{S(t), t > 0\}$, a Wiener process with drift ϑ and variance one per unit time. Based upon times of observation $t_1 < t_2 < \dots$ in a multi-stage sampling scheme, it is desired to test hypotheses about ϑ - e.g. $\vartheta = -1$ vs. $\vartheta = 1$. In the latter case, if $P_{\pm 1}(\text{error}) = \alpha$ is specified and a weight function $\lambda(\cdot)$ is given, we wish to minimize the λ-mixture of ASN's - that is $\sum_i \lambda(\vartheta_i) E_{\vartheta_i} t_N$, where λ is symmetrical about zero. The method calls for stopping at t_n to reject $\vartheta = 1$ if, letting $\Delta t = t_n - t_{n-1}$ and $\Delta S = S(t_n) - S(t_{n-1})$,

$$\sum_i \Phi\left[\frac{\Delta S - \vartheta_i \Delta t}{\sqrt{\Delta t}}\right] \lambda_{n-1}(\vartheta_i) \geq B_{n-1} \Phi\left[\frac{\Delta S - \Delta t}{\sqrt{\Delta t}}\right]$$

(and a similar condition to reject $\vartheta = -1$), where for $k = 1,2,\dots$ $\lambda_k(\vartheta) = \lambda(\vartheta)\exp(\vartheta S(t_k) - \frac{1}{2}\vartheta^2 t_k)$ (normalized to $\sum_\vartheta \lambda_k(\vartheta) = 1$) and $B_k = \lambda_k(1)/2\alpha\lambda(1)$. The desired error probabilities, α, are attained exactly. Simulation results and generalizations appear promising.

A. V. MELNIKOV :

On some problems of regression analysis treated by sequential and recursive methods

On the base of the martingale theory a general parametric regression model is proposed. To estimate the parameter of the model it is involved a sequential modification of the least squares estimate with such an important property as "fixed accuracy".
Another problem under consideration in the talk is to approximate the unique root of the regression equation. It is shown that one can consider the well-known recursive procedures of Robbins-Monro (for discrete and continuous time) as the strong solutions of a special class of stochastic equations with respect to semimartingales. The asymptotic behaviour of these procedures is investigated.

U. MÜLLER-FUNK :

On the convergence of collective risks

Motivated by the task to approximate the collective risk associated with a "large" portfolio, we revisit the CLT for random indices (which are independent of the claims). An elementary approach based on a summation technique shows that for real variables T_n, random indices N_m, $N_m \xrightarrow{P} \infty$, $(T_n)_n \perp (N_m)_m$:
$\mathcal{L}(b_n^{-1}(T_n - a_n)) \xrightarrow{w} G$, $\mathcal{L}(b_{N_m}^{-1}(a_{N_m} - \alpha_n)) \xrightarrow{n} H$

$$\Rightarrow \mathcal{L}(b_{N_m}^{-1}(T_{N_m} - \alpha_m)) \xrightarrow{n} G * H$$

As $G * H$ is normal iff G and H are, we conclude that the asymptotic normality of

$E^{-1/2}(N_m)(N_m - E(N_m))$ entails that of (properly centered and rescaled) risks.

A. A. NOVIKOV :

Sequential testing of many hypotheses

Let $\{P^t_\vartheta, \vartheta \in \Theta \subset R^\ell\}$, be a family of probability measures, generated by an observed process X_t, $t \in \{1,2,...\}$ or $t \in R^+ = [0,\infty]$. We consider a testing problem for hypotheses: $H_j: \vartheta \in \Theta_j$, $1 \le j \le m \ge 2$, where Θ_j are disjoint sets with $\sum_j \Theta_j = \Theta \setminus I$, and I is an "indifference" region. We would like to find a sequential test (τ^*, d^*) such that $\sup_{\Theta_j} P_\vartheta(d \neq i) \le \alpha_i$ for given α_i. At the same time it should have the asymptotic optimality property:

$$\sup_\vartheta E_\vartheta \tau^* \sim \inf_{(\tau, d)} \sup_\vartheta E_\vartheta \tau \quad \text{as} \quad \max \alpha_i \to 0 .$$

We present some generalizations of results by Pavlov I., (1990, Th. Prob. & Appl.) who constructed such a type of tests and proved their optimality properties under different conditions.

CH. G. PFLUG :

On epi- convergence and argmin- convergence of stochastic processes

In stochastic optimization, one replaces a given program $\| F(x) := \mathbb{E}(H(x,\xi)) + \vartheta_S = \min!$, where ξ is a random variable and $\vartheta_S = \begin{cases} 0 & x \in S \\ \infty & x \notin S \end{cases}$ by the "empirical program" $\| F_n(x) := \frac{1}{n} \sum_{i=1}^n H(x,\xi_i) + \vartheta_S = \min!$, where (ξ_i) is an i.i.d. sequence. A natural question arises, whether $\arg\min_x F_n(x)$ converges to $\arg\min_x F(x)$. We use the setup of epi- convergence, looking at the epi- graphs of F_n as random closed sets and give conditions for epi- convergence in distribution. In general, $\arg\min_x F(x)$ is a set valued random variable and the limits of $\arg\min_x F(x)$. This notion is made precise by introducing the concept of asymptotic dominance of set- valued stochastic processes.

M. POLLAK :

Nonparametric changepoint detection

Classical sequential procedures for detecting a change in distribution are Shewhart and Cusum procedures. These schemes are likelihood-ratio based procedures, and invariably require a parametric setup. Nonparametric detection schemes are difficult to analyze, and most schemes involve Brownian motion approximations and are geared towards contiguous alternatives (the change is small, and there will be many observations made before a detection).
We will present a likelihood ratio approach based on ranks designed for non-contiguous alternatives. Preliminary results indicate that the efficiency of procedures based on this approach may be very large.

H. PRUSCHA :

Categorical time series with internal and external evolution schemes

We are dealing with a time series $Y_t, t = 1,2,\ldots$, where the ordered categorical variable Y_t is influenced by (external) covariates Z_t and by the (internal) history $Y_{t-1}, Y_{t-2}, \ldots$ of the process. We propose a time series model which combines the logistic regression model (stemming from the *generalized linear model* family) and the linear OM-chain (stemming from *random systems with complete connections*). To prove the familiar asymptotic results on maximum likelihood estimation and related test statistics NORMAN's ergodicity concept in distance diminishing models is used.
The model proposed here is applied to data on forest damages. The results allow to assess the relevance of the (external) covariable set and of the (internal) transition mechanism w.r. to the evolution of the damage process. Further, questions of goodness-of-fit and of residual-building are discussed.

M. SCHEUTZOW :

The PASTA-property - a martingale approach

Let $(N_t)_{t\geq 0}$ be a Poisson counting process with intensity one on $(\Omega, \mathfrak{F}, (\mathfrak{F}_t), \mathbb{P})$ and $0 = T_0 \leq T_1 \leq T_2 \leq \ldots$ be the sequence of jump times. We say that a stochastic process $(H_t)_{t\geq 0}$ has the "PASTA-property" if $\lim\limits_{n\to\infty} \frac{1}{n} \sum\limits_{i=1}^{n} H_{T_i} = \lim\limits_{t\uparrow\infty} \frac{1}{t} \int_0^t H_s ds$ in the sense that the sets where the limits exist coincide a.s. and the limits agree on that set almost sure. The PASTA-property holds if H is predictable and bounded uniformly in (t,ω) . Using a strong law for local L^2-martingales by Lepingle one gets the

PASTA-property under the weaker condition $\int_0^\infty \frac{H_s^2}{(1+s)^2} ds < \infty$ a.s. for predictable H. We give three examples showing that predictability cannot be replaced by "right-continuous adapted" even in the bounded case and that the integrability condition is not far from being optimal. Finally we indicate how the approach can be generalized to point processes on much more general state spaces by using stochastic integration w.r.t. compensated integer-valued measures as treated e.g. in the monograph by Jacod-Shiryayev (1987).

TH. SELLKE :

How many geometric (p) samples does it take to see all the balls in box?

Let $K_1, K_2, \ldots$ be iid, $P\{K_1 = j\} = p(1-p)^{j-1}$, $j = 1,2,\ldots$ You have a box with m unpainted balls in it. You sample $K_1 \wedge m$ balls without replacement, paint them, and return them to the box. Let X be the number of times you have to repeat this until all m balls are painted. Of interest is EX. The approximation

$$EX = \frac{q + pm\sum_1^m \frac{1}{k} + \sum_{k=1}^{m-1} p^2 q^k \frac{k^2}{m-k}}{1 + \sum_{k=1}^{m-1} \frac{k}{m-k} pq^k} + O\left[\frac{1}{m^2}\right]$$

is derived by comparison with the analogous procedure in which $K_i \wedge m$ balls are sampled with replacement. The argument uses the Wald identity and a correction for boundary behaviour. To check the quality of the approximation, the true value at EX was calculated (using a recursive formula) for $p = \frac{1}{2}$ and various values of m. For $p = \frac{1}{2}$ and $m = 300$, the true value of EX is $939{,}740413$, while the approximation yields $939{,}740401$.

D. SIEGMUND :

Using the generalized likelihood ratio statistic for sequential detection of a change-point

We study sequential detection of a change-point based on the generalized likelihood ratio statistic. For the special case of detecting a change in a normal mean which initially equals 0, the stopping rule takes the form

$$T = \inf\left\{n : \max_{0 \le k < n} \frac{|S_n - S_k|}{\sigma(n-k)^{1/2}} > b\right\},$$

where $S_n = x_1 + \dots + x_n$ is the sum of the first n observations and $\sigma^2 = \mathrm{Var}(x_i)$ is assumed to be known. Our principal result is an asymptotic approximation for the average run length under the assumption that no change occurs:

$$E(T) \sim \sqrt{2\pi}\exp(b^2/2)/[b\int_0^b x\nu^2(x)dx] \quad (b \to \infty),$$

where $\nu(x)$ is a special function arising in fluctuation theory of random walks with normally distributed increments. Several other examples are given.

M. SØRENSEN :

Exponential families of stochastic processes

A review is given of recent results about exponential families of stochastic processes. First it is shown that for time-homogeneous exponential families with a non-empty kernel the canonical process has independent increments. Next exponential families of the form $\exp(\vartheta^{\tau} A_t - \kappa(\vartheta)S_t)$, $\vartheta \in \Theta \subset \mathbb{R}^k$, where A and S are adapted processes and $\kappa(\vartheta)$ is a non-random function of ϑ, are considered. The process S is one-dimensional and non-decreasing. The first-mentioned result is used to show that, under weak conditions, the process A is a stochastically time-transformed Lévy process. This result provides an easy way of establishing the validity for these curved exponential families of results about existence of the maximum likelihood estimator, about asymptotic likelihood theory and about proper conjugate priors which hold for classical regular exponential families. Also exponential families of processes with a time-continuous likelihood function are considered. It is shown that such a family necessarily has a likelihood function of the form $\exp(\vartheta^{\tau} A_t - \frac{1}{2}\vartheta^{\tau} <A>_t \vartheta)$, $\vartheta \in \Theta \subset \mathbb{R}^k$, where A is a continuous local martingale. The properties of the processes in the family are studied and asymptotic results about the maximum likelihood estimator are proved by means of martingale theory.

W. STADJE :

A stochastic model for a researcher's problem

We consider the problem of a researcher who successively uses some random mechanism to select topics to work on for certain time periods, where a random non-increasing output rate is associated to each topic. The objective is to find a strategy, i.e., a sequence of stopping times (sojourn times for the topics) so as to maximize the long-run average expected yield per unit time. If the chosen topics form an IID sequence, a stationary, consisting of independent replications of a certain threshold stopping time, is optimal. This strategy however requires a complete knowledge of the underlying probability distributions. As an alternative, we suggest a non-stationary strategy which is defined in terms of the observable development of the research process. It is shown that this strategy is also optimal in the sense that it achieves the maximum long-run average expected yield almost surely.

V. T. STEFANOV :

Noncurved exponential families associated with observations of finite-state Markov chains

We show that for each ergodic and homogeneous finite-state Markov chain with either discrete or continuous time-parameter there are stopping times which have the property that they reduce the corresponding curved exponential families to noncurved exponential ones. It turns out that simple and well known stopping times possess this property. Examples are:

a) the first time the number of transitions from a fixed state to another (or the same) fixed state reaches a preassigned level,

b) the first time the sojourn time at a fixed state reaches a preassigned level,

c) the first time the number of runs of a fixed state reaches a preassigned level.

Also, as straightforward applications of the results in this paper one gets classical results for the Markov chains; e.g. the well-known regeneration property for the corresponding sequences of the above mentioned stopping times.

J. STEINEBACH :

Pontogram asymptotics

Consider a generalized renewal counting process $\{N(t):t \geq 0\}$, i.e. $N(t) = \max\{n \geq 0: S_0, S_1, \ldots, S_n \leq t\}$, $t \geq 0$, where the S_n denote the partial sums of an i.i.d. sequence $\{X_i:i \geq 1\}$, $S_0 = 0$, with $EX_1 = \mu > 0$, $0 < \mathrm{Var}(X_1) = \sigma^2 < \infty$. In order to re-analyze the "Land's end data" set, D.G. and W.S. Kendall (1980) suggested to use Poisson pontograms $\{K_n(t) \,.\, 0 \leq t \leq 1\}$, where
$$K_n(t) = n^{-1/2}\{N(nt) - tN(n)\}, \; 0 \leq t \leq 1,$$
for testing on an "early decrease (or change)" of the intensity parameter of the process. The Kendall-Kendall asymptotic test is based upon an extreme value asymptotic of $\{K_n(t)\}$ towards an Ornstein-Uhlenbeck process.

Extensions of this work to general renewal processes have been studied by Huse

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(1988), Eastwood (1990), and Eastwood & Steinebach (1991). Here we suggest to study increments of the counting process rather than the process itself in order to detect "early changes" of the intensity. Three different limit theorems are presented for the test statistics

$$M_n^{(1)} = \sup_{0\le t\le T_n} h_n^{-1/2}\{N(t+h_n) - N(t) - h_n(N(n)/n)\},$$

$$M_n^{(2)} = \sup_{0\le t\le T_n} h_n^{-1/2}|N(t+h_n) - N(t) - h_n(N(n)/n)|,$$

corresponding to the conditions $T_n/h_n \to 0$, $T_n/h_n \to c > 0$, and $T_n/h_n \to \infty$ (as $n \to \infty$), where $\{h_n\}$, $\{T_n\}$ are certain sequences of positive real numbers.

W. STUTE :

Integrated U-statistic processes: A martingale approach

For i.i.d. data $X_1,\dots,X_n$ and a kernel h, the integrated U-statistic process is defined as

$$U_n(u,v) = \frac{1}{n(n-1)} \sum_{1\le i\neq j\le n} h(X_i,X_j)1_{\{X_i\le u, X_j\le v\}}.$$

Variants of these processes occur, e.g., in the representation of the product-limit estimator of a lifetime distribution for censored/truncated data or in trimmed U-statistics. We derive an almost sure representation of U_n under weak moment assumptions on h. Proofs rely on a proper decomposition of the remainder term into strong two-parameter martingales.

O. VOROBEV :

Random finite sets and the set-summation theory

An introduction to random finite sets (RFS) and RFS-processes is given. The average measure set of RFSs and random spread processes are introduced. Several formulas of the set summation theory are stated. This theory generalizes the classical results about Möbius functions.

H. WALK :

Estimates in stochastic approximation processes in view of asymptotic optimality

The Robbins-Monro procedure for recursive estimation of a zero-point ϑ of a regression function f with existence of $Df(\vartheta) =: A$, related algorithms of Lai-Robbins, Ruppert-Polyak, Frees-Ruppert, and the Widrow algorithm concerning the linear equation $Ax - b = 0$ are considered in $\mathbb{R}^m$ or $\mathbb{H}$, where $\operatorname{spec} A \subset \{z \in \mathbb{C}; \operatorname{re} z > 0\}$. For the latter an adptive algorithm with gains B_n/n, where B_n with $B_n \to A^{-1}$ a.s. is recursively defined in an analogous manner, yields estimates satisfying a functional CLT with convergence order $1/\sqrt{n}$ and - as to the trace - optimal limit covariance $A^{-1}S(A^{-1})' =: K_{opt}$ (S limit covariance of errors). For the Ruppert-Polyak algorithm a sequential estimate of K_{opt} is given. Further it is shown that, under regularity conditions, weighted means $B_n X_{n+1} + (1-B_n)\bar{X}_n$ ($\bar{X}_n$ arithmetic mean) for a Robbins-Monro process (X_n) with gains $\simeq 1/n$ also lead to asymptotically optimal covariance if $B_n \xrightarrow{P} A^{-1}$; recursive least squares estimates B_n ($\to A^{-1}$ a.s.) with

$$B_{n+1} := B_n - \frac{c}{\log n}[B_n(Y_n - \bar{Y}_n)(X_n - \bar{X}_n)' - (X_n - \bar{X}_n)(X_n - \bar{X}_n)']$$

($c > 0$, $Y_n = f(X_n) + \text{error}$) are proposed.

W. WEFELMEYER :

An optimality property of the maximum likelihood estimator in misspecified models

Suppose we observe a stochastic process, and we have specified a parametric model for its predictable characteristics. What can we say about the maximum likelihood estimator if the model is misspecified? We present three results.

1. We introduce a (random) distance between the true characteristics of the process and the characteristics in the parametric model. For this distance, the maximum likelihood estimator can be interpreted as a minimum distance estimator. For processes with independent increments, the distance is the Kullback-Leibler distance.
2. We determine the asymptotic distribution of the maximum likelihood estimator as an estimator of the (random) minimum distance functional.
3. We obtain an asymptotic variance bound for regular estimators of the minimum distance functional. The maximum likelihood estimator turns out to be efficient.

The results are valid for semimartingale models. To simplify the presentation, we restrict attention to counting processes.

(Joint work with P. Greenwood)

H. v. WEIZSÄCKER :

Consistency versus existence of "perfect" estimators

Let $\{p_\vartheta\}_{\vartheta\in[0,1]}$ be the family of Bernoulli measures on $\{0,1\}^{\mathbb{N}}$. It is shown that a slight perturbation $\{\tilde{p}_\vartheta\}$ of this family exists such that

a) The relative number T_n of 1 - s in the first n digits still is "consistent in probability", i.e.

$$\tilde{p}_\vartheta\{|T_n - \vartheta| > \varepsilon\} \xrightarrow[n\to\infty]{} 0$$

for all $\varepsilon > 0$, $\vartheta \in [0,1]$

b) There is no Borel map $T : \{0,1\}^{\mathbb{N}} \to [0,1]$ such that

$$\tilde{p}_\vartheta\{T = \vartheta\} = 1$$

for all ϑ.

(Joint work with R.D. Mauldin: Ann. of Prob. 1991)

J. WELLNER :

Multiplier CLT's and alternative bootstraps

A general exchangeably weighted "bootstrap" can be described as follows: Let $X_1,X_2,\dots,X_n$ be iid P on $(A,\mathfrak{A})$ with empirical measure $\mathbb{P}_n$. Let $\underline{W}_n = (W_{n1},\dots,W_{nn})$ be a random weight vector satisfying

A.1 $\underline{W}_n$ is exchangeable for each n,

A.2 $W_{ni} \geq 0$, $\sum_i^n W_{ni} = n$.

Then for fixed $X_1(\omega),\dots,X_n(\omega)$ the general exchangeably weighted bootstrap empirical measure is $\mathbb{P}_n^W = \frac{1}{n}\sum_i^n W_{ni}\delta_{X_i}(\omega)$. When $\underline{W}_n = \underline{M}_n \sim \text{Multinomial}_n(n,(\frac{1}{n},\dots,\frac{1}{n}))$, $\mathbb{P}_n^W$ is Efron's bootstrap. When $\underline{W}_n = (Y_1,\dots,Y_n)/\overline{Y}_n$ with $Y_1,Y_2,\dots$ iid nonegative, $\mathbb{P}_n^W$ is an "iid weighted" bootstrap, and, in particular, if the Y's are exponential (1), $\mathbb{P}_n^W$ is Rubin's "Bayesian bootstrap". Many other bootstrap resampling schemes are also included in this formulation.

To validate the general exchangeably weighted bootstrap aymptotically, suppose that the weights also satisfy

A.3 $\lim_{\lambda\to\infty}\limsup_{n\to\infty}\| W_{ni}1_{[W_{ni}\geq\lambda]}\|_{2,1} = 0$, and

A.4 $\frac{1}{n}\Sigma_1^n(W_{ni} - 1)^2 \to_p c^2$ where $\|Y\|_{2,1} := \int_0^\infty\sqrt{P(|Y| > t)}\,dt < \infty$.

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The following theorem of Jens Praestgaard generalizes results of Giné and Zinn for Efron's bootstrap:

Theorem 1 Suppose that $\mathfrak{F} \subset L_2(P)$ satisfies $f \in M(P)$ (measurability), W_n satisfies A.1 - A.4.

A. If $\mathfrak{F} \in CLT(P)$ and $P(F^2) < \infty$, then $\sqrt{n}(\mathbb{P}_n^W - \mathbb{P}_n^{\omega}) \Rightarrow cG_p$ P^{∞}- a.s.

B. If $\mathfrak{F} \in CLT(P)$, then $\sqrt{n}(\mathbb{P}_n^W - \mathbb{P}_n^{\omega}) \Rightarrow cG_p$ in P^{∞}- prob in $\ell^{\infty}(\mathfrak{F})$

The methods used to prove this theorem yield the following result for Efron's bootstrap with bootstrap sample size $m \neq n$. Let $\mathbb{P}_{m,n}^E := \frac{1}{m}\Sigma_1^n M_{ni}\delta_{X_i(\omega)}$ where $M_n \sim \text{Multinomial}_n\,(m,(\frac{1}{n},\dots,\frac{1}{n}))$.

Theorem 2 Suppose that $f \in M(P)$, $f \in CLT(P)$ and $P(F^2) < \infty$. Then $\sqrt{m}(\mathbb{P}_{m,n}^E - \mathbb{P}_n^{\omega}) \Rightarrow G_P$ as $m \wedge n \to \infty$ P^{∞}- a.s.

M. WOODROOFE :

A penalized maximum likelihood estimate of $f(0+)$ when f is non increasing

The problem of estimating the value at $0+$ of a non increasing density f (on $(0,\infty)$) is considered. It is shown by example that the problem is interesting, and noted that the non parametric maximum likelihood estimator is inconsistent. A penalized maximum likelihood estimator is derived as an alternative, and its properties studied through simulations and asymptotic analysis. In particular, the penalized maximum likelihood estimator is shown to be consistent.

Q. YAO :

Tests for change- points with epidemic alternatives

The purpose of this paper is to discuss the tests to detect an epidemic alternative in the mean value of a sequence of independent normal variables. Various test statistics, such as the likelihood ratio, the score- like statistic, the Levin & Kline's statistic, the semi- likelihood ratio, and the recursive residual, are studied. The large deviation approximations to the significance levels and powers are developed by integrating approximations for conditional boundary crossing probabilities. Some results of Monte Carlo experiments confirm the accuracy of these approximations. A numerical comparison of different tests is made.

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