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Controlling Complexity for Strong Stochastic Dependencies

September 10th – September 16th 2000

Organizers: U. Gather (Dortmund), W. Härdle (Berlin), J. Horowitz (Iowa)

The aim of this meeting was to discuss the new challenges for statistical research raised by massive, high-dimensional, dynamic data structures with complex dependence structure. Such data are generated nowadays in many fields of applications like financial markets, intensive care, warehouse controlling etc., and are stored and managed in large data bases. Modeling and analyzing these data seems to be only possible by genuine interdisciplinary procedures, hence the scientific exchange of approaches and methods from statistics, computer science and the applied fields characterized the meeting.

Major topics discussed were problems of non- and semi-parametric regression and multivariate time series, especially in high dimensions, special challenges of high-dimensional data like the contrast of high dimension and small samples, and new statistical challenges with respect to interactive methods and the WWW.

All talks were well attended, in an atmosphere of lively discussions and scientific exchange.

The fact that participants from different disciplines even from intensive care and finance could discuss together with computer scientists, statisticians and mathematicians was extremely stimulating and raised new interesting problems in each of the fields.

The following abstracts presented by the authors show the full range of the topics which have been treated at the conference.

Abstracts

Outliers in high-dimensional data

Claudia Becker

Outliers in datasets can affect statistical procedures in various ways. For high-dimensional data, the effects of outliers may be different compared to the lower dimensional case. Moreover, the consequences of the occurrence of outliers are not even all known because the impact of spurious observations becomes less transparent with growing complexity of models and methods.
Different methods are discussed with respect to the outlier problem and to the development of robustified versions. Developing such robust procedures becomes harder with increasing complexity of the data structure.

Sharpening penalized least squares

Rudolf J. Beran

Technological advances in statistics have intensified the interplay between computational experiments and asymptotic theory. We study adaptive penalized least squares estimators of trend and more ambitious adaptive monotone shrinkage or soft-threshold estimators that exploit the potential economy of orthogonal bases arising in the spectral representation of penalized least squares. Computational experiments indicate that asymptotic minimax properties are not a satisfactory criterion for choosing among such adaptive estimators. Estimated risks and diagnostic plots provide further grounds for selecting a fit.

Nonparametric Regression in Longitudinal Models: Locality of Kernel and Spline Method

Raymond J. Carroll

We consider nonparametric regression in a longitudinal marginal model of GEE–type. In such models, the basic shape of the regression function is affected only by the covariate values and not otherwise by the ordering of the observations. Two methods of estimating the nonparametric function can be considered: kernel methods and spline methods. The kernel methods we investigate are modified forms of those suggested by Severini and Staniswalis in a seminal 1994 JASA paper. We will review recent surprising evidence that suggests that for kernel methods, it is generally asymptotically preferable to ignore the correlation structure in longitudinal data, and instead to assume that the data are independent, i.e., working independence in the GEE jargon. This is a surprising, counterintuitive and indeed distressing finding. As seen through equivalent kernel results, in univariate independent data problems splines and kernels have similar behavior: smoothing splines are equivalent to kernel regression with a specific higher–order kernel, and hence smoothing splines are local. This equivalence suggests that in the longitudinal data problem, working independence might be preferable for spline methods. Our results suggest the opposite: via theoretical and numerical calculations, we provide evidence suggesting that for longitudinal data with a time-varying covariate, marginal smoothing and penalized regression splines are not as local in their behavior as marginal kernel methods. In contrast to the kernel results, our evidence suggests that when using spline methods, it is worthwhile to account for the correlation structure in the data. In the light of this vastly different behavior, we

show that spline methods are more efficient than kernel methods of Severini-Staniswalis type in the GEE–context for longitudinal data.
NOTE: This work was done jointly with Xihong Lin (University of Michigan) and Alan Welsh (Australian National University)

Modality and nonparametric regression

Laurie Davies

The problem is to control the number of local extreme values in nonparametric regression. Given data $(t_i, y_n(t_i)), i = 1, \ldots, n$, we look for the smallest number k_n such that there exists a function f_n with the following property:

$$y_n(t_i) = f_n(t_i) + r_n(t_i)$$

where the residuals $r_n(t_i)$ fulfil the multiresolution condition

$$|w_{ij}| \leq \sigma_n \sqrt{2.5 \log n}$$

with

$$w_{ij} = \frac{1}{\sqrt{2^i}} \sum_{l=j2^i+1}^{(j+1)2^i} r_n(t_l).$$

The problem is well-posed but not easy to solve as there is no immediate relationship between k_n and the multiresolution condition. To overcome this we use the taut string method augmented by local smoothing to obtain functions f_n with few local extremes. The number of extremes is increased until the residuals fulfil the multiresolution condition when the procedure terminates. Examples using artificial data sets are presented.

Testing linearity of regression models with dependent errors by kernel based methods

Holger Dette

In this paper we compare different methods for testing linearity in nonparametric regression models. We prove asymptotic normality of the corresponding statistics under the null hypothesis, local alternatives and fixed alternatives. Using these results, a most efficient procedure is identified from an asymptotic point of view.

P-values for discriminant analysis

Lutz Dümbgen

We consider first a simple classification problem, where one observes a random variable X with distribution P_{θ_*}, where θ_* is an unknown parameter in $\{1, 2, \ldots, L\}$, while $P_1, \ldots, P_L$ are known (for the moment) probability distributions. We argue that replacing a sample classifier $\widehat{\theta} = \widehat{\theta}(X)$, i.e. a point estimator for θ_*, by a vector $(\pi_\theta(X))_{\theta=1}^L$ of P-values for class memberships. Precisely, π_θ is a P-value for the null hypothesis that $\theta_* = \theta$.
Things become more involved if the distributions $P_1, \ldots, P_L$ are unknown and have to be estimated from a set $\mathcal{D}$ of training observations. We show how the P-values can be used to assess the quality of the training data $\mathcal{D}$ themselves. As for the P-values, we present a simple parametric as well as a general nonparametric construction.

How big is the world wide web?

Stephen E. Fienberg

Directly assessing the size of the WWW through sampling or systematic measurement is problematic for a host of different reasons. This presentation focuses on the analysis of a "sample" of 575 queries submitted to 6 major search engines. Each query yields data in the form of a 2^6-dimensional contingency table which we analyzed using a hierarchical Bayesian formulation of the Rasch model from educational testing.
Various approaches to scaling up form the sample of queries to the entire WWW are explored and the estimation of the number of web-pages (indexable pages) as of December, 1997, is on the order of 1 billion.

A generalized dynamic factor model approach in the analysis of large cross-sections of interrelated time series

Marc Hallin

A factor model with infinite-order dynamics and possibly nonorthogonal idiosyncratic components is proposed for the analysis of large cross-sections of time series data. Identification conditions are provided, as well as a consistent (when both the cross-section dimension n and the series length T go to infinity) estimation of the common components. Under adequate assumptions, rates of convergence are also obtained.

Interactive Statistical Documents: MM*Stat and e-books

Wolfgang Härdle, Marlene Müller

MM*Stat (www.mm-stat.de) and e-books (www.xplore-stat.de) are interactive, multimedia-assisted tools which have been developed to assist teachers and researchers to publish written material including statistical methods and algorithms. Interactive statistical documents are written in HTML and/or PDF; the interactive components are based on a client/server technology.

Bootstrap methods for dependent data

Joel Horowitz

The bootstrap is a method for estimating the distribution of statistics by resampling one's data - that is, treating the data as if they were the population. When the data are a simple random sample from a distribution, the bootstrap can provide spectacular reductions in the errors in the coverage probabilities of confidence intervals (ECP's) relative to first-order asymptotic approximations. With dependent data and no parametric model (i.e. an ARMA model) that reduces the data generating process to independent random sampling, the situation is much more problematic. The best known method for implementing the bootstrap is the block bootstrap. It is quite general but gives only a small improvement over first-order asymptotics and has disappointing performance in applications. This has led to attempts to obtain improved results by making stronger assumptions about the data generating process. This paper assumes that the process is a (possibly higher order, possibly vector) Markov process. Bootstrap samples are generated from an estimate of the Markov transition probability. Conditions are given under which the improvement in

accuracy (reduction in ECP) provided by this Markov bootstrap is nearly as large as that available with independent random sampling.

Detection of changes in regression models

Marie Huskova

Various test statistics for detection of changes in linear regression models were discussed, including problem of critical points. Results on permutation tests were presented.

On nonparametric regression estimation

Ildar A. Ibragimov

Let (X, Y) be a pair of random variables where Y takes its value in $\mathbb{R}$ and X in a measurable space $(\mathcal{X}, \mathcal{A})$ endowed by a measure μ. Let $f(x) = E(Y|X = x)$. We consider the problem of estimation of the regression function $f(x)$ on the base of i.i.d. observations $(X_1, Y_1), \ldots, (X_n, Y_n)$.
Suppose that
(i) X has the density function $g(x)$ and $0 < c \le g(x) \le C < d$;
(ii) $Var(Y|X = x) \le \sigma^2$ uniformly in x;
(iii) the regression function $f \in \mathcal{F} \subseteq \mathcal{L}_2(\mathcal{X})$ where $\mathcal{F}$ is a known set of functions such that Kolmogorov's diameters $d_N(\mathcal{F}) = d_N \searrow 0$.
We prove under some additional conditions that there exist estimates $\widehat{f}_n$ of f such that

$$P\left\{E\left(\|\widehat{f}_n - f\|_2^2 | X_1, \ldots, X_n\right) > A \inf_N \left(d_N^2 + \sigma^2 \frac{N}{n}\right)\right\} \le c_1 \left(\frac{1}{A} + e^{-c_2\sqrt{n}}\right)$$

where constants c_1, c_2 depend on c, C, σ^2 only. We show that generally speaking this inequality can not be ameliorated.
This talk has two sources: papers of Ch. Stone (Ann. Statist., Vol. 13, $N = 2$, 1965) about the estimation of additive regression $f(x) = f_1(x_1) + \ldots + f_d(x_d), 0 \le x_j \le 1$, and the question of W. Härdle how in Stone's theorem the rate depends on the dimension d. The answer is that if the functions f_j have β as the order of smoothness then the rate is $\sim d^{2\frac{1+\beta}{1+2\beta}} n^{-\frac{2\beta}{1+2\beta}}$

High dimensional on-line data bases in intensive care medicine: Statistical demands for medical decision support

Michael Imhoff, Ursula Gather

In critical care an abundance of data is generated during the process of care: This data can be stored on-line in clinical information systems which comprise databases with more than 2000 separate patient-related variables. Modelling and analysis of the underlying process is a central task that needs to be solved to develop clinical decision support for intensive care medicine. Important requirements for these methods are the ability to handle the data on-line, the detection of change points, the necessity for the monitoring of the individual patient, good interpretability of results, clinical applications with fast algorithms, as well as the ability to handle multivariate time series.
¿From this desire arise strong challenges for statistics. To come up with methods for on-line pattern recognition, we need on-line model building in high dimensional data with possibly time dependent correlation structure.

The talk shows some directions of current research, such as multivariate control charts which incorporate the dynamics and which are based on a kind of phase space embedding of the time series.
Secondly, methods to get more insight into the complex dependence structure of intensive care time series are discussed and applied, such as graphical models, dynamic PCA, and factor models.
Many issues such as robustness of control charts and on-line dimension reduction remain open problems.

On the distribution of the largest principal component

Iain M. Johnstone

Let $\chi_{(1)}$ denote the square of the largest singular value of an $n \times p$ matrix X, all of whose entries are independent standard Gaussian variates. Equivalently, $\chi_{(1)}$ is the largest principal component of the covariance matrix $X'X$, or the largest eigenvalue of a p-variate Wishart distribution on n degrees of freedom with identity covariance.
Consider the limit of large p and n with $n/p \to \gamma \geq 1$. When centered and scales by

$$\mu_{np} = (\sqrt{n-1} + \sqrt{p})^2,$$

$$\sigma_{np} = (\sqrt{n-1} + \sqrt{p})(\frac{1}{\sqrt{n-1}} + \frac{1}{\sqrt{p}})^{1/3}$$

respectively, the distribution of $\chi_{(1)}$ approaches the Tracy-Widom law of order 1. The latter is defined in terms of the Painlevé II differential equation, and can be numerically evaluated and tabulated in software. Simulations show the asymptotic approximation to be informative for n and p as small as 5.
The limit is derived via a corresponding result for complex Wishart matrices using methods from random matrix theory. In particular, Tracy and Widom's analysis of Fredholm determinants can be adapted to the Laguerre ensemble, and combined with Plancherel-Rotach-type asymptotics of Laguerre polynomials of large degree and order near the largest zero.
The result suggests that some aspects of large p multivariate distribution theory may be easier to apply in practice than their fixed p counterparts.

Inference in the quantile regression process

Roger W. Koenker

Tests based on the quantile regression process can be formulated like the classical Kolmogorov-Smirnov and Cramer von Mises test of goodness of fit employing Bessel processes as in Kiefer (1959). In this talk we consider an approach to nuisance parameters in such problems (the Durbin problem) due to Khmaladze (1981). The approach is illustrated with an application to models for the duration of unemployment.

Nonparametric censored and truncated regression

Oliver Linton

We propose estimators of the conditional mean, its partial derivatives, and the error distribution in a nonparametric model with a fixed censoring point. Our estimators just require

computation of a finite number of nonparametric regressions and a univariate integration. The estimators are normally distributed in large samples with the usual rates.

Additive models

Enno Mammen

In this talk we discuss a modified backfitting estimate for a nonparametric additive regression model. In contrast to other backfitting approaches the definition of the estimate allows a mathematical asymptotic analysis. Optimality properties of the estimates are shown. Related models motivated by applications in econometrics are discussed.

Statistical analysis of high dimension - low sample size data

James Stephen Marron

Simple calculations show that usual conceptual models for high dimensional data can be inappropriate, and are used to motivate a new conceptual model. The new model is used to develop a new approach to discrimination (classification). The ideas and methods are illustrated using a data set of corpora callosa shapes.

ACE: Annealed Competition of Experts

Klaus-Robert Müller

We present a novel framework for the analysis of time series from dynamical systems that alternate between different operating modes. The method simultaneously segments and identifies the dynamical modes by using predictive models. In extension to previous approaches, it allows an identification of smooth transitions between successive modes. The method can be used for analysis, prediction and control. In an application to EEG and respiratory data recorded from humans during afternoon naps, the obtained segmentations of the data agree to a large extent with the sleep state segmentation of a medical expert.

Dependencies in credit risk portfolio modelling

Ludger Overbeck

Basic concepts in modelling the loss distribution for large credit portfolio were given. In particular, the model based on a "latent" normally distributed random variable, namely ability-to-pay, that triggers defaults of counterparts. The event correlation of defaults is though reduced to correlation of the continuous variable "ability-to-pay". These correlation can be determined from a stochastic process for liable hruns. For non-liable hruns the question of estimation of the correlation was considered. Several approaches were presented that were either based on uniformity assumptions or on exploiting the panel structure of the default data. Conditional least squares estimators for the average correlation were proposed and alternative models like common models were mentioned.

Projection methods for multivariate outlier detection and clustering

Daniel Peña

It is shown that we can obtain a powerful procedure for outlier detection by projecting the data on the directions that maximize an minimize the Kurtosis coefficient of the projections. Then we identify outliers on these univariate samples by using standard Stahel-Donoho univariate detection. The procedure is iterated by projecting the data onto an orthogonal subspace, and the $2p$ (where p is the dimension) directions are analyzed. The procedure seems to be faster and more powerful than other existing methods for outlier detection.
Then it is shown that if we have two clusters generated by the mixture of two distributions, the best linear discriminant function can be obtained by minimizing the Kurtosis coefficient. This result is extended to mixtures of elliptical distributions and it is shown that the directions obtained by this procedure have some optimality properties. Based on this result a cluster procedure is presented in which the data is projected over the $2p$ directions that maximize or minimize the Kurtosis an a searching algorithm using spacings is presented. The procedure seems to outperform other procedures in the simulation experiments that we have carried out.

Adaptive methods and confidence intervals

Dominique Picard

Following a strategy due to P. Hall for finding nonparametric confidence intervals with optimal coverage accuracy, we use adaptive thresholding methods as pivotal statistics and build an index of complexity. By plugging this (data driven) index, we obtain a confidence interval with adaptive optimal coverage accuracy.
Some remarkable phenomena occur: Unlike in the minimax context, white noise model and regression setting differ, as well as Lepski procedure of bandwidth selection gives different performances, compared to classical thresholding. It is also worthwile to notice that global, block or local thresholding give comparable results.
These results are obtained under assumption of Lipchizianity and an additional hypothesis which allows to estimate the regularity.

GraphFitI - A computer program for graphical chain models

Iris Pigeot, Angelika Blauth

Fitting a graphical chain model to a multivariate data set consists of different steps some of which being rather tedious. The talk as well as the demonstration outline the basic features and overall architecture of the computer program GraphFitI which provides the application of a selection strategy for fitting graphical chain models and for visualizing the resulting model as a graph. It additionally supports the user at the different steps of the analysis by an integrated help system.

Spatially adaptive procedures for signal detection in functional Magnet-Resonance-Imaging

Jörg Polzehl

Images are often characterized by discontinuities and regions of relative homogeneity. We propose a new spatially adaptive smoothing procedure, that is especially designed to recover

such structures from distorted images. The method adapts to the structural assumption of a local constant model. We demonstrate how this approach can be extended to the problem of adaptive spatial smoothing of time series of images. This type of data typically occurs in functional (fMRI) and dynamic Magnet Resonance Imaging (dMRI). We show how the method can be used for efficient signal detection in fMRI and classification in dynamic MRI experiments.

Robust clustering

David M. Rocke

The most difficult outlier configurations involve clusters, often concentrated. Cluster analysis methods combined with the M-estimates of multivariate location and slope can detect these outliers when most current methods cannot. We have also developed clustering algorithms that are less likely to be perturbed by outliers than existing methods. Finally, we provide accurate tests for outliers given a robust estimate of multivariate location and slope that have approximately the correct size for normally distributed data even in small samples. This fact is based on an F approximation to the distribution of the robust Mahalanobis distances.

Nonparametric (auto-)regression with design-adapted wavelets

Rainer von Sachs

We present a new approach of nonparametric regression with wavelets if the design is stochastic. In contrast to existing approaches we use a new construction of a design-adapted wavelet basis which is constructed given the random regressors. To exemplify the potential of our new methodology we treat the case of using orthogonal design-adapted Haar wavelets for regression with (non-Gaussian) i.i.d. errors. We derive results on the near-optimal rate of convergence of the minimax L_2-risk of non-linear threshold estimators over a certain function class which parallel those of the classical case of fixed equidistant design. We indicate generalisations in various directions and show simulated examples, in particular for the case of nonparametric (non-linear) autoregression and ARCH.

Semiparametric estimation of weak and strong separable models

Stefan Sperlich

A general method for estimating semiparametrically the component functions and parameters in separable models. This family is quite popular in economic theory, empirical research, and also for dimension reduction in non- or semiparametric statistics. Generalized additive, partial linear and some interaction models are special cases in this family. The idea of the new method is based on a combination of local likelihood and "efficient" estimators. Although this imposes hypotheses on the error distribution, this yields a quite general useful method with little computational costs but high exactness for even small samples. In enables us to include censored and truncated variable models. The estimators are shown to be efficient (with the lower dimensional rate and minimal variance). Simulations enforce these theoretical findings.

Structural adaptive approach to dimension reduction

Vladimir Spokoinyi

A new dimension-reduction procedure is proposed. The procedure is based on the idea of structural adaption. It starts from the nonparametric index estimation (ADE) and allows to improve the quality of estimation successfully using the result of previous estimation.

Hazard regression

Young K. N. Truong

In many clinical and medical studies of diseases, one of the primary variables is the time to event - occurrence of the disease or death. The time is censored if the event has not occurred before the end of the study period. For a statistical analysis it may be required to include the observed data as well as the censored ones. Also, to adjust for the other effects, it is necessary to include covariates that are discrete, continuous, or may even vary with time. The talk will present a new procedure for modelling the conditional expectation of the survival time given the covariates. Modelling, properties of the estimates and the dimensionality issues will be discussed using the extended linear modelling (ELM) approach. Comparisons with the existing methods will be discussed and illustrated in data sets from the Eastern Cooperative Oncology Group (ECOG)and the studies of Left Ventricular Dysfunction (SOLVD).

On the role of redescending M-estimates in computer vision (and in other fields)

David E. Tyler

There is a long history of applications of robust methods to problems in computer vision / image understanding. Many of the earlier robust methods used in vision were developed by researchers in the area and arose from a need for such methods in vision research. Such methods include the Hough transform and RANSAC. More recently, researchers in vision have become aware of parallel developments of robust methods in statistics, in particular M-estimators and LMS, and have incorporated them into their toolbox.
This talk is partially intended as a review or as an introduction to robust methods used in vision. We show how many of the seemingly unrelated approaches used in vision can be unified under the banner of "redescending M-estimation". We also argue that two central features needed to properly formulate statistical problems, or data analytic problems, in vision and which are often overlooked are (1) the definition of a residual, and (2) the knowledge of scale. Finally, we conclude by describing how what we learned in vision can be transferred to the problems in statistics in general.

Vivid - VIsualizing Variables' InterDependencies

Antony R. Unwin

Interactive features are essential components of graphics. They improve the use and encourage interaction with domain supports and the incorporation of background information. Parallel coordinates are an interesting tool for displaying many dimensions at once, but are unsatisfactory in a static form. Using a winetasting data set (the 1999 Cabernet Challenge), the interactive implementation of parallel coordinates in the software CASSATT

is demonstrated to illustrate the value of these methods. Some of the innovative selection possibilities in CASSATT are also discussed.

On some implications of recursive generating processes

Nanny Wermuth

Univariate recursive generating processes are a direct extension of linear recursive equations with independent errors to arbitrary univariate conditional distributions: they generate joint distributions in a stepwise fashion. Each conditional distribution is only restricted to be (possibly) independent of some of its potential explanatory variables. Such distributions are said to be generated over directed acyclic graphs. These consist of a node set V of dimension d_V, each node representing a random variable, and of at most one arrow connecting a node pair. Acyclic means that it is impossible to start from any node, follow the direction of arrows and return to the same node.
For such distributions further independence structures can be deduced: e.g. graphs for all pairwise marginal independencies (covariance graphs), graphs for conditional independencies given all remaining variables (concentration graphs), and graphs displaying all implied independencies in arbitrarily selected conditional distributions. Structural zeros in matrices for Gaussian linear systems which imply an independence statement carry over to missing edges in such derived graphs for arbitrary distributions having the same generating process, essentially due to the factorization property of the joint distribution.
This implies in particular that proof for separation criteria, i.e. for condition which permit to read all independencies implied by a graph directly off the graph, can be reduced to matrix operations, and fast algorithms for checking implied independencies can be designed.

Edited by Ursula Gather (Dortmund)

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