4th Workshop on Quality Improvement Methods at the Universitätskolleg Bommerholz

Abstracts

Part 1: Statistical Methods

Orthogonal arrays -- with or without additional structure and properties

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Orthogonal arrays (OAs) were introduced almost 60 years ago. While they have been used in a variety of applications, to statisticians the primary value of OAs comes from their properties when used in fractional factorial experiments. In more recent years there is a vast literature on OAs that have some additional structure (e.g. product arrays, compound OAs, split-plot designs) or some additional properties (e.g. minimum aberration, estimation capacity). In this presentation we will give a selected overview of the current state of knowledge of OAs with special attention to some of the aforementioned developments in recent years.

Some statistical properties of multicriteria-optimization using Derringer-Suich desirabilities

Detlef Steuer
Helmut-Schmidt University of Hamburg, University of the Federal Armed Forces

The biggest shortcoming of the traditional using of desirability functions is the deliberate ignorance of random nature of desirabilities. In this talk some benefits of looking on desirabilities as random variates are given. It is shown, that improvements for the overall product can be expected if normal desirabilities are replaced by what we call realistic desirabilities. Realistic desirabilities concentrate on one feature of the distribution of a desirability function, namely on the expected value for a given factor setting x.
Furthermore it is shown, that the distribution function for the Derringer-Suich can be calculated. For weight 1 the distribution can be given explicitly, for other weights it is shown how to use a simple generalisation of the Derringer-Suich functions to approximate the actual distribution. Using these results we have simple access to failure rate, expected value or any other feature we´re especially interested in. A few concluding remarks will be given on the distribution of the index.

Part 2: Current work at the SFB 475

Spiralling in BTA deep-hole drilling -- Models of varying frequencies

Nils Raabe
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One serious problem in deep-hole drilling is the formation of a dynamic disturbance called spiralling which causes holes with several lobes. Since such lobes are a severe impairment of the bore hole the formation of spiralling has to be prevented. Gessesse et al. (1994) explain spiralling by the coincidence of bending modes and multiples of the rotary frequency. This they derive from an elaborate finite elements model of the process. In our work we show that the time variation of the frequencies of the bending moment may be estimated based on spectogram data e.g. of the acceleration signal. Therefore first frequency bands are determined by bivariate clustering. The estimation of the time relation is essentially done by quadratic regression on time. The results are linked to the free parameters of a system of differential equations, which describes the dynamics of the boring bar. By this procedure a significant simplification of the usage of the explanation given by Gessesse et al. can be obtained, because the finite elements model has to be correctly modified for each machine and tool assembly while the statistical method uses observable measurements. Estimating the variation of the frequencies as good as possible opens up the opportunity to prevent spiralling on-line by e.g. changing the rotary frequency.

An Efficient Optimization Approach for Sheet Metal Spinning

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Due to technological advance in science, the complexity of processes under investigation increased continuously in recent years. For example in mechanical engineering, there are often highly nonlinear input-output relationships combined with a large number of unknown constraints restricting the space of feasible design points. Sheet metal spinning is one example of such a production process. The high process complexity imposes increased demands with respect to the optimization procedures used. Although Response Surface Methodology (RSM) is a powerful statistical tool for process optimization, its use is limited in these situations. The present paper presents a new adaptive sequential optimization procedure (ASOP) to cope with these problems, and hence guarantee an efficient optimization of complex processes. The approach is exemplified by optimizing the sheet metal spinning process. These optimization results are compared to the ones obtained by using the classical RSM.

Part 3: Experimental design

Combining categorical design variables and spectroscopic measurements in process modelling – general principles

Tormod Næs
Matforsk, Ås and University of Oslo

Combining categorical design variables and spectroscopic measurements in process modelling – examples

Kjetil Jørgensen
Matforsk, Ås

Experimental designs are often used for investigating properties of industrial production processes. Typical goals are better understanding, prediction and optimisation. In some important cases additional information may be available about raw materials and/or about process status during processing. This type of information may typically be acquired by spectroscopic instruments like for instance NIR or FTIR analysers. These instruments may give hundreds, sometimes thousands of highly correlated measurements. The problem is then to combine all these variables with the categorical variables in the design. There are many possibilities available for this, ranging from classical PLS regression to more advanced techniques based on so-called multi-block PLS methodology. The present paper will discuss an alternative approach to the modelling of this type of data. The methodology is based on combining PLS' ability to model highly collinear spectral data with the ability of LS to model design variables in a straightforward and simple way. A number of distinctions between different situations will be made and methodology for the various situations will be outlined. The methodology will be illustrated by examples.

Part 4: Evolutionary Multivariate Optimization

Multiobjective Evolutionary Algorithms - A practical presentation of the state-of-the-art with examples from mechanical engineering

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The term evolutionary algorithm (EA) comprises different classes of stochastically driven optimization techniques such as the evolution strategy, genetic algorithms, evolutionary programming, and genetic programming. Generally, these algorithms are known to be good optimization techniques for solving difficult one-criterion problems. Since the last five years a new generation of EA is getting into the focus of interest of computer scientists as well as of engineers: multiobjective evolutionary algorithms (MOEA).
The presentation gives an introduction to continuous multiobjective optimization, typical test problems, measuring techniques for Pareto-front-qualities, a short description on EA and an example of an important MOEA – the NSGA II. The problem of finding optimal designs for mold temperature control systems – a practical problem from mechanical engineering – is used to illustrate the power and the weakness of MOEA applications.

Evolutionary Multi-criteria Optimization for Robust Designs

Jürgen Branke
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Evolutionary algorithms (EAs) are general-purpose optimization heuristics inspired by the principles of natural evolution. Since they always work with a population of solution candidates, they are particularly suited for multi-criteria optimization, simultaneously searching for several alternative solutions with different trade-offs. At the example of the two criteria "expected quality" and "robustness" it will be demonstrated how multi-criteria evolutionary algorithms can be used for robust design optimization. In order to save computation time, the two optimization criteria are estimated based on local approximation models generated during the run. Finally, a modification of the algorithm is proposed that focuses the search on the solutions with the presumably most interesting trade-offs.

Part 5: Applications in Industry

Robustness assessment of exhaust manifolds

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Joint work with Frank Gerhorst, Master Black Belt, Ford Motor Company, Cologne, and David Lloyd-Thomas, responsible Black Belt, Ford Motor Company, Dunton.

Advanced engine design today requires exhaust manifolds that survive higher thermal loads while enabling after treatment systems like catalysts to work optimally. This is a multi-objective problem. We show how design of experiments in connection with CAE has been used to optimise both of these in the framework of a Design-for-6-Sigma project. The CAE model has been applied to an orthogonal column latin hypercube design according to Ye (1998), and non-parametric interpolation has been achieved with a Gaussian Stochastic Kriging (GSK) algorithm. The multi-objective optimisation has been conducted based on graphical output by the interpolation routine, using a panel of experts who picked candidate optima from Pareto frontiers. For the resulting optima, robustness to part-to-part variation was also a very relevant criterion for selection of the final optimum. The team is very confident that the approach used here will increase robustness not only of the exhaust for the one specific project but even of the design process for exhausts in general.

Limit Inflators – How DOE and Monte-Carlo can be applied to build inflators which represent long-term production variability

Anja Schleppe
Autoliv, Dachau

Today, there is a procedure existing on how airbag plants define and build limit inflators. A limit inflator is an inflator which is built in an artificial way to represent long-term production variability. The limit inflator is tested in airbag deployment tests to simulate extreme but realistic conditions of inflator performance. The airbag needs to fulfil customer and law requirements even when tested with limit inflators. In this project, a combination of DOE and Monte-Carlo was used to come up with a more sophisticated limit inflator definition.

Measurement agreement

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Industry applies precise, but sometimes expensive measurements to judge product quality and process stability. It is often well appreciated that precise and expensive measurements are replaced by cheap and good-enough measurements, but what is good enough? An interesting example is the measurement of the concentration of analytes in chemical substances, where precise chemical measurements are replaced by less precise spectral measurements. The

question that naturally arises is about *measurement agreement*: how well do two methods agree in their measurement results? Note that this question is usually not answered by a regression analysis or by computing a correlation coefficient. The equivalence of measurement methods may be well defined, however the deviation between them can exist in many ways. As a consequence, many measures for (dis)-agreement of measurement methods are reported in statistical literature. However, the value of such a measure to answer a specific industrial *research question* is not always clear.

In our view we start with industrial research questions. A relevant question at the above example is to decide on product quality: is the product good or bad? The less precise spectral measurements should give (about) the same decision results as the precise chemical measurements, but what does this mean for the quality requirements on the spectra? We apply a flexible model for bivariate measurements with well interpretable parameters to translate research questions into requirements and hypotheses on model parameters. Finally, we test these hypotheses and find model parameter estimates. Two research questions will be worked out at the presentation.