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Abstract
We consider the design of dimensional analysis experiments when there is more than a single response. We first give a brief overview of dimensional analysis experiments and the dimensional analysis (DA) procedure. The validity of the DA method for univariate responses was established by the Buckingham Π-Theorem in the early 20th century. We extend the theorem to the multivariate case, develop basic criteria for multivariate design of DA and give guidelines for design construction. Finally, we illustrate the construction of designs for DA experiments for an example involving the design of a heat exchanger.

Abstract
Response surface designs (RSDs) are a core component of the response surface methodology, which is widely used in the context of product and process optimization. In this contribution, we consider three-level RSDs, which can be viewed as matrices with entries equal to $\{-1,0,1\}$. Each column of an RSD corresponds to a factor and each row to an experimental test. We define a new family of orthogonal RSDs, for which there is no aliasing between the main effects and the second-order effects (two-factor interactions and quadratic effects). Using integer programming techniques, we construct a database of 55,531 such RSDs for 3–7 factors. We name these designs orthogonal minimally aliased RSDs (or OMARS designs). Each design in the catalog is extensively characterized in terms of efficiency, power, fourth-order correlations, fraction of design space plots, projection capabilities, etc. We identify interesting designs and investigate trade-offs between different quality criteria. Finally, we present a multiattribute decision algorithm to select designs from the catalog. An important result of our study is that we discovered some novel and interesting designs that challenge standard RSDs.

Abstract
Abstract–Definitive screening designs permit the study of many quantitative factors in a few runs more than twice the number of factors. In practical applications, researchers often require a design for *m* quantitative factors, construct a definitive screening design for more than *m* factors and drop the superfluous columns. This is done when the number of runs in the standard *m*-factor definitive screening design is considered too limited or when no standard definitive screening design (sDSD) exists for *m* factors. In these cases, it is common practice to arbitrarily drop the last columns of the larger design. In this article, we show that certain statistical properties of the resulting experimental

design depend on the exact columns dropped and that other properties are insensitive to these columns. We perform a complete search for the best sets of 1–8 columns to drop from sDSDs with up to 24 factors. We observed the largest differences in statistical properties when dropping four columns from 8- and 10-factor definitive screening designs. In other cases, the differences are small, or even nonexistent.

Constructing D-Efficient Mixed-Level Foldover Designs Using Hadamard Matrices P. 48-56

Nam-Ky Nguyen, Tung-Dinh Pham & Phuong Vuong Mai

Abstract

This paper introduces a new class of Hadamard matrix-based mixed-level foldover designs (MLFODs) and an algorithm which facilitates the construction of MLFODs. Our new MLFODs were constructed by converting some 2-level columns of a Hadamard matrix to 3-level ones. Like the 2-level foldover designs (FODs), each new MLFOD was constructed by a half fraction and its foldover. Our Hadamard-matrix based MLFODs are compared with the conference matrix-based FODs of Jones & Nachtsheim (2013) in terms of the D-efficiencies and the maximum of the absolute values of the correlation coefficients among the columns of the model matrix. Like the latter, our designs are also *definitive* in the sense that the estimates of all main effects are unbiased with respect to any active second order effects. In addition, they require fewer runs and can be used to study the presence of the second-order effects more efficiently. Examples illustrating the use of our new MLFODs are given.

Optimal Blocked and Split-Plot Designs Ensuring Precise Pure-Error Estimation of the Variance Components P. 57-70

Kalliopi Mylona, Steven G. Gilmour & Peter Goos

Abstract

Textbooks on response surface methodology generally stress the importance of lack-of-fit tests and estimation of pure error. For lack-of-fit tests to be possible and other inference to be unbiased, experiments should allow for pure-error estimation. Therefore, they should involve replicated treatments. While most textbooks focus on lack-of-fit testing in the context of completely randomized designs, many response surface experiments are not completely randomized and require block or split-plot structures. The analysis of data from blocked or split-plot experiments is generally based on a mixed regression model with two variance components instead of one. In this article, we present a novel approach to designing blocked and split-plot experiments which ensures that the two variance components can be efficiently estimated from pure error and guarantees a precise estimation of the response surface model. Our novel approach involves a new Bayesian compound D-optimal design criterion which pays attention to both the variance components and the fixed treatment effects. One part of the compound criterion (the part concerned with the treatment effects) is based on the response surface model of interest, while the other part (which is concerned with pure-error estimates of the variance components) is based on the full treatment model. We demonstrate that our new criterion yields split-plot designs that outperform existing designs from the literature both in terms of the precision of the pure-error estimates and the precision of the estimates of the factor effects.

A New Process Control Chart for Monitoring Short-Range Serially Correlated Data P. 71-83

Peihua Qiu, Wendong Li & Jun Li

Abstract

Abstract–Statistical process control (SPC) charts are critically important for quality control and management in manufacturing industries, environmental monitoring, disease surveillance, and many other applications. Conventional SPC charts are designed for cases when process observations are independent at different observation times. In practice, however, serial data correlation almost always exists in sequential data. It has been well demonstrated in the literature that control charts designed for independent data are unstable for monitoring serially correlated data. Thus, it is important to develop control charts specifically for monitoring serially correlated data. To this end, there is some

existing discussion in the SPC literature. Most existing methods are based on parametric time series modeling and residual monitoring, where the data are often assumed to be normally distributed. In applications, however, the assumed parametric time series model with a given order and the normality assumption are often invalid, resulting in unstable process monitoring. Although there is some nice discussion on robust design of such residual monitoring control charts, the suggested designs can only handle certain special cases well. In this article, we try to make another effort by proposing a novel control chart that makes use of the restarting mechanism of a CUSUM chart and the related spring length concept. Our proposed chart uses observations within the spring length of the current time point and ignores all history data that are beyond the spring length. It does not require any parametric time series model and/or a parametric process distribution. It only requires the assumption that process observation at a given time point is associated with nearby observations and independent of observations that are far away in observation times, which should be reasonable for many applications. Numerical studies show that it performs well in different cases.

A Diagnostic Procedure for High-Dimensional Data Streams via Missed Discovery Rate Control P. 84-100

Wendong Li, Dongdong Xiang, Fugee Tsung & Xiaolong Pu

Abstract

Monitoring complex systems involving high-dimensional data streams (HDS) provides quick real-time detection of abnormal changes of system performance, but accurate and efficient diagnosis of the streams responsible has also become increasingly important in many data-rich statistical process control applications. Existing diagnostic procedures, designed for low/moderate dimensional multivariate process, may miss too much important information in the out-of-control streams with a high signal-to-noise ratio (SNR) or waste too many resources finding useless in-control streams with a low SNR. In addition, these procedures do not differentiate between streams according to their severity. In this article, we formulate the diagnosis problem of HDS as a multiple testing problem and provide a computationally fast diagnostic procedure to control the weighted missed discovery rate (wMDR) at some satisfactory level. The proposed procedure overcomes the limitations of conventional diagnostic procedures by controlling the wMDR and minimizing the expected number of false positives as well. We show theoretically that the proposed procedure is asymptotically valid and optimal in a certain sense. Simulation studies and a real data analysis from a semiconductor manufacturing process show that the proposed procedure works very well in practice.

A Class of Tests for Trend in Time Censored Recurrent Event Data P. 101-115

Jan Terje Kvaløy & Bo Henry Lindqvist

Abstract

Statistical tests for trend in recurrent event data not following a Poisson process are generally constructed for event censored data. However, time censored data are more frequently encountered in practice. In this article, we contribute to filling an important gap in the literature on trend testing by presenting a class of statistical tests for trend in time censored recurrent event data, based on the null hypothesis of a renewal process. The class of tests is constructed by an adaption of a functional central limit theorem for renewal processes. By this approach a number of tests for time censored recurrent event data can be constructed, including among others a version of the classical Lewis–Robinson trend test and an Anderson–Darling type test. The latter test turns out to have attractive properties for general use by having good power properties against both monotonic and nonmonotonic trends. Extensions to situations with several processes are considered. Properties of the tests are studied by simulations and some asymptotic calculations, and the approach is illustrated in data examples.

Tensor Mixed Effects Model With Application to Nanomanufacturing Inspection P. 116-129

Xiaowei Yue, Jin Gyu Park, Zhiyong Liang & Jianjun Shi

Abstract

Raman mapping technique has been used to perform in-line quality inspections of nanomanufacturing processes. In such an application, massive high-dimensional Raman mapping data with mixed effects is generated. In general, fixed effects and random effects in the multi-array Raman data are associated with different quality characteristics such as fabrication consistency, uniformity, and defects. The existing tensor decomposition methods cannot separate mixed effects, and existing mixed effects model can only handle matrix data but not high-dimensional multi-array data. In this article, we propose a tensor mixed effects (TME) model to analyze massive high-dimensional Raman mapping data with complex structure. The proposed TME model can (i) separate fixed effects and random effects in a tensor domain; (ii) explore the correlations along different dimensions; and (iii) realize efficient parameter estimation by a proposed iterative double Flip-Flop algorithm. We also investigate the properties of the TME model, existence and identifiability of parameter estimation. The numerical analysis demonstrates the efficiency and accuracy of the parameter estimation in the TME model. Convergence and asymptotic properties are discussed in the simulation and surrogate data analysis. The case study shows an application of the TME model in quantifying the influence of alignment on carbon nanotubes buckypaper. Moreover, the TME model can be applied to provide potential solutions for a family of tensor data analytics problems with mixed effects.

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