technische universität dortmund

SFB 823

17th Workshop on Quality Improvement Methods

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The cautious use of Bayesian methods in reliability data analyses

Fr 14:10

William Q. Meeker

Iowa State University

The development of theory and application of Monte Carlo Markov Chain methods, vast improvements in computationally capabilities and emerging software alternatives have made it possible for the wide use of Bayesian methods in reliability applications. Bayesian methods, however, remain controversial in Reliability (and other applications) because of the concern about where the needed prior distributions should come from. On the other hand, there are many applications where engineers have solid prior information on certain aspects of their reliability problems based on physics of failure or previous experience with the same failure mechanism (e.g., imprecise knowledge about the activation energy in a temperature-accelerated life test or about the Weibull shape parameter in analysis of fatigue failure data). In such applications, the use of Bayesian methods offers an appropriate compromise between assuming that such quantities are known and assuming that nothing is known. In this work we compare the use of Bayesian methods with the more extreme alternatives based on traditional maximum likelihood methods for a set of examples including the analysis of field-failure data, accelerated life test data, and accelerated degradation test data.

From statistical models for fatigue failure time to shape optimization

Fr 14:55

Hanno Gottschalk

Bergische Universität Wuppertal

The talk surveys recent work on the connection of stochastic failure time models with the field of shape optimization. Starting from a probabilistic model of Low Cycle Fatigue (LCF) involving finite element post-processing along with statistical calibration based on experiments, it is shown that new approaches of shape optimization become feasible using reliability as an objective function. We also calculate shape derivatives and shape flows towards better reliability using the discrete adjoint formalism. This is also extended to multi criteria optimization minimizing the conflicting goals of material consumption and probability of failure.

Gaussian process modeling on a disk. Application to process control in microelectronics

Fr 15:40

Olivier Roustant

École des Mines Saint-Étienne

This talk is motivated by quality control of disks of semiconductor (called wafers) in microelectronics. This task is challenging since the output of interest (e.g. thickness, material concentration) is defined spatially on the disk, whereas measurements are done at a few design points in that disk. Restricting process control to the measurement points can be enough to detect some global problems (e.g. drift deviations) but is often not adequate to detect geometrical defects. To improve quality control, a two-stage "profile" monitoring is usually performed: 1) Modeling stage: to predict the spatial output everywhere from the design points. 2) Control stage: to apply process control on a vector of features extracted from the model. For stage 1, we show how to use spatial approximation / interpolation techniques for disks. We present Zernike polynomials and two kinds of Gaussian processes (or kriging models). We illustrate stage 2 by considering various features, such as model parameters or sensitivity indices.

Monitoring zero inflated Poisson processes: estimated parameter case and extensions

Fr 17:15

Philippe Castagliola

Université de Nantes

Zero-inflated probability models are used to model count data that have an excessive number of zeros. Shewhart-type control charts have been proposed for the monitoring of ZIP (Zero-Inflated Poisson) processes. Usually their performance is evaluated under the assumption of known process parameters. However, in practice, their values are rarely known and they have to be estimated from an in-control historical Phase I sample. In this presentation, we investigate the performance of Shewhart-type control charts for ZIP processes with estimated parameters and propose practical guidelines for the statistical design of the examined charts, when the size of the preliminary sample is predetermined.

We also propose and study a two-parameter modification of the ordinary Poisson distribution that is suitable for the modeling of non-typical count data. This model can be viewed as an extension of the ZIP distribution. We derive the proposed model as a special case of a general one and focus our study on it. Three practical examples illustrate its usefulness. The results show that the proposed model is very flexible in the modeling of various types of count data.

Estimation and prediction for trend-renewal processes

Fr 18:00

Alicja Jokiel-Rokita

Wrocław University of Science and Technology

The trend renewal process (TRP) model was introduced by Lindqvist in [2]. The TRP is defined as a transformed in time renewal process and incorporate both time trend and renewal-type behavior. The most commonly used models for recurrent events such as nonhomogeneous Poisson processes and renewal processes are special cases of TRP's. Inhomogeneous gamma processes, introduced by Berman in [1], are also the TRP's.

In the presentation, we make some review of estimation methods for semiparametric and parametric TRP models. We also propose methods of prediction of the next event time which are preceded by a selection of the best model (in some sense) from a wide class of TRP's.

References

[1] Berman M. (1981). Inhomogeneous and modulated gamma processes. *Biometrika*, 68:143–152.

[2] Lindqvist B. H. (1993). The trend-renewal process, a useful model for repairable systems. Malmö, Sweden. Society in Reliability Engineers, Scandinavian Chapter, Annual Conference.

Industrial data science for quality improvement Sa 9:15

Marco S. Reis

University of Coimbra

The landscape of Quality Improvement is changing as industrial processes evolve, becoming more interconnected (therefore complex), data intensive (with the 5Vs of Big Data), with stronger multiscale elements (both in the time and spatial domains) and non-stationary patterns [1]. These are only a few characteristics that raise considerable challenges when addressing Quality Improvement initiatives following the classical toolkit and workflows that were so successful in the past. I believe they will remain important in the future as well, but is also undeniable that these tools and methods should be upgraded and expanded with the necessary technology and new analysis principles that accommodate the current/future industrial scenarios. In this talk, some of these challenges will be addressed, together with work carried out to address them. In particular, the fields of process monitoring, quality prediction and improvement strategies will be targeted [2].

References

[1] M.S. Reis, R.D. Braatz, L.H. Chiang, Big Data - Challenges and Future Research Directions, Chemical Engineering Progress, Special Issue on Big Data (2016) 46-50.

[2] M.S. Reis, G. Gins, Industrial Process Monitoring in the Big Data/Industry 4.0 Era: From Detection, to Diagnosis, to Prognosis, Processes, 5,35 (2017) 1-16.

Parallelized monitoring of dependent spatiotemporal processes

Sa 10:00

Philipp Otto

Leibniz Universität Hannover

With growing availability of high-resolution spatial data, like high-definition images, 3d point clouds of LIDAR scanners, or communication and sensor networks, it might become challenging to timely detect changes and simultaneously account for spatial interactions. To detect local changes in the mean of isotropic spatiotemporal processes with a locally constraint dependence structure, we propose a monitoring procedure, which can completely be run on parallel processors. This allows for a fast detection of local changes, i.e., only a few spatial locations are affected by the change. Due to parallel computation, high-frequency data could also be monitored. We, therefore, additionally focus on the processing time required to compute the control statistics. Finally, the performance of the charts is analyzed by a series of Monte-Carlo simulation studies.

Equivalence of experimental designs

Sa 11:00

Ulrike Grömping

Beuth Hochschule für Technik (BHT) Berlin

We consider equivalence (=isomorphism) of experimental design plans: two designs are called equivalent or isomorphic, if they can be obtained from each other by

- swaps of columns
- and/or swaps of rows
- and/or *appropriate* relabelings of factor levels.

For the last bullet, the qualifier appropriate introduces a difference between qualitative and quantitative factors: for quantitative factors, relabelings apart from reversing the order among levels (i.e., 1,2,3,4 to 4,3,2,1) may lead to different properties of the resulting designs. Equivalence in terms of quantitative factors is sometimes called geometric isomorphism (see e.g. Cheng and Ye 2004). For qualitative factors, on the other hand, each relabeling of factor levels leads to an isomorphic design, because one could simply re-assign the factor levels accordingly; this type of isomorphism is called combinatorial equivalence. This talk focuses on combinatorial equivalence. It is based on Grömping (2018), and also relates to as-yet unpublished joint work with Roberto Fontana.

Proving equivalence of two designs can be achieved by providing a mapping that transforms one design into the other, and it can be very resource-intensive to find such a mapping. Such a mapping may be needed if one wants to match data from an existing experiment to a design from a software, for a teaching example. For cataloging designs, one would want to only include non-equivalent ones, in order to avoid a waste of space and time when choosing a design from the catalogue. Schoen, Eendebak and Nguyen (2010) provided an algorithm for finding only non-isomorphic orthogonal arrays, and published several resulting designs in a web catalogue as well as a software (Eendebak and Schoen 2010, Eendebak and Vazquez 2019). The software avoids post-hoc checks for equivalence by building up designs along a path, successively extending the non-isomorphic designs from previous steps by a single further column.

When presented with a pair of designs, proving the absence of equivalence requires to show that no suitable mapping between the two designs can be found. There are numerous necessary criteria for combinatorial equivalence: all quality criteria suitable for assessing designs with qualitative factors must be identical for combinatorially equivalent designs. These include generalized word length patterns (GWLPs, Xu and Wu 2001) and more detailed criteria such as projection frequency tables (PFTs, Xu, Chen and Wu 2004), Average R2 frequency tables and Squared Canonical Correlation frequency tables (ARFTs and SCFTs, Grömping 2017). More detailed criteria (like the SCFTs) are better at discovering non-equivalence, but also require more computational resources. Criteria for assessing combinatorial equivalence have to be coding-invariant in two ways: they must not depend on swapping some levels in any design column, and for a given set of levels, they must not depend on a particular coding of a model matrix. Among the above-mentioned criteria, all except SCFTs consider multi-degree-of-freedom effects as a whole (e.g. the 3-factor interaction of a triple of factors with 2, 3, and 4 levels with a single contribution based on all 6 degrees of freedom, or with three contributions from seeing each factor once in the role of the main effect which is confounded by the interaction among the other two factors (for ARFTs)). SCFTs manage to remain coding invariant in spite of considering individual degrees of freedom for the latter approach: they achieve that by basing assessment on canonical correlation analysis of a main effects model matrix in relation to an interaction model matrix.

Fontana, Rapallo and Rogantin (2016) introduced a degree-of-freedom based criterion for symmetric designs (i.e. designs with all factors at the same number of levels) that is easy to calculate and decomposes the GWLP; it is based on the complex coding and is alas not suitable for the assessment of combinatorial equivalence. ICFTs (Grömping 2018) were inspired by this work and provide a degree-of-freedom based approach which is suitable for assessing combinatorial equivalence (but otherwise has no quality interpretation, except that its entries also decompose the GWLP); unfortunately, the effort involved in calculating ICFTs is approximately comparable to that needed for SCFTs, and the information content in terms of combinatorial (in)equivalence also seems to be similar. In joint work with Roberto Fontana, we work on developing an even more detailed resource-intensive criterion (working name PAFTs), which has been able to distinguish some designs that have not been distinguished by any other method known to us (work in progress).

Legend for acronyms:

ARFT	Average R2 frequency table
GWLP	generalized word length pattern
ICFT	Interaction contribution frequency table
PFT	projection frequency table
SCFT	Squared canonical correlation frequency table
PAFT	Permutation aberration frequency table

References

[1] Cheng, S.-W. and Ye, K.Q. (2004). Geometric isomorphism and minimum aberration for factorial designs with quantitative factors. *The Annals of Statistics* **32**, 2168-2185.

[2] Eendebak, P. T. and Schoen, E. D., (2010). Orthogonal Arrays Website. http://www.pietereendebak.nl/oapackage/series.html.

[3] Eendebak, P.T. and Vazquez, A.R. (2019). OApackage: A Python package for generation and analysis of orthogonal arrays, optimal designs and conference designs. *Journal of Open Source Software*, **4** (34), 1097. https://doi.org/10.21105/joss.01097

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[5] Grömping, U. (2017). Frequency tables for the coding invariant quality assessment of factorial designs. *IISE Transactions* **49**, 505-517.

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[7] Schoen, E. D., Eendebak, P. T. and Nguyen, M. V. M. (2010). Complete enumeration of pure-level and mixed-level orthogonal arrays. *Journal of Combinatorial Designs* **18**, 123-140. doi:10.1002/jcd.20236.

[8] Xu, H., Cheng, S.-W. and Wu, C.F.J. (2004). Optimal projective three-level designs for factor screening and interaction detection. *Technometrics* **46**, 280-292.

[9] Xu, H. and Wu, C.F.J. (2001). Generalized minimum aberration for asymmetrical fractional factorial designs [corrected republication of MR1863969]. *The Annals of Statistics* **29**, 1066-1077.

Blocking in multi-stage experiments   Sa 11:45

Rosemary A. Bailey
University of St Andrews

In a multi-stage experiment, the same experimental units are used in each stage but different treatment factors are applied at different stages. Constraints on processing imply that these units must be partitioned into blocks (such as batches or lots) at each stage. However, unlike in the classical situation, the blocks are not inherent, and the designer of the experiment can choose the partition into blocks at each stage. Is it better to align the Stage 2 blocks with the Stage 1 blocks as far as possible or to make them as orthogonal to each other as possible? In either case, how should treatments be assigned?

In the simplest case, the treatment factors applied at each stage can be orthogonal to the blocks in that stage. In other cases, there may be one or more stages in which the treatment factor(s) applied in that stage must have each level applied to whole blocks.

Both of these are comparatively straightforward compared to the case where there is one (or more) stage(s) in which the allocation of the treatments to experimental units must be that of an incomplete-block design.

In the talk, I will develop some general principles for good design, along with methods for evaluating competing designs.

Optimal designs for frequentist model averaging Sa 14:00

Kirsten Schorning
Ruhr-Universität Bochum

We consider the problem of designing experiments for estimating a target parameter in regression analysis when there is uncertainty about the parametric form of the regression function. A new optimality criterion is proposed, which chooses the experimental design to minimise the asymptotic mean squared error of the frequentist model averaging estimate. Necessary conditions for the optimal solution of a locally and Bayesian optimal design problem are established. The results are illustrated in several examples and it is demonstrated that Bayesian optimal designs can yield a reduction of the mean squared error of the model averaging estimator by up to 45%.

Augmenting definitive screening designs

Sa 14:45

John Stufken

Arizona State University

Definitive screening designs (DSDs) are economical 3-level designs that can be used to screen for important factors. Part of the appeal is that DSDs also allow for fitting certain second-order models. Since the number of runs in a DSD is relatively small, to fit a second-order model reliably, the number of active terms must be relatively small. If this condition does not hold, then augmentation of the DSD with additional runs may be needed. If so, immediate questions center on the number of runs to be augmented, and which runs to be augmented. After introducing DSDs and some of their properties, this presentation focuses on considerations to address these questions.

The presentation is in part based on joint work with Abigael Nachtsheim (Arizona State University), Bradley Jones (SAS), and Douglas Montgomery (Arizona State University).

Poster session

Fr 16:45

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Dortmund

- **Computer experiments with both continuous and categorical data**, Dominik Kirchhoff (Fachhochschule Dortmund)
- **Load sharing models with damage accumulation**, Kevin Leckey, Christine H. Müller, Mirko Jakubzik (Technische Universität Dortmund)
- **Modelling and optimisation of an HVOF-process**, Christina Becker-Emden, Sonja Kuhnt (Fachhochschule Dortmund)
- **Numerical statistical fan of a noisy design**, Arkadius Kalka, Sonja Kuhnt (Fachhochschule Dortmund)
- **Ongoing work in SFB Project C2**, Rakhi Singh, Joachim Kunert (Technische Universität Dortmund)
- **Optimal design of inspection times for interval censoring**, Nadja Malevich, Christine H. Müller (Technische Universität Dortmund)