5th Workshop on Quality Improvement Methods
at the Universitätskolleg Bommerholz
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# Abstracts

## Session 1: Process Control

### Using Control-Charts to drive the process improvement in a company

*Winfried Theis, Cologne*

After implementing an enormously improved process at one of our clients the question arose, how to transform this improvement into a steady process and drive the company to even more improvements. The first step was to implement a regular meeting of all parties involved in the process and make the success visible within the working area. Within these meetings all aspects of the highly complex process with many sub-processes are discussed and improvements are searched for. A statistician of course thinks first about a control chart to ensure the steadyness of the process.
Since no true "in-control" process can be achieved because of the highly complex structure of the problem at hand it has to be assumed (and further observation does manifest this) that we have an in-control state.
For the second task a special interpretation was asked for:
Since the target shall be increased the upper control limit of a CUSUM chart triggers a control box which allows to increment the target-value. Such an increment then triggers a re-calculation of the necessary parameters.
We present an EXCEL-Tool which implements this idea and our experiences with this idea.

### A New Nonparametric Multivariate Exponentially Weighted Moving

*Amor Messaoud, Dortmund*

In this work, we propose a new nonparametric exponentially weighted moving average (EWMA) control chart for multivariate processes. It is based on data depth. Nonparametric or distribution-free control charts are useful in statistical process control when there is limited knowledge about the underlying process distribution. The proposed control chart is a generalization of the univariate nonparametric EWMA for individual observations proposed by Hackl and Ledolter (1992). Its in-control and out-of-control performances are studied and compared to existing control charts. It is used to develop a real-time monitoring strategy for the early and reliable detection of chatter vibration in a deep hole drilling process. Deep hole drilling methods are used for producing holes with a high length-to-diameter ratio, good surface finish and straightness. For drilling holes with a diameter of 20 mm and above, the

BTA (Boring and Trepanning Association) deep hole machining principle is usually employed. The process is subject to dynamic disturbances usually classified as either chatter vibration or spiraling. Previous work showed that the eigenfrequencies of the boring bar of the BTA tool play an important role in the discrimination between stable operation, chatter and spiraling. Thus, we used the proposed control chart to monitor the amplitudes of the relevant frequencies simulataneously, using a model obtained from engineering knowledge. The results showed that the proposed monitoring strategy can detect chatter vibration and that some alarm signals are related to changing physical conditions of the process.

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Hackl, P. and Ledolter, J. (1992). A New Nonparametric Quality Control Technique. Communications in Statistics-Simulation and Computation, 21, pp. 423–443.

## Chatter detection by spectral analysis of structure-borne sound

*Anita Busch, Dortmund*

Single-lip deep-hole drilling is susceptible to dynamic disturbances, like tool chatter, which possibly result in poor drill-hole quality and affect tool and machine life. We consider the signal of the structure-borne sound of the machine as a suitable choice for the detection of chatter vibration in the process. A method for the detection of spectral changes in the structure-borne sound signal is developed. This control chart is a modified version of the MEWMA chart and is based on values of the SLEX (smooth localized complex exponential) -periodograms that are calculated in overlapping windows over time. The SLEX-spectrogram constitutes a time and frequency localized representation of the spectrum. Instead of the Mahalanobis distance, spectral distortion measures are used in the control chart. A comparison of different measures is based on an empirical investigation. A further modification step is necessary to ensure that small changes in the spectrum of signals from processes without chatter vibration are ignored.

# Session 2: Consulting

## Data Quality and Data Pre-processing in Data Mining

*Andrea Ahlemeyer-Stubbe, Gengenbach*

Most companies have plenty of Data but very little Information. That's why you must place your Data into a structure and context that actually answers your business questions.

Doing this allows you to convert customer's multiple touch point Data into the information you need for successful Data Mining.

During the Data Mining Process Data Preparation use between 60% and 95% of time and resources.

How the Data is aggregated and transformed has a great influence on the possible Data Mining Results.

This talk gives you an overview on basic Data Warehouse and Data Mart technologies under Data Mining aspects.

You learn about typical aggregations and transformation to support different Data Mining Methods.

## Loss of Robustness in a Product Function after a Production Change was made – An Example for a Root Cause Search

*Anja Schleppe, Munich*

An electrical failure mode caused warning lights flashing in cars. Parts were replaced in service stations, and root cause analysis was started. The team could not reproduce the failure mode because returned parts never failed a second time. After 3 months of investigations, the root cause had not been found. This talk is about how the team was coached, what main steps were taken, and what soft skills were needed, to finally solve the problem.

# Session 3: Design of Experiments

## Designing Factorial Experiments with Binary Response

*David Steinberg, Tel Aviv*

Many experiments involve binary responses. Yet we know little about how to design efficient experiments for such experiments and what we know is largely limited to one-factor designs. For example, we will show that classical two-level factorial designs can be very inefficient in binary response experiments. An important, and problematic, aspect is that good designs depend on knowledge of the unknown model parameters. We will present some effective, and practical, algorithms for designing experiments that achieve a high degree of robustness to initial assumptions about the model parameters. Our main algorithm takes advantage of a fast scheme for generating locally optimal designs together with a clustering procedure. We illustrate the performance of the algorithm on several applications.

## D-optimal Designs with Partial Inclusions

*Theo Wember, Datteln*

D-optimal designs are widely used in industrial applications for process optimization. The usual algorithms use an exchange strategy on the basis of a candidate set. Constraints in design space and inclusions are supported by state of the art software. However, in some situations special constraints have to be imposed which cannot be formulated in terms of design space. They occur in multi process optimization very common in semiconductor applications or in problems with a clear distinction between “Hardware” and “Software” factors being very common in automotive applications where sample parts have to be made for DoEs. The goal is to minimize the necessary number of variants for expensive Hardware factors. To solve such problems two strategies can be applied. If Hardware variants (e.g. sample parts) can be used for several trials a slight modification of the candidate set usually being a fullfactorial design with appropriate number of gridpoints is successful. This set itself is restricted to a D-optimal design for the Hardware factors. In case one Hardware variant can be used only once (e.g. a Wafer in semiconductor frontend) the candidate set is not suited to reflect the desired restriction. To solve this problem the concept of inclusions has to be generalized. The exchange algorithm has to be extended to partial inclusions. Normal inclusions can't be exchanged by the algorithm. Partial inclusions are treated the same for the Hardware factors. Only the Software factors settings are in reach of the exchange algorithm.

## Joint Optimisation Plots for Multiple Responses

*Sonja Kuhnt, Dortmund*

Off-line quality control prior to the actual manufacturing includes in many applications the analysis and optimisation of multiple responses. So far, existing methods usually require some kind of weighting of the responses, for instance by costs or desirability. Particularly at the design stage, such information is often not available. We will present an alternative strategy of robust parameter design for multiple responses. For each element of a sequence of possible weights assigned to the individual responses, parameter settings are determined, which minimise the estimated mean of a multivariate loss function. The effect of different weighting is displayed in so-called joint optimisation plots in terms of predicted response means and variances. The engineer can thereby gain valuable insight into the production process and decide on the most sensible parameter setting. We will discuss the use of joint optimisation plots for two and more responses and extensions to discrete responses. The proposed method is applied to data from high-pressure sheet metal hydroforming.

# Session 4: Modelling

## A Revised Neurobiologically Inspired Model of the Human Cochlea and an Attached Auditory Image Processing Network

*Tamas Harczos, Budapest*

Modern auditory implants are undoubtedly the most successful prostheses ever. Yet, current cochlear implants do not truly mimic the human auditory system. A neurophysiologically parameterised auditory model will be presented, which could substantially enhance, or even substitute, current "quick and dirty" calculation methods. One way we evaluated the model was to attach an experimental vowel recognizer. Many pattern recognition problems can be solved by mapping the input data into an n-dimensional feature space in which a vector indicates a set of attributes. One powerful pattern recognition method is the Hough-transform, which is usually applied to detect specific curves or shapes in digital pictures. Here, the Hough-
transform is applied to the time series output data of the auditory model, in which both frequency and phase information is partly preserved. Practical vowel recognition of different speakers with the help of this transform is investigated and the findings are discussed.

## Statistical Modelling of Unbalanced Laundry in Washing machines

*Dirk Surmann, Gütersloh*

The talk gives a look at the distribution of the laundry inside a washing machine during the spin cycle. The laundry inside the drum gets a random place on the barrier of the drum at the beginning of the spin cycle. Due to this fact, the laundry is heterogenic distributed inside the drum and results in an unbalance of the drum. Through the unbalance, the tube containing the drum vibrates in the container of the washing machine, and affects other units inside the container. If the vibrations get too high, the tube may strike other units around the tube and thus cause damages of the washing machine. To obtain a better knowledge about the situations of too high unbalances, a description of the unbalance distribution is interesting.
We first show a method to describe the complex situation inside the drum with one virtual unbalanced mass and a corresponding virtual position inside the drum. In an initial approach the distribution of the unbalance is derived in a simplified two-dimensional situation . It is a special Weibull distribution. To estimate the two parameters of the Weibull distribution, even in situations with sample sizes of about 10, two methods of parameter- and interval-estimation are shown in the thesis.
Finally, a method to simulate unbalances is shown. This is an interesting part, because the generation of real unbalances is expensive. By contrast a simulation once fitted to some real unbalances can generate as many virtual unbalances as needed. The simulation uses Gaussian Markov Random Fields to lay an altitude map over the barrier of the drum. This map is summarised to one virtual mass and position to get a simulated virtual unbalance. A comparison with the distributions from the real unbalances shows that the simulation fits reality in an adequate way.

# Session 5: Optimization of Processes

## Issues in the Integration of Statistical Process Control and Automatic Control

*Alessandro Di Bucchianico, Eindhoven*

Classical Statistical Process Control (SPC) assumes that observations are independent. However, in many industrial processors devices are implemented that automatically try to keep process characteristics on target. Standard control charts cannot be used here, since automatic control heavily distorts the independence assumption. Apart from this technical point, there is also an important methodological issue. Automatic control (APC) and SPC have different philosophies, since they are based on different models. APC is based on the assumption that processes continually wander, and hence must be adjusted continually. SPC, however, is based on the assumption that when so-called special causes are not present, the process does not wander and thus needs to be left alone in order to avoid increasing process variance (cf. Deming's famous funnel experiment). We will give an overview of approaches in the literature to reconcile these two approaches, with special emphasis on the following issues.
Since SPC and APC have different philosophies, they also have performance measures. We will discuss some basic SPC-APC configurations and the implications on appropriate performance measures. Connected to this is the development of specialized control charts for

specific out-of-control situations caused by automatic controllers. If time permits, we will illustrate some issues in a stylized case study, where we also show the potential of modelling processes using Petri nets.

## A Response Surface Approach to Tolerance Design

*Jan Engel, Eindhoven*

In spite of Taguchi's robust parameter design, tolerance design is still important at the design stage of products and processes. Taguchi's proposal and related methods for tolerance design, however, do not efficiently use the information that can be obtained from the parameter design experiment. In this paper, we introduce a new method for tolerance design based on the response surface approach to parameter design. It is a flexible method since non-normal distributions of the noise factors and the quality characteristic are allowed. Moreover, it is unnecessary to perform a new physical experiment. Essentially, tolerances of noise factors are maximized, subject to constraints to ensure that the mean value of the quality characteristic remains on target and the fraction nonconforming is below a pre-specified maximum. Some aspects of model uncertainty are discussed and the method is illustrated by means of an example.

# Session 6: Miscellaneous Topics

## The Quality of Samples in Diagnostic Studies

*Ursula Garczarek, Penzberg*

Abstract: to follow.

## Decomposing the response variance in linear regression

*Ulrike Grömping, Berlin*

A typical question in regression analysis of observational data (e.g. customer satisfaction data) is: "How can the explanatory power of the model be decomposed among the different regressors?". Since the most familiar metric for explanatory power is model R2, the desired answer is a decomposition of R2 or – equivalently in terms of relative importance – a decomposition of the total model sum of squares. It is well-known that such a decomposition is unique for uncorrelated regressors only, while the decomposition of the model sum of squares is order-dependent in case of correlated regressors.
In observational studies, regressors are typically correlated so that a unique decomposition of the model R2 poses a challenge. Lindeman, Merenda and Gold (1980, henceforth LMG) and Kruskal (1987) propose to simply average decompositions over all orderings – a proposal that has been followed increasingly often recently because powerful computers are nowadays available to applied researchers from many fields. LMG's proposal does have a game-theoretic justification as the so-called Shapley value (Shapley, 1953; Myerson, 1991;

Lipovetsky and Conklin, 2001). In spite of its being frequently used – in the absence of alternatives – the behavior of the thus-obtained decompositions is not very well-understood and does have some drawbacks (which may be one of the reasons that it has not become a standard methodology). There is a recent alternative suggestion by Feldman (2005) who proposes to use the game-theoretic proportional value (Ortmann, 2000) instead of the game-theoretic Shapley value for decomposing the response variance. The concept of the proportional value does have an interesting advantage over the Shapley value for this application, which comes at the price of a higher variability in the estimates and higher computing demands.

This talk discusses the logic behind variance decomposition in linear regression with random regressors – which is the adequate model for observational studies. The properties of the currently available estimators of variance shares are discussed, computation issues are briefly covered, and application of the methodology is illustrated with a customer satisfaction example.

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## Sequential Design of Computer Experiments to Determine Constrained Optimum

*Thomas Santner, Columbus*

In the last 10-15 years, an increasing number of phenomenon that could previously be studied using only physical experiments, can now be investigated using ``computer experiments.'' Advances in the mathematical modeling of many physical processes, in algorithms for solving these mathematical systems, and in computer speeds have combined to create many instances of (black-box) deterministic computer codes that produce outputs, y(x), given an arbitrary set of inputs. Given training data, i.e., a set of inputs {x_i} and the corresponding {y(x_i)}, the goal of a computer experiment can range from the prediction of the y(x) surface at a `new' set of input sites to that of locating the global optimum of y(x). This talk will describe the sequential design of a computer experiment, i.e., the sequential choice of a set of input sites, when the objective is to determine the global optimum of a linear function of y(x) for the frequently occuring case where there are two types of input variables: ``manufacturing'' (control) variables, $x_c$, and ``environmental'' (noise) variables, $x_e$. For example, in engineering applications, control variables are determined by the product engineer and environmental variables are determined by field conditions. The designs are based on a

Bayesian approach in which the the prior information about $y(.)$ is modeled as a draw from a stationary Gaussian stochastic process with parametric correlation function. The idea of the method is to compute the posterior expected ``improvement" over the current optimum for each untested site; the design selects the next site to maximize theexpected improvement. The procedure is illustrated with some simple examples. This is joint work with Brian J. Williams and William I. Notz.