Abstracts

Robust Statistical Process Monitoring of Resistance Spot Welding Profiles

arXiv

Christian Capezza, Fabio Centofanti, Antonio Lepore, Biagio Palumbo

Dept. Industrial Engineering, U Naples Federico II, Naples, Italy, christian.capezza@unina.it, fabio.centofanti@unina.it, antonio.lepore@unina.it, biagio.palumbo@unina.it

The quality of a resistance spot welding (RSW) process in the automotive industry is critical to guarantee the structural integrity and solidity of welded assemblies in each vehicle. Among online measurements of RSW process parameters, the dynamic resistance curves are recognized as the full technological signatures of the metallurgical development of a spot weld and, thus, can be used as an informative proxy of the quality of a finished sub-assembly. In classical statistical process monitoring (SPM) applications the Phase I sample is assumed to come from an in-control process, which is however not always valid, especially when the monitoring char- acteristic for each item/case is a vector of profiles, i.e., a multivariate functional quality characteristic. As is known, control charts are very sensitive to the presence of outlying observations in Phase I, which can lead to inflated control limits and reduced power to detect process changes in Phase II. In the multivariate functional data setting, this issue is exacerbated by the curse of dimensionality and motivates the use of monitoring frameworks that are robust to the presence of outliers. Traditional multivariate robust estimators are affected by the problem of the propagation of outliers and may fail under an independent contamination model such as cellwise outliers (i.e., contamination in each variable is independent of the other variables). When the dimensionality of the data is high, the fraction of perfectly observed cases can be in fact very small.

We propose a new framework for the SPM of multivariate profiles that is capable of mitigating the presence of cellwise outliers. The performance over existing methods and the practical applicability are assessed along with the aforementioned motivating industrial case study and a wide Monte Carlo simulation, respectively.

Structural Health Monitoring with Functional Data: Two Case Studies from Highway Bridges ✌

Philipp Wittenberg, Sven Knoth and Jan Gertheiss

Dept. Mathematics & Statistics, Helmut Schmidt U Hamburg, Germany, pwitten@hsu-hh.de, knoth@hsu-hh.de, jan.gertheiss@hsu-hh.de

Structural Health Monitoring (SHM) is increasingly used in civil engineering. One of its main purposes is to detect and assess changes in built structure conditions to reduce possible maintenance downtime. Ideally, this process should be automated and implemented in real-time. Recent advances in sensor technology facilitate data collection and process automation, resulting in massive data streams. Functional data analysis (FDA) can be used to model and aggregate the data obtained transparently and interpretably. In two real-world case studies of bridges in Germany and Belgium, this paper demonstrates how a function-on-function regression approach, combined with profile monitoring, can be applied to SHM data to adjust sensor outputs for environmental-induced variation and detect changes in construction. Specifically, we consider the R

package `funcharts` and discuss some challenges when using this software on real-world SHM data. For instance, we show that pre-processing/smoothing of the initial data can improve and extend its usability.

Graph Laplacian Based Smooth Sparse Decomposition for Monitoring of Streaming Manifolds

Qian Wang, Kamran Paynabar

H. Milton Stewart School Industrial & Systems Engineering, Georgia Institute of Technology Atlanta, GA, USA, qwang435@gatech.edu, kamran.paynabar@isye.gatech.edu

In many applications in manufacturing and healthcare, quality characteristics are in form of manifolds. However, existing process monitoring methods fail to fully utilize the information of manifold streams due to their non-Euclidean global structure, high dimensionality, spatio-temporal correlation, and nonstationarity. To fill this gap, we propose a novel Graph Laplacian based smooth sparse decomposition (GL-SSD) for monitoring of manifold data streams. GL-SSD combines Autoencoders and Graph Laplacian to model the smooth spatio-temporal mean and separate it from sparse anomalies identified by applying L1 regularization. Following the identification of anomalous regions, their location information is aggregated into a maximal local statistic for rapid detection of process changes. The performance of the proposed method is evaluated using simulations and a case study. The results demonstrate its advantage over the benchmarks in terms of detection time, anomaly localization and trend estimation.

Individual-Moving Range (IMR) Control Charts — another look utilizing accurate numerical algorithms

Sven Knoth

Dept. Mathematics & Statistics, Helmut Schmidt U Hamburg, Germany, knoth@hsu-hh.de

Given individual observations instead of samples, the IMR control chart is a classical proposal in both SQC books and ISO standards (e. g., ISO 7870-2 whose revision is under way) for monitoring level and scale. Simple rules are given for setting the limits. However, it is more or less known that the MR limits are misplaced. There are some early accurate numerical (zero-state) Average Run Length (ARL) results by Crowder in 1987 already! However, they are not flawless. Another, accurate algorithm is proposed. Moreover, there was quite some discussion of IMR charts in the 199x, cf. to Roes et al. (1993), Rigdon et al. (1994), Amin and Ethridge (1998), which suggests that IMR charts are rather ineffectual tools. Later, Acosta-Mejía and Pignatiello (2000) came up with a single MR chart for monitoring scale alone and made some mistakes while calculating the ARL. We provide the whole numerical package for IMR and MR control charts including lower and two-sided limits designs (Crowder dealt with upper ones only). Eventually, we present some conclusions about whether and how IMR (and only MR) control charts should be applied. We should mention that the data form an independent series of normally distributed random variables.

References

1. Acosta-Mejía & Pignatiello (2000). "Monitoring Process Dispersion without Subgrouping". *Journal of Quality Technology*, 32(2), 89–102.

2. Amin & Ethridge (1998). "A Note on Individual and Moving Range Control Charts". *Journal of Quality Technology*, 30(1), 70–74.

3. Crowder (1987a). "Computation of ARL for Combined Individual Measurement and Moving Range Charts". *Journal of Quality Technology*, 19(2), 98–102.

4. Crowder (1987b). "A Program for the Computation of ARL for Combined Individual Measurement and Moving Range Charts". *Journal of Quality Technology*, 19(2), 103–106.

5. Rigdon, Cruthis & Champ (1994). "Design Strategies for Individuals and Moving Range Control Charts". *Journal of Quality Technology*, 26(4), 274–287.

6. Roes, Does & Schurink, Y. (1993). "Shewhart-Type Control Charts for Individual Observations". *Journal of Quality Technology*, 25(3), 188–198.

Comparing the MEWMA and the double MEWMA Control Charts Using the Criterion of First to Signal ✌

Steven E. Rigdon

College Public Health & Social Justice, Saint Louis U, St. Louis, MO, USA, steve.rigdon@slu.edu

The double exponentially weighted moving average (dEWMA) chart has been proposed as an alternative to the usual EWMA chart to detect small to moderate shifts. The dEWMA chart involves smoothing the data with an EWMA with parameter r_1, and then smoothing these smoothed values with smoothing parameter r_2 . We investigate the efficiency of the dEWMA chart compared to the univariate EWMA chart. We also consider the problem of selecting optimal values for the smoothing constants r_1 and r_2.

A Change-Point-Detection Chart for Detecting Process Mean Drifts with an Application for Monitoring the Shape of the Salton Sea ✌

Fan Yi, Xiulin Xie, Peihua Qiu

Dept. Statistics, U Idaho, Moscow, ID, USA, yifan@ufl.edu; Dept. Statistics, Florida State U, Tallahassee, FL, USA, xx23d@fsu.edu; Dept. Biostatistics, U Florida, Gainesville, FL, USA, pqiu@ufl.edu

The Salton Sea is a shallow inland lake located in the southeastern border of California. Climate change and decreasing inflowing water have caused its elevation to drop gradually and more lakebed to expose. The exposed lakebed is a significant source of dust emissions and particulate matters, consequently has a great impact on the health of nearby residents. To monitor the gradual shrinkage of the Salton Sea, this paper develops a change-point-detection chart for detecting process mean drifts. The proposed chart is based on the generalized likelihood ratio statistic with the unknown drift size estimated by an exponentially weighted least square regression procedure. Numerical studies show that it is effective for detecting process mean drafts. Application of this method to monitoring the gradual shrinkage of the Salton Sea using the observed Landsat images of the Salton Sea region is discussed in detail.

Monitoring the Value at Risk over time in Finance ✌

Manuel Cabral Morais, Yarema Okhrin and Wolfgang Schmid

Dept. Mathematics & CEMAT, Instituto Superior Técnico, U Lisboa, Portugal, maj@math.ist.utl.pt; Faculty Business & Economics, U Augsburg, Germany, yarema.okhrin@wiwi.uni-augsburg.de; Dept. Statistics, European University Viadrina, Frankfurt (Oder), Germany, schmid@europa-uni.de

The value-at-risk (VaR) has become the standard market risk measure since the 1980s and regulators have traditionally used VaR to calculate the capital required for banks to keep.

On the one hand, autoregressive moving average (ARMA) models with generalized autoregressive conditionally heteroscedastic (GARCH) innovations, also termed ARMA-GARCH, have proved to be adequate to describe financial time series that tend not to operate under the assumption of constant conditional variance. On the other hand, control charts have been thoroughly used to detect relevant structural deviations in the process underlying a financial time series.

In this paper, we propose a novel chart for monitoring the VaR of financial assets assuming that the returns follow a general ARMA-GARCH process. The suggested approach helps investors detect structural breaks in the riskiness of their positions; it also assists them in adjusting their portfolios to comply with regulatory require- ments. We provide gripping illustrations showing that this chart has the potential to play a crucial role in the swift detection of structural changes in ARMA-GARCH processes and additionally leads to economically profitable investment strategies.

The Sequential Normal Scores Approximation as a Bridge Between Parametric and Nonparametric Statistical Process Monitoring ✌

Alvaro E. Cordero-Franco, Gerardo Pérez-Arriaga, Víctor G. Tercero-Gómez

Facultad de Ciencias Físico Matemáticas, U Autónoma de Nuevo León, San Nicolás de los Garza, Mexico, alvaro.corderofr@uanl.edu.mx; gerardo.perezarg@uanl.edu.mx; School Engineering & Sciences, Tecnologico de Monterrey, Monterrey, Mexico, victor.tercero@tec.mx

Emphasis in power had led to the creation of increasingly complex, and even doubtful, approaches in nonparametric process monitoring research. A proper method is as useful as it is likely to be used. Computational complexity, design limitations, and reduced interpretability, are common barriers practitioners face when choosing a chart. Sequential normal scores (SNS) transformation, a nonparametric sequential linear rank transformation where only the most recent observations are ranked and transformed into independent normal scores, offers a solution that alleviates some of these problems by extending the use of methods designed for independent and normal observations. Alternatives using normal scores show power levels comparable to the best tradition of rank transformation methods when in-control behavior is matched. The normal approximation reduces the need to rely on special lookup tables and case-by-case numerical calibrations. By avoiding re-ranking, computational complexity is reduced. Finally, as bonus, interpretation is facilitated by using a Gaussian reference. With the natural updating capabilities of SNS, novel approaches such as cautions learning with guaranteed performance are readily available for practitioners with no special set up required but a pre-processing transformation. Results show robustness to distribution with power equivalent to parametric counterparts when assumptions hold.

Healthcare and Public Health Monitoring and Management

Kwok-Leung Tsui

Grado Dept. Industrial & Systems Engineering, Virginia Polytechnic Institute and State U, Blacksburg, VA, USA, kltsui@vt.edu

Due to the advancement of computation power, sensor technologies, and data collection tools, the research on healthcare and public health monitoring and management has been evolved over the past several decades under different names among various application domains, such as statistical process control (SPC), process monitoring, health surveillance, prognostics and health management (PHM), personalized medicine, etc. There are tremendous opportunities in interdisciplinary research on health monitoring and management through integration of SPC, system informatics, data analytics, PHM, and personalized health management. In this talk we will present our views and experiences in the related research. In particular, we will focus on research on healthcare and public health surveillance and forecasting.

On design of early warning systems based on sensor data

Emmanuel Yashchin

IBM, Thomas J. Watson Research Ctr., Yorktown Heights, USA, yashchi@us.ibm.com

We will discuss situations where initiating an early warning system (EWS) is necessary for an operation or a piece of equipment based on a very limited amount of sensor data. Such situations often occur in applications involving infrastructure health monitoring, and data limitations may result from a lack of information about failures, data retention policies, insufficient documentation on maintenance, or systemic data quality issues. A consultant tasked with initiating an early warning system will need to overcome several hurdles, including identifying data features that can be reliably used in the initial version of the EWS and developing a plan for its future expansion. In this process, it is essential to take advantage not only of the available data but also of the existing engineering knowledge, which can come in various forms. In the paper, we present a sequence of steps that are useful for establishing the degree of feasibility and are likely to lead to an EWS design that is acceptable to the customer. We illustrate the methodology using an example of a water pump health monitoring problem recently offered for the Kaggle data science community.

Federated analytics for generalized tensor regression

Mostafa Reisi Gahrooei

Dept. Industrial & Systems Engineering, U Florida, Gainesville, FL, USA, mreisigahrooei@ufl.edu

Data privacy concerns have been exacerbated in recent years and drove the demand to store and analyze data at the edge of networks rather than share it with a centralized server. Federated learning frameworks have been introduced as a solution to these concerns. These frameworks allow local clients to learn local models and collaborate with others to develop a more generalizable aggregated model while handling data privacy issues. At the same time, complex systems are generating more and more high-dimensional data for which tensor analysis showed promising results by capturing complex correlation structures of data. In this paper, we propose a federated generalized

scalar-on-tensor regression framework where multiple local tensor models are learned at the edge, and their parameters are shared with and updated by an aggregator. Experiments on synthetic data sets and two real-world data sets from agriculture and manufacturing domains show the superiority of our approach over several benchmarks.

Statistical Process Control in Oshibori Rental Business

Tomomichi Suzuki, Katsuyuki Fujinami, Masaru Akiba, Taku Watanabe, Shizu Itaka and Seiichi Yasui

Dept. Industrial & Systems Engineering, Tokyo University of Science, Noda, Chiba, Japan, szk@rs.tus.ac.jp, shizu@rs.tus.ac.jp, yasui@rs.tus.ac.jp;

FSX Inc., Tokyo, Japan, katsu@fsx.co.jp, akiba@fsx.co.jp, t.watanabe@fsx.co.jp

Oshibori is a wet hand towel offered to customers in places such as restaurants or bars, and used to clean one's hands before eating. Oshibori have long been part of hospitality culture in Japan. Many restaurants and bars often do not prepare them in the store, but instead employ a rental service which launders them, rolls them into the typical cylindrical shape, and delivers them already damp. There are many rental service companies that offer oshibori rental services in Japan. One of the important tasks for those companies is to control the total number of oshiboris. They lend oshiboris to their customers such as restaurants and bars. They then collect the used oshiboris after their use. The problem is the total number of collected oshiboris is often less than how many they had lent. These losses of oshiboris are major cause of hindering the benefits of oshibori rental service companies. Thus increasing the return rate of oshiboris is important. Obvious measures would be to ask customers to return them and confirm the number of returned oshiboris by counting, but that is practically impossible because the delivery staff who collects the returned oshiboris has to collect many oshiboris in very short time. There is not any time to count oshiboris when collecting them. Only an approximate guess is possible in that process. In this study, a method to estimate the return rate of the customers are proposed using data obtained through actual oshibori rental service. The accurate estimate would give the grounds that allow the rental service companies to take necessary actions to their customers, which eventually leads to the decrease of losses of oshiboris.

Estimation of the Proportion of Defective Items Under a Group Testing Setting

Yaakov Malinovsky

Dept. of Mathematics and Statistics, U Maryland, Baltimore County, MD, yaakovm@umbc.edu

Consider a large population where item i has a probability p of being defective, independent of the other units. A group test is a binary test performed on an arbitrary group of items with two possible outcomes: all items are good (negative test outcome), or at least one item is defective (positive test outcome). When p is "small" enough relative to the arbitrary group size k, then the group test outcome is likely to be negative. In this situation, we can use one binary test to identify that all k items are good, versus the k tests necessary when using individual testing. This suggests that when the test budget is limited, it may be more efficient to estimate the unknown parameter p using grouped data than individual data. In this talk, I will discuss the sampling

procedures that lead to efficient (unbiased) point and interval estimation of p based on group data. Most of these procedures are sequential. The talk is based on joint works with Paul Albert, Gregory Haber, and Shelemyahu Zacks.

AI and the Future of Work in Statistical Quality Control: Insights from a First Attempt to Augmenting ChatGPT with an SQC Knowledge Base (ChatSQC)

Fadel M. Megahed, Ying-Ju (Tessa) Chen, Inez Zwetsloot, Sven Knoth, Douglas C. Montgomery, and L. Allison Jones Farmer

Farmer School Business, Miami U, Oxford, OH, USA, fmegahed@miamioh.edu, farmerl2@miamioh.edu; Dept. Mathematics, U Dayton, Dayton, Ohio, USA, ychen4@udayton.edu; Faculty Economics & Business, U Amsterdam, The Netherlands, i.m.zwetsloot@uva.nl; Dept. Mathematics & Statistics, Helmut Schmidt U Hamburg, Germany, knoth@hsu-hh.de; School Computing & Augmented Intelligence, Arizona State U, Tempe, AZ, USA, doug.montgomery@asu.edu

We introduce ChatSQC, an innovative chatbot system that combines the power of OpenAI's Large Language Models (LLM) with an extensive knowledge base in Statistical Quality Control (SQC). Our research focuses on enhancing LLMs using specific SQC references, shedding light on how data preprocessing parameters and LLM selection impact the quality of generated responses. By illustrating this process, we hope to motivate wider community engagement to refine LLM design and output appraisal techniques. We also highlight potential research opportunities within the SQC domain that can be facilitated by leveraging ChatSQC, thereby broadening the application spectrum of SQC. A primary goal of our work is to equip practitioners with a tool capable of generating precise SQC-related responses, thereby democratizing access to advanced SQC knowledge. To continuously improve ChatSQC, we introduce a crowdsourcing approach to accumulate further SQC references, thereby enhancing the contextual understanding of the chatbot. A dedicated web platform has been created for the SQC community to contribute, and we commit to vetting these contributions and updating ChatSQC on a quarterly basis. Overall, ChatSQC serves as a testament to the transformative potential of AI within SQC, and we hope it will spur further advancements in the integration of AI in this field.

Statistical Thermodynamics, Real World Data, and Clinical Trial Designs

George-Rafael Domenikos and Choudur Lakshminarayan

School of Business, Stevens Institute of Technology, Hoboken, NJ, USA, gdomenik@stevens.edu, lchoudur@stevens.edu

The 21st century Cures act promulgated by the 114st United States congress mandated the Food and Drug Administration (FDA) to advise and instruct pharmaceutical companies to incorporate RWD in clinical trials. The provisions of the act included: Expedite approvals of new drugs, prescription drugs monitoring program, new indications on existing drugs and informed consent waiver when certain drugs pose minimal risk. The act permits RWD from observational studies, insurance claims, patient inputs and surveys as well as anecdotal data. RWD is subject to selection bias, effect of confounders that influence the intervention as well as the outcome. It has been a subject of scrutiny and skepticism by opposition groups. The vast repositories of data is a godsend and together with suitable data [re-processing and statistical machinery] it can be leveraged for responsible trial design. The benefits are patient representation across larger

demographic populations, accelerate clinical trials, while allaying perceived skepticism regarding observational data.

Detection and Estimation of Multiple Transient Changes

Michael Baron, Sergey V. Malov

Dept. Mathematics & Statistics, American U, Washington D.C., USA, baron@american.edu; Peter the Great St.-Petersburg Polytechnic University; St. Petersburg, Russia, sergey.v.malov@gmail.com

Change-point detection methods are proposed for the case of temporary failures, or transient changes, when an unexpected disorder is ultimately followed by a readjustment and return to the initial state. A base distribution of the "in-control" state changes to an "out-of-control" distribution for unknown periods of time. Likelihood based sequential and retrospective tools are proposed for the detection and estimation of each pair of change-points. The accuracy of the obtained change-point estimates is assessed. Proposed methods offer simultaneous control the familywise false alarm and false readjustment rates at the pre-chosen levels.

Data processing and analysis using statistical learning for decision support on Care Unit Intensive (CUI) and Unmanned Aerial Vehicles (UAV's): How are these areas similar?

Magda Ruiz, Luis Eduardo Mujica, Ricard Mellado-Artigas, Antonio Fernández

Dept. Matemàtiques, Escola d'Enginyeria de Barcelona Est (EEBE), U Politècnica de Catalunya (UPC), San Adrià de Besòs-Barcelona, Spain, magda.ruiz@upc.edu, luis.eduardo.mujica@upc.edu; Dept. d'Anestesiologia, Hospital Clínic, Institut D'investigació August Pi i Sunyer, Barcelona, Spain, rmartigas@gmail.com; Escuela Técnica Superior de Ingenieríía Aeronáutica y del Espacio (ETSIAE), U Politécnica de Madrid (UPM), Madrid, Spain, antonio.fernandez.lopez@upm.es

When we talk about data analysis, it is possible to cover almost all possible problems or situations that can arise in the world (present or past). This new wave or way of "analysing" data creates new opportunities to prevent or propose solutions to these problems. On the other hand, it can be argued that the view of a problem and its possible solution can be biased by experience or limited by the lack of it. Thus, the data analyst faces the challenge of finding and recognising patterns, correlations in the data by classifying or clustering them. All this with the main objective of making predictions and/or forecasts. Two areas are presented which at first sight do not appear to be similar, but in the search for a solution they converge on the same point. These areas are: structural health monitoring (SHM) and decision support for medical staff in the intensive care unit (ICU). In SHM, the problems of damage detection will be addressed using different types of signals collected by unmanned aerial vehicles (UAVs). In the ICU, we will focus on the need for intubation in pathologies such as coronavirus (COVID-19) and subarachnoid haemorrhage. In all of these areas, data is collected for further analysis using concepts such as hypothesis testing, correlation analysis, resampling, models based on statistical or machine learning, among others. In addition, sometimes simple solutions using basic statistical concepts have enabled the development of data analysis. The methods developed in each case have allowed the development of predictive models for decision making. The results show that the accuracy and efficiency of structural health monitoring and medical diagnosis have improved. In

conclusion, these methods could be a powerful tool for potential disease treatments and they can detect damage at an early stage, allowing the expert to identify and develop solutions.

Augmentation of No-Confounding 16-Run Fractional Factorial Designs ✌

Carly E. Metcalfe, Douglas C. Montgomery, Bradley Jones

School Mathematics & Statistics, Rochester Institute of Technology, Rochester, NY, USA, cmsma@rit.edu; School Computing & Augmented Intelligence, Arizona State U, Tempe, AZ, USA, doug.montgomery@asu.edu; JMP Division of SAS, Bradley.Jones@jmp.com

Nonregular fractional factorial designs are a preferable alternative to regular resolution IV designs because they avoid complete confounding of 2-factor interactions. Consequently, nonregular designs can estimate and identify a few active two-factor interactions. However, due to the sometimes-complex alias structure of non-regular designs, standard factor screening strategies can fail to identify all active effects. Previous research by these authors has developed an alias-informed-model-selection (AIMS) technique. We have shown how the AIMS technique can be applied to 6, 7 and 8 factor non-regular designs. We have compared AIMS to three other standard analysis methods for non-regular designs, stepwise regression, the lasso, and the Dantzig selector. AIMS consistently outperforms these methods in identifying the set of active factors. This research provides a method for augmenting no-confounding designs based on a model spaces and maximum average D-efficiency criterion. Several augmented design strategies are provided for different situations. A simulation study with the augmented designs shows significant performance improvement for augmenting the 16-run designs with 4 additional runs. We recommend this strategy if time and experimental resources permit.

Monitoring Colour Image Processes ✌

Yarema Okhrin, Viktoriia Petruk and Wolfgang Schmid

Faculty Business & Economics, U Augsburg, Germany, yarema.okhrin@wiwi.uni-augsburg.de; Dept. Statistics, European University Viadrina, Frankfurt (Oder), Germany, petruk@europa-uni.de, schmid@europa-uni.de

Monitoring digital images plays a key role in manufacturing, engineering, meteorology, etc. The objective is to detect changes in colours, intensities, and other image characteristics of a sequence of images or photos as soon as possible after their occurrence. This allows companies to reduce the costs by using digital quality control tools. A sequence of colour images defines a time series of three-dimensional matrices that typically possesses a strong temporal and cross-sectional dependence. In this paper we develop a novel monitoring technique for this type of complex objects that considers the complex dependence structure. Moreover, we use the concept of regions of interest to reduce the dimensionality of the problem and allow for the monitoring of high-resolution images. It is assumed that the images are observed with noise, and we focus on the shifts in the mean of image characteristics. For monitoring purposes, we consider GLR and EWMA control schemes and extend them to a very general setting. The performance of the suggested schemes is evaluated within an extensive simulations study. The results are summarized in the form of detailed recommendations on chart specifications for the practitioners.

Phase I of Spatiotemporal Profile Monitoring for Functional Data ✌

Mohammadreza Nasiriboroujeni and Philipp Otto

Leibniz U Hannover, Institute Cartography &Geoinformatics, nasiri@ikg.uni-hannover.de, otto@ikg.uni-hannover.de

Statistical process monitoring (SPM) is a quality control method that employs statistical methods to monitor and control a process, e.g., industrial production processes. We focus on profile monitoring of spatiotemporal functional data. Profile monitoring can generally be applied to any process where a functional relationship between one or more quality characteristics of interest (as the response variable/s) and one or more explanatory process variables is present. Then, the stability of this functional relationship is continuously monitored, and changes from the tar- get relationship should quickly be detected. Profile monitoring is conducted in two phases, the first of which is a retrospective phase. The main goal of this phase, or the so-called Phase I, is to analyze historical data to elucidate and find a suitable model for the target process. Thus, the Phase-I data should not contain anomalous or outlying observations, which must be identified and removed in this first phase. Moreover, the in-control process parameters are determined and used to design process control charts for the following online period, or Phase II. The primary purpose of Phase II is to quickly detect deviations from the target process determined in Phase I. In this study, our focus is on environmental applications, where the physical variables are observed in a functional domain over a two-dimensional space (e.g. geo-referenced locations) and time. For instance, such multidimensional data are collected by radiosondes or laser-based methods, including light detection and ranging called LiDAR. We show the Phase-I analysis for a case study on the active monitoring of a bike-sharing scheme in Helsinki. For instance, the active monitoring of such a process is relevant for re-balancing the available bikes at each station in case of abnormal usage, e.g., because of events. For this reason, we consider a functional hidden dynamic geostatistical model (f-HDGM).

Distribution-free joint monitoring of location and scale for modern univariate processes ✌

Marcus Perry

Dept. Information Systems, Statistics & Management Science, U Alabama, Tuscaloosa, AL, USA, mperry@cba.ua.edu

Autocorrelated sequences of individual observations arise in many modern-day statistical process monitoring (SPM) applications. Often times, interest involves jointly monitoring both process location and scale. To jointly monitor autocorrelated individuals data, it is common to first fit a time series model to the in-control process and subsequently use this model to de-correlate the observations so that a traditional individuals and moving-range (I-MR) chart can be applied. If the time series model is correctly specified such that the resulting residuals are normal and independently distributed, then applying the I-MR chart to the residual process should work well. However, if the residual process deviates from normality and/or, due to time series model misspecification, contains levels of autocorrelation, the false alarm rate of such a strategy can dramatically rise. In this paper we propose a joint monitoring strategy that can be designed so that its in-control average run length is robust to non-normality and time series model misspecification. We compare its performance to that of the I-MR control chart applied to the residuals under different misspecification scenarios.

Our conclusions suggest that the proposed joint monitoring strategy is a useful tool for today's modern SPM practitioner, especially when model misspecification is a concern.

Statistical Process Control/Monitoring: A View on the Fundamental Definitions and Terminology ✌

Stefan Steiner, Nathaniel T. Stevens and R. Jock Mackay

Business & Industrial Statistics Research Group, Dept. Statistics & Actuarial Sciences, U Waterloo, Canada, shsteiner@uwaterloo.ca, nstevens@uwaterloo.ca, jock.mackay@uwaterloo.ca

The purpose of this paper is to examine the fundamental definitions, theory, and practice of Statistical Process Monitoring (SPM), that we narrowly define as control charting. We consider issues such as the definition of common and special causes, the use of redundant terminology, contradictions in definitions proposed by various major authors and the definition of control. We demonstrate with numerous quotations from various authors that over the years the fundamental ideas and theory behind control charting have become convoluted and confused. Due to this confusion, learning, understanding, and thus using control charting effectively is not straightforward. These issues are important because an understanding of control charting is necessary for industry practitioners as it is often tied to quality standards. We believe that to increase effectiveness, statistical process monitoring needs a standardized set of definitions, terminology and aims that are currently absent. In the final part of this paper, we propose a robust and clear set of goals, procedures, concepts, definitions, and terminology for SPM.

Shewhart and Profile Monitoring for Industry 4.0 ✌

Geoff Vining and Eric Bae

Dept. Statistics, Virginia Tech, Blacksburg, VA, USA, vining@vt.edu, ericbae@vt.edu

Shewhart (1931A, 1931B, 1939) make quite clear that the purpose of the control chart is to establish appropriate limits for the prediction of a critical quality characteristic over time to maximize economic benefit. These limits reflect the variability created by "a system of chance causes." Chance means unknown, not random. He is aware of the Neyman-Pearson work on hypothesis tests. He makes clear that the control chart is not a sequence of hypothesis tests because the variability is not random. The fundamental premise underlying modern statistical process monitoring is that the control chart is a sequence of hypothesis tests. The focus is on detecting shifts over time in the parameters rather than predicting the critical quality characteristic. Many Industry 4.0 processes have critical quality characteristics highly correlated with a large number of ancillary variables. The variability in these ancillary variables reflects the system of chance causes for this process. This chapter uses linear models theory to analyze data collected for a common commercial jet turbine. The critical quality characteristic is a temperature. There are hundreds of ancillary variables available. It compares this analysis to the community's current profile monitoring approach.

References

1. Shewhart (1931A). *"Economic Control of Quality of Manufactured Product"*. D. Van Nostrand Company, Inc.: Toronto, New York, London.

2. Shewhart (1931B). "Statistical Method from an Engineering Viewpoint". *Journal of the American Statistical Association*, 26(175), 262–269.

3. Shewhart (1939). *"Statistical Method from the Viewpoint of Quality Control"*. Edited by W. E. Deming. The Graduate School, Department of Agriculture, Washington.

Detecting manipulated Data Sets using Benford's Law ✌

Wolfgang Kössler, Hans-Joachim Lenz and Xing D. Wang

Institut Informatik, Humboldt U Berlin, Germany, koessler@informatik.hu-berlin.de, wangxida@informatik.hu-berlin.de; Institut Statistik & Ökonometrie, Freie U Berlin, Germany, koessler@informatik.hu-berlin.de

The Benford Law is used world-wide for detecting non-conformance or data fraud of numerical data. It says that the significand of a data set from a universe is not uniformly, but logarithmically distributed. Especially, the random first non-zero digit is One with probability approximately equal to 0.3. In this article we consider data sets manipulated by multiple entries, and are looking whether such data fraud may be detected by statistical tests of Benford's law. Therefore, we designed a scenario for simulating data manipulations based on duplicated values. The model is motivated by a case study on billing fraud reported by Nigrini (2000). We estimate the rejection probabilities of eight test statistics, χ^2, first (GoF1) and second significant digit (GoF2) of a value, a kind of mean absolute deviation test, first and second significant digit (MAD1 and MAD2), and four variants of an Invariant Sum test. The latter statistics differ in the distance used, i.e., Euclidean or Mahalanobis. Moreover, we investigate the first and second signif- icant digit, respectively, cf. Kössler, Lenz and Wang (2023). It turns out that in the majority of cases the invariant sum tests ISE and ISM outperform the classical gooodness-of-fit tests GoF and MAD. In some cases of small first digit the test GoF2 is leading.

References

1. Kössler, Lenz & Wang (2023). "Invariant sum tests for the assessment of Benford's law". *submitted*.

2. Nigrini (2000). *"Digital Analysis Using Benford's Law: Tests and Statistics for Auditors"*. Global Audit Publication, Vancouver, 2000.

Index