MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

Tagungsbericht 5/1997

Punktprozesse: Modelle und Anwendungen
02.02. – 08.02.1997

The meeting was organized by K. Krickeberg (Paris), Y. Ogata (Tokyo) and R.-D. Reiss (Siegen).

The aim of the meeting was to bring together researchers working on

- statistical modelling in various applied fields
- related theoretical questions about point processes
- inference on various point process models.

The relevant subdomains were

- extreme value analysis and time series with infinite variance (with applications to financial data)
- computing methods
- physical sciences and engineering (including seismology)
- queueing theory
- spatial processes and space-time modelling (including modelling in forestry, rainfalls and other environmental problems)
- stochastic geometry.

The meeting was attended by 38 participants. There were 32 talks including 11 main or survey lectures and one poster session. Given the intensive discussions after the talks and fruitful collaborations throughout the meeting we are sure that this conference will have a significant impact on future research work.

Vortragsauszüge

Elja Arjas

On prequential model assessment from point process data

A criticism often voiced against the Bayesian paradigm to statistics is that it does not provide clear–cut procedures for model checking or validation against data. It is indeed true that the traditional model testing procedures, starting from the idea of "truth" of a null hypothesis and assigning probabilities to the behaviour of (future) samples, do not match well with the Bayesian position of keeping the data fixed, and thinking of probability primarily as a means of expressing subjective degrees of belief in different values of the model parameters. Perhaps the most natural way of making Bayesian inferential ideas operational in model checking is to consider prediction, or model validation, and always match one or more "future" data prints against the predictive distribution based on the "past". We show how such techniques can be applied in the context of the "dynamic approach to point processes", leading them to simple exact statistical tests. These ideas are closely connected to "prequential" forecasting, introduced and discussed by A.P. David in a series of papers. The talk is based on joint work with Dario Gasbarra.

Linda Collins

Analysis of spatial point patterns using bundles of product density LISA functions

The analysis of a spatial point pattern is often involved with looking for structure, such a clustering or regularity. This can be done through (kernel density) estimates of the K–funtion or its derivative, the product density function. We define a local version of the product density function for each event derived under Anselin's (1995) definition of a local indicator of spatial association (LISA). These product density LISA functions are then grouped by a standard hierarchical clustering algorithm into bundles of functions with similar behavior. Events corresponding to LISA functions within the same bundle are similar with respect to their distance to other nearby events. This grouping of events is very different from the usual clustering notion in spatial point patterns. Our research provides a new quantification of structure in the analysis of spatial point patterns.

This is joint work with Noel Cressie.

Daryl Daley

Long range dependence of point processes

Definitions of long range dependence (LRD) of point processes are given and illustrated via processes that arise in queueing models. The LRD property can be induced by single–server queues but seemingly not by infinite server queues, for example.

Richard A. Davis

Point process theory for bilinear and stochastic volatility models

A limit theory is developed for the weak convergence of point processes based on the points of a bilinear and a stochastic volatility (SV) model. In the former, the noise is assumed to be heavy–tailed. A number of interesting applications of the point process convergence ensue. For example, the limit distributions of the extremes, partial sums, and sample autocorrelation function (ACF) can be derived from this convergence. Surprisingly, the sample ACF converges in distribution to a non–degenerate without any normalization.

In the SV case, the point process convergence is the same as for the "associated" independent case. That is, there is no clustering in the limit. The proof uses the Esscher transform (for deriving tail behavior of the marginal distribution) and a modification of the normal comparison lemma (for the point process convergence.

Michael Falk

Local asymptotic normality of truncated empirical processes

Given n iid copies $X_1, \ldots, X_n$ of a random element X in some arbitrary measurable space S, we are only interested in those observations that fall into some subset D having but a small probability of occurence. It is assumed that the distribution P_X of X belongs on D to a parametric family $P_X(\cdot \cap D) = P_\vartheta$, $\vartheta \in \Theta \subset \mathbb{R}^d$. Nonlinear regression analysis and the peaks–over–threshold (POT) approach in extreme value analysis are prominent examples. For the POT approach on $S = \mathbb{R}$ and P_ϑ being a generalized Pareto distribution it is known that the complete information about the underlying parameter ϑ_0 is asymptotically contained in the number $r(n)$ of observations in D among $X_1, \ldots, X_n$, but not in their actual values. This result is formulated in terms of local asymptotic normality of the loglikelihood ratio of the point process of exceedances with $r(n)$ being the central sequence.

We establish a necessary and sufficient condition such that $r(n)$ has this property for a general truncated empirical process in an arbitrary sample space and for an arbitrary parametric family. The known results are then consequences of this result. We can moreover characterize the influence of the actual observations in D on the central sequence, if this condition is violated.

Immediate applications are asymptotically optimal tests for testing ϑ_0 and, if $\Theta \subset \mathbb{R}$, asymptotic efficiency of the ML–estimator $\hat{\vartheta}_n$ satisfying $P_{\hat{\vartheta}_n}(D) = r(n)/n$, where these statistics are based on $r(n)$ only.

Lothar Heinrich

Tail triviality of point processes and Poisson convergence of particle motions

For a stationary point process Φ on $\mathbb{R}^d, d \geq 2$, with trivial tail σ–field and a family of Lebesgue measure preserving homeomorphisms $\theta_\tau, \tau > 0$, of $\mathbb{R}^d$ which put the most part of mass off from the origin towards infinity as $\tau \to 0$, it is shown that $\Phi \circ \theta_\tau$ weakly converges to a stationary Poisson process as $\tau \to 0$. Conditions ensuring tail triviality (or, equivalently, short–range correlations) for a point process are investigated for cluster processes, Cox processes, hard– and soft–core processes. In the particular case of point processes generated on a Poisson flat process this limit theorem follows under slightly weaker conditions. In this class also counterexamples exist.

Jürg Hüsler

Extremes of Gaussian processes

The asymptotic behaviour of extremes of stationary Gaussian processes with continuous paths is well–known. However, this is not the case for all nonstationary Gaussian processes. A certain new class of nonstationary Gaussian processes arises in the approximation of a Gaussian process. Here the process $X(t)$ is e.g. approximated by a piecewise linear Gaussian process $L_n(t)$ where $L_n(t_{k,n}) = X(t_{k,n})$ for some points $t_{k,n}$ with $\sup_k(t_{k+1,n} - t_{k,n}) \to 0$ as $n \to \infty$. Of main interest is the deviation process $Y_n(t) = X(t) - L_n(t)$ and its supremum $M_n(T) = \sup_{t \leq T} |Y_n(t)|$. These processes $Y_n(t)$ where analysed by Selezniev and V. Piterbarg under certain conditions.

We extend their results and show that a weaker long range dependence is sufficient. As usual with Gaussian processes and extremes, Berman's condition is sufficient.

Valerie Isham

Applications of point process–based models in hydrology

Stochastic spatial–temporal models of precipitation have a vital role to play in addressing problems in hydrology. The aim is to represent only the main physical features of the rainfall process, and to allow for the detailed complexities of the actual process using stochastic elements. Thus, the models to be described are constructed in continuous time and space using point processes, with a limited number of parameters, interpretable in terms of rain cells clustered within moving storm events. These models are not developed for predictive purposes, except perhaps locally in space and time, for the storms are assumed to occur at random. Rather, an aim is to provide models that can be used to simulate "artificial" rainfall processes for use, for example, in the development of flood drainage systems and dam designs.

Such models also provide one means of tackling the problem of disaggregating precipitation totals for a large spatial region over successive time–periods (such as those that are predicted by a General Circulation Model) into a spatial–temporal pattern of rainfall over that region that has realistic local properties. Markov random field models provide an alternative approach to this problem.

Pierre Jacob

Regression, edge estimation, and asymptotical location of multivariate samples

For a broad class of multidimensional probability distributions with bounded support, every estimate of the conditional radial mean value can be modified in order to give an estimate of the edge of the support. The practical interest is to provide smoother estimates than the usual ones, more or less related to the convex hull of the sample, and to allow the estimation of star–shaped domains.

In the case of unbounded supports, the same method, combined with some arguments from multidimensional extreme values theory, give a solution to the problem of asymptotical location of a sample by smooth surfaces. For some sufficiently fast decreasing conditional radial distributions, large samples can be encompassed by a sequence of dilations of estimators of the radial regression.

However the general problem of finding kernel–type estimators of star–shaped domains, based directly upon extreme values, still remains without a satisfactory solution, and it should be a nice subject of discussion.

Yurii Kutoyants

Statistical inference for spatial Poisson processes

The asymptotic properties of different estimators are described for the models of inhomogeneous Poisson processes observed on a sequence of subsets of metric space.

Under regularity conditions it is proved that the maximum likelihood, bayesian and minimum distance estimators are consistent, asymptotically normal and asymptotically efficient. Several examples of particular inhomogeneous Poisson precesses are studied in details. Moreover, the asymptotic expansions of these estimators as well as their distribution functions are presented. The asymtptotic properties of these estimators are also studied in the cases of a) misspecification b) nonidentifiability. The problem of optimal choice of observation window are discussed. Then several problems of change–point type on the plane for the Poissonian fields are studied. Particularly, the problem at discontinuous intensity function identification is considered.

The problems of nonparametric estimation of intensity measure and intensity function are also discussed.

Günter Last

On the spherical contact vector of stationary germ–grain models

We consider a stationary germ–grain model X in $\mathbb{R}^d$ with convex and compact grains and the essentially unique spherical contact vector pointing from $x \in \mathbb{R}^d$ to the point $p(x) \in X$ closest to x. The conditional distribution of the distance $t(x) := ||x-p(x)||$ given that x is not covered by X is called the spherical contact distribution of X. We show how the distribution of $p(x)$ is related to the times it takes a "typical" boundary point of X to hit another grain if all grains starting growing at the same time and at the same speed. The rigorous formulation of this relationship involves the generalized curvature measures of X and generalizes a well known principle for point processes on the line. The talk is based on joint work with Rolf Schassberger.

Friedrich Liese

A class of goodness of fit tests for Poisson point processes

Given i.i.d. Poisson point processes $\Phi_1, \ldots, \Phi_n$ with intensity measure Λ we construct test for $H_0 : \Lambda = \Lambda_0$ versus $H_A : \Lambda \neq \Lambda_0$. The true intensity measure is estimated by $\hat{\Lambda}_n = \frac{1}{n} \Sigma_{i=1}^n \Phi_i$. To compare $\hat{\Lambda}_n$ and Λ_0 which are mutually singular in general we restrict both $\hat{\Lambda}_n$ and Λ_0 to a partition of the state space into m cells. The distance of the corresponding discrete measures is described by f–divergences and especially by the χ^2–distance. Convergence in distribution of the test statistic is established both under the null hypothesis and under local alternatives for fixed and for increasing number of cells. It is shown that in the case of increasing cell asymptotic for composite null hypothesis the unknown parameter can be substituted by an $\sqrt{n}$–consistent estimator without changing the limit distribution.

Frank Marohn

Estimating the shape parameter in Pareto models with partially known scale via the POT–Method

Consider an iid sample $X_1, \ldots, X_n$ of random variables with common distribution function F, whose upper tail belongs to a certain neighborhood of that of a generalized Pareto distribution with unknown shape and scale parameters β and $a = g(\eta)$, where g is a known function. A classical example is the distribution of the absolute value of a symmetric stable random variable with index $0 < \beta < 2$. Based on the exceedances among X_i over a threshold sequence t_n, we define an explicit two–step–estimator of β that is efficient and behaves asymptotically as if a was known. Simulations show the tendency that for finite sample sizes the two–step–estimator outperforms with increasing stability parameter β the asymptotically efficient estimator with known scale considerably.

Shigeru Mase

Asymptotic normality of maximum pseudo–likelihood estimators of Gibbsian processes with superstable potentials

The Gibbsian model is a statistical model for spatial mapped point patterns. Given an activity constant and a parametrized potential function, we can construct various point patterns and it emerges a statistical problem to estimate the activity and the potential function from an observed spatial point pattern. Due to theoretical

and numerical complexity of maximum likelihood estimators for this model, Besag porposed maximum pseudo–likelihood estimators and several authors studied its properties. Among them is a remarkable asymptotic normality result of Jensen & Künsch (1994) for continuous state space stationary Gibbsian models. My talk is about an estension of their result. The basic idea is theirs but their basic assumption of finite–range potentials is replaced by the most general (probably) one, that is, superstability of potentials.

Ely Merzbach

Strictly simple set–indexed point processes

Different kinds of set–indexed martingals are defined and Doob–Meyer decompositions are presented. A topology for the class of outer–continuous with inner–limits set–indexed processes is studied. Using the concept of strictly simple set–indexed point process, a general weak convergence result is obtained. As an application, the weak convergence of point processes to a set–indexed Poisson process is implied by the uniform pointwise convergence of the respective compensators to a deterministic diffuse measure. As example, we compute the compensator associated with a single jump process. We give a condition on the compensator in order that a point process will be strictly simple. Finally we present a martingale charaterization of the set–indexed doubly–stochastic Poisson process using its compensator. By localizing, this characterization holds even in the non–integrable case.

Thomas Mikosch

Pathwise solutions to stochastic integrals equations

We consider linear stochastic integral equations driven by processes such as α–stable Lévy motion, certain other Lévy processes and fractional Brownian motions. We are interested in pathwise solutions to these equation. The underlying integrals are defined by purely deterministic calculus using the generalised Riemann–Stieltjes approach by L.C. Young (1936) and its modifications due to R. Dudley (1992) and R. Dudley and R. Norvaiša (1997). The central notion in this calculus is the p–variation of the integrand and of the sample path of the driving process. The solutions to the linear equations considered are similar to those obtained by Itô calculus.

Robin Milne

Simple derivations of properties of counting processes associated with Markov renewal processes

Let $\hat{N}_t$ be the number of occurences in $(0,t]$ of some event defined in terms of an underlying Markov renewal process, e.g. the number of jumps in $(0,t]$ between a specified pair of states, or the number of entries in $(0,t]$ to a specified subset of states. In a unified approach to such counting processes $\{\hat{N}_t\}$, we derive a simple expression for the factorial moment densities, and hence for the factorial moments of $\hat{N}_t$, in terms of the Markov renewal kernel of a Markov renewal process embedded in the underlying process. These results generalize known results for a renewal process. Asymptotic results for the factorial moments of $\hat{N}_t$ can be derived, and specialization to an underlying continuous-time Markov chain yields more explicit results. Our motivation for this study has come from applications in reliability modelling and in stochastic modelling of the behaviour of ion channels.

Jesper Moeller

Perfect simulation of locally stable point processes

A recent topic, which has drawn great attention after the seminal work of Propp and Wilson, is "exact" or "perfect" simulation, i.e. when one is assured that equilibrium has been attained. Propp and Wilson consider Markov chain algorithms (especially the Gibbs sampler) for simulating finite state space models satisfying a certain monotonicity condition such as the Ising model and the accompaning random cluster model. The idea is to use possibly several runs of the algorithm backwards in time (started from time 0) and by monotonicity and coupling dominate these by some lower and upper chains until there is coalescence at time 0.

This has now been extended to perfect simulation fo finite point processes in different ways assuming a local stability condition on the density (namely a uniform bound on the Papangelou conditional density) which is satisfied by most point processes as used in spatial statistics and stochastic geometry. In the talk I'll review these recent developments based on different joint works with Olle Häggström, Wilfried Kandall and M.-Colette Van Lieshout.

Werner Nagel

Stereology of polyhedrons: Refined observation yields better estimation

The lecture deals with stereological problems for spatial systems of homothetic polyhedrons. In contrast to the traditional technique of estimating the size distribution of the particles only from the sizes of section profiles—the extra information which is contained in their shapes is used to improve the estimator. As an example the case of cuboidal particles with random edge length is considered. The estimator of the size distribution of the cubes is based on the observation of the diameter and the edge number of the polygons arising on planar sections.

Yoichi Nishiyama

Weak convergence of stochastic integrals with respect to marked point proceses

A tightness criterion for weak convergence of stochastic integrals with respect to marked point processes is presented, in the same fashion as that of empirical processes.

As its application, we show the asymptotic normality of Nelson–Aalen's estimator for point processes with a general mark space.

Yoshihiko Ogata

Statistical discrimination of foreshocks from other earthquake clusters

When earthquake activity begins, it may be a foreshock sequence to a larger earthquake, or it may be a swarm or simple mainshock–aftershock sequence. This paper is concerned with the conditional probability that it will be foreshock activity of a later larger earthquake, depending on the occurrence pattern of some early events in the sequence. The earthquake catalogue of the Japan Meteorological Agency (1926 $\sim$ 1993, $M_J \geq 4$) is decomposed into numbers of clusters in time and space to compare statistical features of foreshocks with those of swarms and aftershocks. Using such a data set, Ogata et al. (1995) revealed some discriminating features of foreshocks relative to the other type of clusters, for example the events' stronger proximity in time and space, and a tendency towards chronologically increasing magnitudes, which encouraged us to construct models which forecast the probability of the earthquakes being foreshocks. Specifically, the probability is a function of the history of magnitude differences, spans between origin times and distances between epicentres

within a cluster. For an illustrative implementation, the models were fitted to the early part of the data (1926 $\sim$ 1975) and the validity of the forecasting procedure were checked on data from the later period (1976 $\sim$ 1993). Two procedures for evaluating the performance of probability forecast are suggested. Further, for the case where only a single event is available (i.e., either it is the first event in a cluster or an isolated event), we also forecast the probability of the event being a foreshock as a function of its geographic location. Then, the validation of the forecast is demonstrated in a similar manner. Finally, making use of the multi–elements prediction formula, we will see that the forecasting performance is enhanced by the joint use of the information in the location of the first event, and that in the subsequent inter–event history in the cluster.

Mario Peruggia

Bayesian analysis of earthquake activity

We present a Bayesian analysis of the seismic activity in the Sannio–Matese region of Italy using data from the historical catalog of Italian earthquakes. We model the evolution through time of the sequence of quakes and respetive magnitudes. The earlier, less accurate portion of the catalog data is used to elicit the prior distribution of the model parameters. The posterior distributions of several quantities of interest are computed conditional on the more recent portion of the catalog data. The various posterior estimates are obtained via Markov chain Monte Carlo simulation. We also discuss possible extensions of our inferential approach that account for spatial dependencies of seismic events. These extensions allow modeling of quakes occurring in regions with heterogeneous geophysical characteristics.

This is joint work with Thomas Santner.

Dietmar Pfeifer

Point process models in statistical ecology

Point processes in statistical ecology are frequently being used for modeling the spatial dispersal of individuals of a single species or even of whole communities. In this lecture we present two approaches of such a modeling, for different purposes:

1. A Thomas process (cluster) model for the description of the dispersal of benthic meiofauna which is in parabiosis with benthic makrofauna, together with statistical evaluation methods in case of quadrat–counts of individuals;

2. A point process model in connection with techniques from stochastic geometry

for a solution of the so–called "minimal area problem", which is concerned with the selection of a "smallest" representative sampling area to cover all or a certain percentage of species present.

Sidney Resnick

Heavy tailed time series modeling

Large numbers of large, high quality data sets now exist which seem to require probabilistic modeling with heavy tails. These are from varied fields: insurance (large claims), finance and economics (exchange rates), telecommunications (file lengths, interarrivals, transmission lengths). Methods for assessing when heavy tailed modeling is appropriate are fairly successful and methods for determining when independent variables can successfully be used also succeed. Less successful are attempts to build models when dependencies are present. Some pitfalls of autoregressive modeling applied to heavy tailed data are reviewed.

Manfred Schmidt

Point processes of rare events

We discuss the limits of point processes, which are generated by a triangular array of rare events. Such point processes are motivated by the exceedances of a high bounndary by a random sequence, since exceedances are rare events in this case. This application relates the problem to extreme value theory, where the method is used to treat the asymptotic approximation of these point processes. The presented general approach extends, unifies and clarifies some of the various conditions used in extreme value theory.

Volker Schmidt

Taylor expansion for functionals of marked point processes

We give finite and infinite expansion formulas for the expected value of functions of transient amd stationary state variables induced by random marked point processes.

Expansions for Laplace transforms, moments and tail functions of these variables are considered as specific instances of our general expansion formulas. A few examples such as expansions for characteristics of Boolean models and stochastic Petri

nets are given in order to illustrate the proposed expansion method. The results were obtained in joint research with F. Baccelli, B. Blaszczyszyn, S. Hasenfuss and E. Merzbach.

Dietrich Stoyan

The impact of forest statistics on point process theory and statistics

Several fundamental ideas of point process theory and statistics have their roots in problems of forest statistics. Point patterns with tree locations serve frequently as demonstration and test objects.

The lecture discusses some point process models such as Matérn's hard core and cluster process and their variants and modifications as well as Strauss' process and other Gibbs processes.

Ecological questions have led to many tests of the hypothesis of complete randomness of point patterns. For non–Poisson processes parametric methods have been developed.

In many applications marks play an important role. They describe e.g. tree hights, trunk diameters or degrees of damage by environmental factors. Correlations of marks give valuable information on ecological processes, e.g. on the interaction of trees. Related statistical concepts such as mark correlation function and mark variogram were first suggested for the statistical analysis of forestal marked point patterns.

Winfried Stute

Model checks for regression: An innovation approach

For a given parametric family of regression functions it is known (cf. Stute, Ann. Statist. (1997)) that the associated residual cusum process—a point process marked by the residuals—may serve as a basis for the construction of various omnibus, smooth and directional goodness–of–fit tests. In this talk we derive its innovation process—the martingale part in its Doob–Meyer decomposition. As it turns out tests based on the innovation martingale are (asymptotically) distribution–free under composite null models and may be easily performed. A simulation study is reported on which indicates that the distributional approximation already work for small to moderate sample sizes.

Yoichiro Takahashi

Scattering length, large deviation for equilibrium processes and fock space representation associated with Poisson random fields

About 20 years ago M. Kac studied the scattering length for Schrödinger equation as the long time asymptotics of a Brownian motion expectation.

The main target of the talk is to show that it is a large deviation result for the equilibrium process consisting of infinitely many independent Brownian particles. But the method is of its own interest.

One can construct the Fock space representation associated with Poisson random fields and it works (unexpectedly) very well to obtain

(a) the criterion of mutual absolute continuity of Poisson random fields,

(b) the neat expression of the Dirichlet form of the equilibrium process,

(c) the computation of large deviation rate functional.

Elke Thönnes

A comparative study on the power of Van Lieshout and Baddeley's J–function

Summary functions like the empty space function (F) and nearest neighbour distribution function (G) are often used to test for complete spatial randomness in point patterns. Van Lieshout and Baddeley have proposed an alternative summary function, the J–function, which is defined as $J = (1 - G)/(1 - F)$. The J–function can be evaluated for many more models than the F– or the G–function, which is a major advantage. In this simulation study we examine how the power ot tests based on J compares to the power of tests based on F and G.

Kamil F. Turkman

Extremes of bilinear processes with light–tailed innovations

The class of bilinear time series models is anobvious generalization of linear ARMA models. It is known that the sample paths of even the simplest bilinear processes are capable of producing sudden bursts of large values depending on the model parameters.

In this talk we look at the extremal properties of the bilinear processes and explain how model parameters effect the extremal behaviour.

Ilia Vonta

Estimation in transformation models in survival analysis

A non–proportional hazards model is considered in which the parameter of interest is the vector of regression coefficients. In the uncensored parametric case, we consider jointly implicitly defined estimators of both the parameter of interest and the nuisance parameter. The strong consistency and efficiency of these estimators are established. In the censored semiparametric case we examine the local existence and uniqueness of a NPMLE of the nuisance parameter when the parameter of interest is assumed to be known.

Nakahiro Yoshida

Asymptotic expansion of martingales with jumps and applications to statistics

Asymptotic epansion of the distribution of martingales is derived by using the Malliavin calculus (global approach). As applications, an asymptotic expansion for MLE of an ergodic diffusion was presented. Also, an expansion for the quasi–MLE of diffusion coefficient of a SDE was obtained. It is also possible to show the validity of the asmptotic expansion for martingales with jumps. If the geometrically strong mixing condition holds, it is possible to derive expansions with conditional Cramér type condition which is verified by means of the Malliavin calculus.

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