MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

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Design of Experiments: Optimality, Construction, and Applications

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The conference was organized by Ching-Shui Cheng (Berkeley), Friedrich Pukelsheim (Augsburg), and Dieter Rasch (Wageningen).

Various topics in the field of designing experiments were presented in 40 talks each of which was followed by intensive discussions of the 42 participants (17 from Germany, 25 from abroad). The contributions included e.g. optimal designs for correlated errors, fractional factorial designs, optimality of block designs, Plackett and Burman designs, Youden designs, problems with interacting factors, design and analysis of computer experiments, Bayesian designs, designs for response surface experiments, and software for the numerical computation of optimal designs.

Abstracts

MARKUS ABT

Design of computer experiments

In the recent literature on computer experiments one of the problems considered is the choice of an appropriate design. For this purpose several algorithms have been proposed, but no explicit formulas are given up to now. In the present work we investigate "linear covariance functions" in one dimension and show how exact optimal designs can be found for several design criteria. Linear in this context means that the obtained predictive function interpolates the observations linearly. Even in this rather simple situation it is quite tedious to get reasonable results. An interpretation of the results according to the different distributional assumptions is given.

ROSEMARY A. BAILEY

Constructions for complex block structures

Before an experiment can be designed, the block structure on the experimental units must be elucidated. This structure consists of inherent factors, and their crossing and nesting relations, which can usefully be represented on a Hasse diagram. If all the block factors correspond to random effects, then, under nice conditions, the block structure determines orthogonal homogeneous strata for the analysis of variance.

A design is said to be orthogonal if the space of treatment contrasts is the orthogonal direct sum of subspaces each of which lies in one stratum. One method of constructing orthogonal designs is Patterson's design key. Slightly more general is the Abelian group method, in which the treatments are identified with the elements of an Abelian group G, and, for each block factor F, the treatments allocated to levels of F are all cosets of a subgroup H_F of G. The induced Hasse diagram for the subgroups H_F is isomorphic to that for the block factors. The order of G is not restricted to being a prime power, so the method generalizes Boses's classic work for factorial designs.

The Abelian group method extends readily to non-orthogonal designs, by replacing "cosets of a subgroup H_F" by "translates of a subset B_F". Such designs have orthogonal factorial structure: it is easy to calculate their efficiency factors (using complex eigenvectors) and to interpret their analysis.

Another useful source of constructions is mutually orthogonal Latin Squares. An example is given of an experiment comparing 12 feed treatments for 12 sheep. The sheep are in 3 houses of 4 sheep, and the experiment has 3 periods, with each sheep's treatment changing after each period.

ROSEMARY A. BAILEY

Semi-Latin squares

Consider an $n \times n$ array of cells, each of which consists of k plots. A semi-Latin square is an allocation of nk treatments to the cells in such a way that each treatment occurs once in each row and once in each column. Some construction methods will be given and optimality results discussed.

WOLFGANG BISCHOFF

On $D-$optimal designs when the observations are correlated

In the general linear model consider the designing problem for the Gauß-Markov estimator with respect to the $D-$criterion. For exact designs we investigate the relation of efficiency for the correlated case and the uncorrelated case with common variance. Moreover, lower bounds for the efficiency of an exact design are given in the correlated case.

Next, approximate designs are considered. Problems appearing in the correlated case are discussed. We argue under which conditions an approximate $D-$optimal design for the uncorrelated case may be considered as approximate $D-$optimal design in the correlated case. Then we show analogous results for the least squares estimator.

CHING-SHUI CHENG

Some projection properties of orthogonal arrays

The definition of an orthogonal array imposes an important geometric property: the projection of an $\mathrm{OA}(\lambda 2^t, 2^k, t)$, an $\lambda 2^t-$run orthogonal array with k two-level factors and strength t, onto any t factors consists of λ copies of the complete 2^t factorial. In this talk, projections of an $\mathrm{OA}(\lambda 2^t, 2^k, t)$ onto more than t factors will be discussed. Some general results and their statistical implications will be presented. For example, if N is not a multiple of 2^{t+1}, then the projection of an $\mathrm{OA}(N, 2^k, t)$ with $k \geq t+2$ onto any $t+1$ factors must contain at least one complete 2^{t+1} factorial. This may not be true for the commonly used regular fractional factorial designs. LIN and DRAPER (1993) observed that the projection of the 12-run Plackett-Burman design onto any four factors is of resolution V. We prove that this important property holds for all $\mathrm{OA}(N, 2^k, 2)$ whose size N is not a multiple of 8.

PAUL L. DARIUS

Computer aided design of experiments

Although current statistical packages are convenient and powerful tools for statistical analysis, their usefulness in the planning stage of the experiment is limited. We have been working on a software system aimed at providing the user with a maximum of software support during the process of designing an experiment. The key elements are

- an object oriented software representation of a design with which the user can interact under the form of a structure diagram,
- a window based graphical and interactive environment, providing a number of simultaneous and linked views on different aspects of the current design,
- support for a strategic approach, signalling problems and suggesting changes.

A prototype has been implemented with Objectworks/Smalltalk on a Sun workstation.

ANGELA M. DEAN

Designing experiments for drug combination studies

In a combination drug study, several drugs may be administered singly, or in combination with several other drugs, to a number of subjects according to a cross-over design. A measurement is taken on each of the drugs administered in a given time period. Thus, this is a multiple response study with factorial treatment combinations.

If a drug is not present in the treatment combination administered to a subject in a given time period, then no measurement is taken on this particular drug in this particular period. Therefore, depending upon the treatment combination administered, there may be a "missing" observation on one or more of the responses for any given subject in any given time period.
A survey is given of recent work on designing experiments for drug combination studies. It is shown that the lower bound for the average variance of a set of contrasts in the usual block design setting with a single measured response also provides a bound for a similar set of contrasts in the multiple response setting. The information matrix is derived for the theoretical optimal block design for estimating a given set of treatment contrasts in the single response study.

HOLGER DETTE

Minimax designs in linear regression models

We investigate the geometric structure of Elving's minimax criteria and Kiefer's ϕ_p-criteria in the linear regression model $y = f(x)'\theta$. It is shown that the optimal designs with respect to these criteria are also optimal for $A'\theta$ where A is any inball vector (in an appropriate norm) of a generalized Elving set. The results explain the particular role of the $A-$ and $E-$optimality criterion and are applied determining the minimax spring balance weighing design and the minimax design for polynomial regression.

NORMAN R. DRAPER

Mixture designs for four or more components in orthogonal blocks

The problem of partitioning the blends (runs) of four or more mixture components into two orthogonal blocks when a quadratic model is fitted is considered. The solution proposed by JOHN (University of Texas Center for Statistical Science Technical Report No. 8, 1984), and described by CORNELL (Experiments with Mixtures, Wiley, 1990) is discussed and extended. For four components, study of the characteristics of Latin squares of side four leads to reliable rules for quickly obtaining designs of specified kinds. Mixture component values that cause singularity in the new designs are identified, and values that provide designs with highest $D-$criterion values, for the class of designs discussed, are obtained. An industrial example illustrates the use of the designs.

MIKE F. FRANKLIN

Some alternatives to Latin hypercube sampling

In some problems a description of a function $f(x)$ is required. Each x_i is continuous and bounded above and below. There are no other constraints on the choice of the x_i. However, the cost of determining $f(x)$ for any x is high. Normally the number of data points is chosen and then the levels of each factor chosen to span the range for that factor. To obtain a fair degree of orthogonality between variables, randomisation procedures are built into the choice of levels and data points. One class of these designs is that of Latin hypercubes. The properties of any design are dependent on the outcome of the randomisation. Here three alternative constructions are described and the properties of the resulting designs outlined.

NORBERT GAFFKE

Symmetric optimal designs for multiple cubic regression

In the joint technical report with B. HEILIGERS "Computing optimal approximate designs for cubic regression on multidimensional balls and cubes" (Augsburg, 1992), we computed numerically Φ_p-optimal invariant designs (invariant with respect to permutations and sign changes of coordinates), and also optimal (third order) rotatable designs. The talk points out some of the specific results on the moment matrices of invariant designs, which gave a basis for the algorithmic computations.

SUBIR GHOSH

Efficient response surface designs with a small number of runs

The talk will present the construction of second order response surface designs with higher efficiencies than designs available in the literature. The standard optimality criteria are considered in comparing efficiencies.

SYLKE GIERER (together with K. Engel)

Optimal designs for models with correlated observations

Optimal block designs are determined assuming two special structures for the covariance matrix of the observations, namely that the covariances between and the variances of the observations depend only on the blocks respectively the treatments. It can be shown that the weighted least squares estimators equal the ordinary least squares estimators. The optimality criteria considered here are the $A-$ and $MV-$optimality with respect to a given set L of contrast vectors. It is proved that block-block correlations respectively treatment-treatment correlations do not have any influence on the $A-$ and $MV-$optimality respectively $A-$optimality. Finally, the idea of invariance is used to find $MV-$optimal $C-$matrices in the case of treatment-treatment correlations.

VOLKER GUIARD

Design of experiments for estimation of variance components with ANOVA in the one-way-classification under non-normality

Let the one-way random model

$$y_{ij} = \mu + a_i + e_{ij},\ i = 1, \ldots, a; j = 1, \ldots, n_i; n_1 + n_2 + \ldots + n_a = N$$

be given with random effects a_i and e_{ij}. The first four moments of the distributions of a_i and e_{ij} may be finite with kurtosis γ_{2a} and γ_{2e}, respectively. The designing of experiments for estimating $\sigma_a^2 = V(a_i)$ and $\sigma_e^2 = V(e_{ij})$ by means of ANOVA with respect to the $C-, A-$, and $D-$optimality is demonstrated. In the class of concrete designs with given a and N it is proved that the $A-$ and $D-$optimum design is quasi-balanced if $\gamma_{2e} \geq 0$. For $\gamma_{2e} \geq 0, c_e(a-1)N \leq c_a(N-1)a$ and $c_a > 0$ or $c_e = 1$ and $c_a = 0$ the $C-$optimum design with $c' = (c_a, c_e)$ is also quasi-balanced. These results can not be generalized to all values of γ_{2e}. An example is given with $\gamma_{2a} = \gamma_{2e} = -2$. In this example the optimum design is not quasi-balanced.

BERTHOLD HEILIGERS

Totally nonnegative moment matrices and $E-$optimal designs for weighted polynomial regression

The finite dimensional moment matrices of symmetric designs over $[-b, b]$ for weighted polynomial regression are totally nonnegative. As a consequence, the nonzero eigenvalues of these matrices have multiplicity less or equal to two, and the coordinates of the corresponding eigenvectors possess a characteristic sign pattern.

An application of this result to a dual problem to the $E-$optimal design problem shows that the optimal approximate designs are supported by the extrema of the only equi-oscillating weighted polynomial over $[-b, b]$ with leading coefficient 1, provided the experimental region is 'small enough', e.g. $b \leq 1$. In particular, by specializing the weight function we obtain results on $E-$optimality found by PUKELSHEIM and STUDDEN (1991).

RALF-DIETER HILGERS

Optimal designs for mixture amount experiments

New results extending the work of SCHEFFÉ (1959, 1963), KIEFER (1961), URANISI (1964), and ATWOOD (1969) are presented. The later authors calculated $D-$optimum designs for various regression models introduced by Scheffé to describe the quantitative response in mixture experiments on the unit simplex. While in his setting the response depends only on the proportions of the components, in mixture amount experiments the response also depends on the total amount of the mixture. In this context the simplex has a useful interpretation as an adequate factor space. Admissibility and optimality of the extended simplex centroid design for models with regression functions of the $\nu-$tic type on the q simplex are investigated.

PETER W. M. JOHN

Fractional factorial designs

A semiconductor engineer wished to carry out a 2^4 factorial experiment. He had at his disposal a lot of twenty wafers and so a subset of four had to be selected to be duplicated. The obvious approach is to repeat an orthogonal quarter replicate, but there are alternatives. If the base point is duplicated there are 455 choices for the other three points. These fell into nineteen non-isomorphic sets. Four of these sets gave the same best value for the $D-$ and $A-$optimality criteria. The $E-$optimality criterion was of no use beause it gave the same value for every set. The four sets that gave the best values for the $D-$ or $A-$criteria are also the four best choices for omitting from the 2^4 to provide a resolution V three quarter replicate with twelve points. Two of the sets of four points are orthogonal quarter replicates. One gave a design that is isomorphic to the Srivastava-Chopra design for twenty points. Details of the underlying matrix structure that lead to the existence of four non-isomorphic 'best' solutions with the same $D-, A-, E-$values are discussed.

ANDRE KOBILINSKY

Some useful tricks in building efficient asymmetrical block factorial designs

In many practical situations, block or fractional factorial designs involve a mixture of factors having different and possibly coprime numbers of levels.

To build efficient designs with not too many units in these asymmetrical cases, it is often possible to use some little tricks - collapsing levels, using pseudofactors for instance - which allow to bring back the construction to that of classical factorial designs. These tricks are illustrated on some examples coming from a problem in food research.

OLAF KRAFFT

On exact $G-$optimum designs for quadratic regression

For $x = (x_1, x_2, \ldots, x_n) \in [-1,1]^n$ let $s_i(x) = \sum_{j=1}^n x_j^i, 0 \leq i \leq 4$ and

$$M(x) = \begin{pmatrix} s_0 & s_1 & s_2 \\ s_1 & s_2 & s_3 \\ s_2 & s_3 & s_4 \end{pmatrix}.$$

The point x^* is $G-$optimal, if

$$\sup_{y \in [-1,1]} (1, y, y^2) M^{-1}(x^*)(1, y, y^2)' \leq \sup_{y \in [-1,1]} (1, y, y^2) M^{-1}(x)(1, y, y^2)'$$

for all x for which $M(x)$ is regular. In the talk we discuss a conjecture concerning the solution of this problem. This work has been done together with Martin Schaefer.

JOACHIM KUNERT

Optimality of block designs with variable block sizes and random block effects

We consider the simple block model with random block effects, the block effects having variance $\sigma_b^2 = \lambda\sigma^2$, with σ^2 the variance of the errors. It is assumed that the experimenter can vary the sizes of the block. The universal optimality of certain designs for all λ over all designs with the same number of blocks and the same number of observations is shown.

It is of interest to note that if Balanced Incomplete Block Designs compete, then they perform equally well for $\lambda = 0$ and $\lambda = \infty$, i.e. in the one way classification model and in the simple block model with fixed block effects, but they perform worse for every $\lambda \in (0, \infty)$.

DENNIS K. J. LIN

On Plackett and Burman Designs

One major problem in industrial experimentation is screening, i.e. identifying those factors that matter. In this talk, I will present some of my recent work in this area (some jointly with Norman Draper), using Plackett amd Burman type designs for illustration. The subjects to be addressed include small composite design, column selection, alias structure, projection properties, and supersaturated designs. The straightforward extension to other orthogonal arrays is possible, of course.

DIBYEN MAJUMDAR

Trend-free and nearly trend-free block designs

In 1983, YEH and BRADLEY conjectured that a binary connected block design with blocks of size k and constant replication number r for each treatment, can be converted

to a linear trend-free block design iff $r(k+1)$ is even. They established the conjecture for $k = 2$ and $k = v$. STUFKEN, in 1988, gave a family of counterexamples for certain design classes with k odd. We will show that the conjecture is indeed true for a large number of designs, including all designs with k even, and BIB designs.

We also consider situations where $r(k+1)$ is odd, hence no trend-free design exists. Several families of nearly trend-free designs (definition due to YEH, BRADLEY and NOTZ) will be identified. For example, a BIB design can be converted to a nearly trend-free BIB design whenever $r(k+1)$ is odd.

RICHARD J. MARTIN

Efficient experimental designs for dependent data

Although there is much current interest in designing block experiments to take dependence into account, most results have been for particular dependence structures or on balancing neighbour effects. Results for dependence structures can also depend crucially on the estimator to be used. However, for large numbers of blocks some unification over estimators and dependence structures is possible. This will be discussed in the usual case of a linear array of plots within a block, and in the case of a spatial array. For a small number of blocks, results depend on the particular dependence structure and estimator used. Good designs usually require more than neighbour balance, and may not be constructible by combinatorial methods. Exhaustive evaluation may also be impractical. Recursive methods of construction will be discussed, and criteria for constructing designs that are reasonably robust to misspecification of the dependence structure.

JOHN P. MORGAN

Pairs of Youden designs

Let there be two $p \times q$ row-column layouts, as for example in an agricultural experiment in two fields with elimination of heterogeneity in two directions. If p and q are such that a generalized Youden design (GYD) exists, will a pair of GYD's be optimal for the usual analysis in the bottom stratum? In general the answer is no: by making the row and column component designs inferior to that of two GYD's (for which they are optimal) it is sometimes possible to obtain uniformly better designs. The result is dependent on the values of p and q, however, and it is also proven that an infinite series of pairs of GYD's is $E-$optimal. In addition, a lower bound for the $E-$efficiency of pairs of GYD's is found, which is an $A-$efficiency bound within the equireplicate class.

MAX D. MORRIS

An overview of some recent developments in the design and analysis of computer experiments

The talk begins with a definition of "computer experiment", examples of generic computer experiments, characteristics which make these different from physical experiments, and some examples of how conventional statistical ideas have been applied in *ad hoc* ways to computer experiments. Latin hypercube sampling, and other randomized sampling plans, are then reviewed, along with their statistical motivation for use in uncertainty analysis.

In the second part of the talk, an approach to the approximation of computer models based on the use of stochastic processes as "metamodels" is examined from both classical and Bayesian points of view. A design optimality criterion based on entropy is discussed, and examples of optimal designs are presented. The approach is generalized to accomodate information about derivatives with respect to inputs. Finally, some unresolved problems and areas of active research are noted.

RAHUL MUKERJEE (read by C. F. Jeff Wu)

On the existence of saturated asymmetrical orthogonal arrays

For saturated asymmetrical orthogonal arrays the Bose-Bush bound may not be sharp. We improve their bound by developing a new combinatorial condition, which further limits the choice of integral solutions to the system of equations in the Bose-Bush approach. For saturated asymmetrical orthogonal arrays of strength two, our approach can provide a substantial improvement over the Bose-Bush approach. We show that a class of saturated OA$(N, s^{m_1}(s^r)^{m_2})$ constructed by WU, ZHANG and WANG (1992) attains the maximum for m_2, a result which cannot be proved by the Bose-Bush approach. Other applications include

(i) 12 in the OA$(36, 2^{11}3^{12})$ is maximum for the 3−symbol factors,

(ii) nonexistence of a class of arrays of strength four.

CHRISTINE MÜLLER

Efficiency of designs for robust and non-robust estimation of non-linear aspects

For estimating a non-linear aspect of a linear model only locally optimal designs can be derived. For classical non-robust estimation based on the least squares estimator this is well-known. For robust estimation based on robust one-step-M-estimators this also holds and moreover only locally optimal robust estimators can be derived. But the locally optimal designs and estimators can be used for efficiency comparisons and for calculating maximin efficient designs.

In particular for non-robust estimation maximin efficient designs are derived for the case that the support of the regarded designs is given and provides linearly independent regressors. Besides a general result two special results are presented, which provide maximin efficient designs under simple conditions. One of these results gives a simple condition so that the uniform design is maximin efficient. The other result deals with designs with a two-point support. The result concerning uniform designs also holds for robust estimation. Some examples demonstrate the applicability of the results.

HANS-MATTHIAS NEUGEBAUER

Bayesian D−optimal designs for exponential regression models

We consider the Bayesian D−optimal design problem for exponential growth models with one, two or three parameters. For the one parametric models conditions on the shape of the density of the prior distribution and on the range of its support are given guaranteeing that a one point design is also Bayesian D−optimal within the class of all designs. In the case of two parameters the best two point designs are determined and for special prior distributions it is proved that these designs are globally optimal. Finally, the exponential growth model with three parameters is investigated. The best

three point designs are characterized by a non-linear equation and it is investigated if these designs are also Bayesian $D-$optimal within the class of all designs.

FRIEDRICH PUKELSHEIM

Optimality of BIBD's in the approximate theory

A block design is treated in the approximate theory relaxing the relative frequencies n_{ij}/n to be continuous weights $w_{ij} \in [0,1]$. Balancedness then means invariance under the action of an appropriate group, and to this end we sketch the general framework of invariant design problems. We introduce the *Kiefer* ordering, as a superposition of the usual *Loewner* matrix ordering and matrix majorization. Together with other block designs, less structured block designs, BIBD's are shown to be *Kiefer* optimal for the treatment contrasts (J.C. KIEFER, 1975, and B.K. SINHA, 1972). Moreover, BIBD's are distinguished by being uniquely optimal under all matrix means, for a maximal parameter system, among a class of support restricted designs.

DIETER RASCH

The robustness of exact locally optimum designs in non-linear regression - a case study

For a special set of data a model choice in a class of ten isotonic non-linear regression models leads to the Bertulanffy function as the best fitted and to the Gompertz function as the second best fitted function. $D-$ and three $C-$optimum designs are determined for the estimated parameter. For three criteria a relatively high robustness of these optimum designs against parameter variation was found. The remaining criterion was very sensitive. The optimum designs for the Bertulanffy function are very similar to the corresponding optimum designs for the Gompertz function fitted to the same data. Therefore for all criteria a robustness against a wrong model selection and except for one $C-$optimality criterion also against parameter variation could be stated.

JAMES L. ROSENBERGER

Design problems in calibration studies

This talk will discuss the design of experiments for nonlinear models with attention to the issues arising in calibration studies. The goal of calibration is to estimate the value of an unknown quantity, based on the calibration curve of the relationship between known standards and the observed response function. The linear logistic function and the four parameter log-logistic curve used in the calibration of ELISA experiments will be illustrated. Both the known standards and the unknown quantities are assayed by using serial dilutions of the quantities, in order to insure that the observed response spans the optical density scale. A special technique referred to as parallel fitting allows the entire set of measurements to be included in the calibration procedure.

RAINER SCHWABE

Optimal designs for models with partly interacting factors

In many experimental situations the experimenter is faced with the influence of more than one factor. Of course, the performance of any experimental design depends on the underlying model and in particular on the structure of interactions between the factors in the situation at hand. In the two most outstanding cases of complete product type interaction and of no interactions, product designs have shown up to be $D-$optimal

for the whole model and the marginals of these designs are the $D-$optimal ones for the models corresponding to the single factors. In the presence of partial interactions the situation is more complicated. For a variety of simple but practically useful examples product designs are presented which are $D-$optimal. The marginals of these designs depend on the interaction structure and hence differ from the $D-$optimal ones for the single factor models.

KIRTI R. SHAH

Optimal block designs under partially mixed models

In some situations, the experimenter has the freedom to choose some of the blocks at random from a population of blocks. We formulate the problem of choosing an optimal design in such situations. We derive some results for optimal selection of random blocks when the basic design is a balanced design or a group divisible design. We also consider the problem of optimal selection of both the basic design as well as the choice of random blocks from this basic design.

BIKAS K. SINHA

Optimal estimation of total weight in chemical balance and spring balance designs

We consider chemical balance and spring balance weighing designs (without bias in the measuring instruments) and address the problem of optimal (most efficient) estimation of total weight of a number of objects, subject to retaining estimability of all of the individual weights. We also discuss the problem of estimation of the total distance covered by a number of (natural) objects placed along a line or along the corners of a ploygonal fence. The concept of designs with string property (circular/non-circular) is introduced in this context.

The purpose of this talk is to review all the available results in this fascinating area of research.

NEIL J. A. SLOANE

New designs

This talk will discuss new results on the structure of quadratic designs, spherical designs, interaction designs, mixture designs, designs with correlated errors, orthogonal arrays, covering designs, supersaturated (or search) designs, and will give tables of all these designs.

JOHN STUFKEN

On the construction of orthogonal arrays

We will emphasize various tools for the construction of orthogonal arrays. As fractional factorial designs these arrays are heavily used in, especially, industrial experiments. Our tools are suitable for the construction of symmetrical orthogonal arrays as well as for the construction of asymmetrical orthogonal arrays. Examples of the use of these tools will be provided.

BEN TORSNEY

Construction of optimal designs for binary response experiments with two design variables

$D-$optimal designs for three parameter binary response and other generalized linear models depending on two design variables are first considered. These are derived using a parameter dependent canonical linear transformation of the design variables which changes the design problem to a weighted linear design problem in two design variables z_1 and z_2. This is the approach introduced by FORD, TORSNEY and WU (JRSSB, 1992) for the case of one design variable but a new feature here is that one of z_1, z_2 must be bounded. This guarantees that the problem is further equivalent to a linear design problem with constant variance and uncorrelated errors for which the induced design space $G \subset \mathbb{R}^3$ of SILVEY is bounded. His minimal ellipsoid argument is then applied to G to identify or characterize $D-$optimal supports. Results are extended to more than two design variables and to the $c-$optimality criterion. This is joint work with Randy SITTER, University of Ottawa, Canada.

JEAN-PIERRE VILA

Intensive computing and bootstrap-based optimal designs in regression

Optimal design criteria for improved estimations of parameters or functions of parameters or model responses in nonlinear regression are considered.

These criteria are based upon exact regions (Gaussian context) or at least second order exact bootstrap confidence regions. In the last case, the critical quantile of the root used to define the region is consistently estimated by Monte-Carlo from parameter estimations and residual sampling distribution of a previous model fitting. This last approach is free of any model approximation and of any probability distribution hypthesis for the errors which are just supposed to be centered and independent and identically distributed. The specific form of these criteria (expected measure of confidence set) as well as the inadequacy of the usual minimizing schemes suggest the use of stochastic approximation procedures for their minimization.

ADALBERT WILHELM

Numerical computation of optimal designs using generalized gradients

Several iterative methods for constructing optimal designs in linear regression models have been proposed in the last two decades. All of them are restricted to differentiable objective functions. So there is neither a possibility to tackle singular moment matrices nor is there a way to treat $E-$optimality without further assumptions. In this talk we outline a new approach for computing optimal approximate designs based on the knowledge of one generalized gradient in each iteration. Our approach can treat design problems on either a discrete or continuous regression range and allows consideration of arbitrary linear parameter systems. In the implemented version (Fortran 77) one can choose the optimality criteria among all matrix means $\Phi_p, p \in [-\infty, 1]$. Numerical results for polynomial regression models indicate that the method is of practical interest.

C. F. JEFF WU

Construction and layout techniques in factorial designs: an overview of recent advances

Factorial designs can be classified into two broad classes: regular and nonregular designs. In regular designs the mathematical structure is simple and the main questions are

(i) assignment of factors,
(ii) choice of good blocking schemes,
(iii) accomodation of specified interactions.

For nonregular designs construction of new arrays, especially those with small runs and mixed levels, is still an outstanding question. A new aspect is the accomodation of intercations using a new notion called hidden interactions. Related topics like supersaturated designs and nearly orthogonal arrays will also be discussed.

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