
# WROCŁAW
# February 16-20, 2015

Booklet of abstracts.
Information for participants.

rok zał. 1919
ptm
POLSKIE
TOWARZYSTWO
MATEMATYCZNE

The Conference4me smartphone app provides you with the most comfortable tool for planning your participation in the 12th Workshop on Stochastic Models, Statistics and Their Applications. Browse the complete programme directly from your phone or tablet and create your very own agenda on the fly. The app is available for Android, iOS, Windows Phone and Kindle Fire devices.

Android

iOS

Windows Phone


Issue editor: Marek Skarupski
Editors: Ewaryst Rafajłowicz, Krzysztof Szajowski, Ansgar Steland

Publisher:
Polskie Towarzystwo Matematyczne
ul. Śniadeckich 8
00-956 Warszawa
Poland

Co-publishers:
Politechnika Wrocławska
Wybrzeże Wyspiańskiego 27
50-370 Wrocław
Poland

RWTH Aachen University
Institut für Statistik und Wirtschaftsmathematik
Wüllnerstr. 3
52062 Aachen
Germany

Conference logo designed by Ansgar Steland
Main cover designed by Marek Skarupski
Back cover designed by Karolina Koryniowska

Wrocław 2015

ISBN 978-83-937220-2-0

# Preface

Following the successful previous workshops, the conference will put together recent advances and trends in areas related to stochastic modeling, statistical inference and their applications. Contributions motivated by or addressing issues in engineering, industry and natural sciences are particularly welcomed, as several focused sessions are devoted to such topics. The workshop aims at facilitating the exchange of research ideas, stimulating collaboration and promoting young researchers.

In 2015 the workshop will be organized as - but not limited to - a German-Polish one and takes place at Wrocław. It is an activity of the Society of Reliability, Quality and Safety and is organized by the Institute of Mathematics of Wrocław UoT, in collaboration with the Institute of Statistics, RWTH Aachen University, and the Institute of Computer Engineering, Control and Robotics of Wrocław UoT. The workshop is supported by the Polish Mathematical Society and the German Statistical Society.

The invited plenary presentations are held by Laszlo Györfi (Budapest University of Technology and Economics and Hungarian Academy of Sciences), Teresa Ledwina (Polish Academy of Sciences) and Marie Hůsková (Charles University of Prague). The authors who have contributed to this volume come from Austria, Brazil, Canada, Croatia, Czech Republic, Finland, France, Germany, Greece, Hungary, Italy, Japan, Netherlands, Norway, Poland, Russia, Slovak Republic, Spain and U.S.A. It is our intention and hope that the preparation of the articles for this volume as well as the talks and discussions at the workshop deepen existing cooperations and partnerships which stimulate new collaborations.

We hope you enjoy your stay and the talks.

Aachen and Wrocław,

*Ansgar Steland*
*Krzysztof Szajowski*
*Ewaryst Rafajłowicz*

Wrocław, January 25, 2015

# Acknowledgements

We would like to thank the following colleagues who accepted our invitation to organize an invited session: Marco Burkschat (Aachen), Maik Döring (Hohenheim), Dietmar Ferger (Dresden), Josef Högl (Munich), Hajo Holzmann (Marburg), Piotr Jaworski (Warsaw), Uwe Jensen (Hohenheim), Sven Knoth (Hamburg), Wolfgang Kössler (Berlin), Jacek Koronacki (Warsaw), Adam Krzyzak (Montreal), Eckhard Liebscher (Merseburg), Ryszard Magiera (Wrocław), Mirek Pawlak (Winnipeg), Rainer Schwabe (Magdeburg), Wolfgang Schmid (Frankfurt Oder) Krzysztof Szajowski (Wrocław), Darius Ucinski (Zielona Góra), Christian Weiss (Hamburg), Aleksander Weron (Wrocław) and Rafał Weron (Wrocław).

The organizers are grateful to the leadership of the Technical University of Wroclaw, in particular, prof. Aleksander Weron, Director of the Institute of Mathematics and Computer Science, Technical University of Wroclaw , for administring the resources of the workshop participants and organizational support. We have gotten an invaluable help of Ms. Beata Stanisławczyk, Ewelina Rabska ( Dept. of Math. ) and Iga Wąsowicz ( Dept. of ACM) . Effective workshop facilities also became the Foundation for the development of the Wroclaw University of Technology and their secretary Ms. Anna Romek. We acknowledge the support of M. Sc. Annabel Prause who has helped us in organizing the sessions and communicating with the session organizers.

The workshop logo was desinged by Ansgar Steland. The poster of the workshop has been designed by Karolina Koryniowska (Wrocław Accademy of Art). Her poster is used as the back cover of the booklet. The front cover was designed by Marek Skarupski.

Aachen and Wrocław,
January 2015

*Ansgar Steland*
*Krzysztof Szajowski*
*Ewaryst Rafajłowicz*

# Scientific Committee

Chair: Ansgar Steland (Aachen)

Krzystof Szajowski (Wrocław)

Ewaryst Rafajłowicz (Wrocław)

Uwe Jensen (Hohenheim)

Sven Knoth (Hamburg)

Marko Burkschat (Aachen)

Waltraud Kahle (Magdeburg)

# Local Organizing Committee

Chair: Krzystof Szajowski (Wrocław)

Ewaryst Rafajłowicz (Wrocław)

Ansgar Steland (Aachen)

Ewa Skubalska-Rafajłowicz (Wrocław)

Mohammed Abujarad (Aachen)

Annabel Prause (Aachen)

# Secretary and Address

Department of Mathematics
Faculty of Fundamental Problems of Technology
Wrocław University of Technology
ul. Janiszewskiego 14a 50-372 Wrocław

tel.: +48 71 320 25 29, +48 71 320 22 18 fax : +48 71 328 07 51

e-mail: mat.inf@pwr.wroc.pl
URL: http://im.pwr.edu.pl

# Supporting Organizations and Sponsors

# SURVIVAL GUIDE

## Important numbers

Emergency Telephone Number: **112**

"Duty officer" of the Workshop:
**+48 796 534 746**

Police: **997**
Fire Brigade: **998**
Ambulance: **999**
Municipal Police: **986**

**Taxi numbers**
The name of taxi corporation with sign (*) means that they accept payment cards.

| | | | |
|---|---|---|---|
| EXPRES RADIO TAXI (*) | 19628 | Z.T.P. RADIO TAXI (*) | 19622 |
| FENIX RADIO TAXI (*) | 19665 | RYBA TAXI | 516 007 700 |
| HALLO RADIO TAXI (*) | 19621 | TAXI GROSZ | 796 000 666 |
| NOVA METRO TAXI (*) | 19696 | TIGER TAXI | 500 250 200 |

## Important addresses

Address of the Workshop:
**Wrocław University of Technology**
**Centrum Wiedzy i Informacji**
**Naukowo-Technicznej**
**Pl. Grunwaldzki 11 (bud. D-21)**
**50-377 Wrocław**
**e-mail: centrum@pwr.edu.pl**

Address of the hotel:
**Hotel im. Jana Pawła II**
**ul. św. Idziego 2**
**50-328 Wrocław**
**tel./fax (+48 71) 327 14 00**
**http://www.hotel-jp2.pl/**

Address of the airport:
**Port Lotniczy Wrocław S.A**
**ul. Graniczna 190**
**54-530 Wrocław**
http://airport.wroclaw.pl/
The website is available in the following languages: PL, ENG.

Information about departures and arrivals:
tel. (+48 71) 35 81 381
Information about lost baggage:
tel. (+48 71) 35 81 387

Address of the main railway station:

**Dworzec Kolejowy**
**PKP Wrocław Główny**
**ul. J. Piłsudskiego 105**
**50-085 Wrocław**
http://pkp.wroclaw.pl/

Timetable:
http://rozklad-pkp.pl/
Timetable is available in the following languages: PL, ENG, DE, RUS.

## Wrocław public transport

In Wrocław public transport includes buses and trams. You can buy tickets in each vehicle in vending machine. The machines are available in the following languages: PL, ENG, DE, FR. There are also stationary machines in different places of the city.
Warning! In vehicles you can pay only by card!


The tickets are divided into two groups: single-ride tickets and time-ride tickets.

There are two different types of single-ride tickets: for Normal lines (3 PLN) and Express and Night lines (3.20 PLN).

For time-tide tickets there are the following types: 30min-ticket (3 PLN), 60min-ticket (4.40 PLN), 90min-ticket (6 PLN), 24h-ticket (11 PLN), 48h-ticket (20 PLN), 72h-ticket (26 PLN), 168h-ticket (46 PLN). During the period of validity of the ticket time is possible an unlimited number of transfers.

Remember to validate your ticket in bus or tram. Phd students are entitled to 50% discount.

The way from John Paul II Hotel to WUT can go by :

- Express bus C from stop Bem Square (Plac Bema) to Grunwaldzki Square (Plac Grunwaldzki) (ca. 4 min)
- trams 0P, 1 from stop Bem Square (Plac Bema) to Grunwaldzki Square (Plac Grunwaldzki) (ca. 7 min)
- trams 2,10 from stop Cathedral (Katedra) to Grunwaldzki Square (Plac Grunwaldzki) (ca. 4 min.)

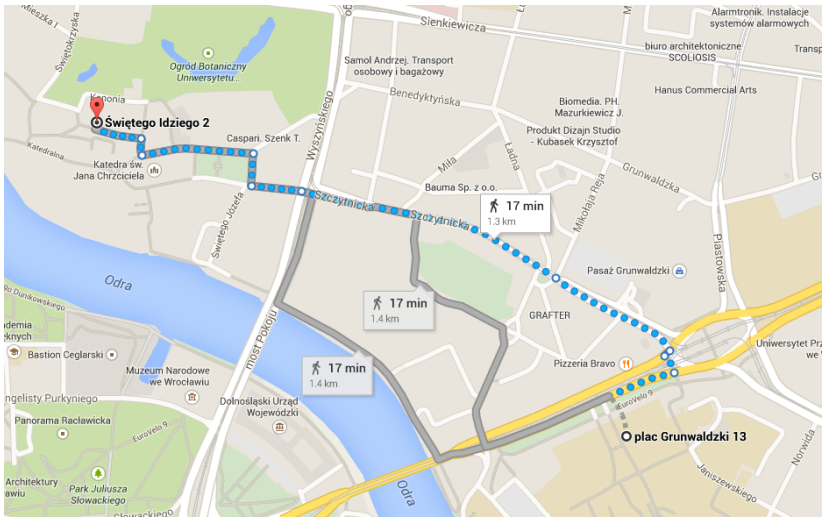
The way from John Paul II Hotel to railway station can go by:

- Express bus N from stop Botanical Garden (Ogród Botaniczny) to Main Railway Station (Dworzec Główny PKP) (ca. 11 min)
- by trams 8, 9, 11 from stop Bem Square (Plac Bema) to Main Railway Station (Dworzec Główny PKP) (ca. 9 min)
- trams 2,10 from stop Cathedral (Katedra) to Main Railway Station (Dworzec Główny PKP) (ca. 9 min)

The way from Main Railway Station to Wrocław University of Technology you can go by:

- trams 2,10 from stop Main Railway Station (Dworzec Główny PKP) to to Grunwaldzki Square (Plac Grunwaldzki) (ca. 13 min)
- buses 145, 146 from stop Main Railway Station (Dworzec Główny PKP) to to Grunwaldzki Square (Plac Grunwaldzki) (ca. 9 min)

From airport there is a bus to main railway station. The bus is number 406 from stop Airport (Port Lotniczy) to Main Railway Station (Dworzec Główny PKP) (ca. 29 min).
To check the timetable of public transport you can visit: http://komunikacja.iwroclaw.pl/ or http://wroclaw.jakdojade.pl/. The websites are available in the following languages: PL, ENG. The university is not so far from the hotel so it is also possible to get there by foot. The way is presented below.



# Programme

## Monday, 16.02.2015

Arrival to Wrocław. Accommodation.

## Tuesday, 17.02.2015

**8.00 - 9.00** Registration ( CSTI D-21, Hall)

**9.00-10.00** Opening & poster session ( CSTI D-21, Hall)

**10.00-10.45** Plenary session ( CSTI D-21, r. 007)
Teresa Ledwina: Validation of positive quadrant dependence and visualization of dependence structure

**10.45-11.15** Coffee break ( CSTI D-21 - Hall )

**11.15-13.15** Invited Sessions ( CSTI D-21)

### Change detection, estimation and testing (Part I)

Organizers: Ewaryst Rafajłowicz, Ansgar Steland (Room 102)

1. Steve Coad: Bias Calculations for Adaptive Generalised Linear Models.
2. Maik Döring: Asymmetric Cusp Estimation in Regression Models.
3. Elena Yudovina: Model Selection for Bayesian Multi-Step Ahead Predictions.
4. Zuzana Prášková: Monitoring changes in RCA models.
5. Martin Wagner: Monitoring Euro Area Real Exchange Rates.

### Statistics for High-Dimensional Data

Organizers: Jacek Koronacki (Room 103)

1. Małgorzata Bogdan: SLOPE - Adaptive Variable Selection via Convex.
2. Sang Kyun Lee: Variable Selection via Lasso and Graphical Lasso.
3. Jan Mielniczuk: Selection consistency of Generalized Information Criterion for sparse logistic model.
4. Andrzej Polański: Gaussian mixture decompositions for computation of features of protein spectral signals.

### Stochastic Dynamics and Anomalous Diffusion

Organizers: Aleksander Weron (Room 201)

1. Michał Balcerek: Stochastic dynamics of G-protein-coupled cell-surface receptors.
2. Agnieszka Wyłomańska: The analysis of stochastic signal from LHD mining machine.
3. Julien Chevallier: Statistical method to estimate regime-switching Lévy model.
4. Boubaker Smii: Asymptotic expansions for SDE's with small multiplicative noise.

**13.20-14.30** Lunch (CSTI D-21 - Hall)

**14.30-16.00** Invited Sessions ( CSTI D-21)

### Stochastic models in engineering

Organizer: Marco Burkschat (Room 102)

1. Marco Burkschat: On the Asymptotic Behavior of Systems Based on Sequential Order Statistics.
2. Waltraud Kahle: Incomplete Maintenance in Degradation Processes.
3. Tomasz Rychlik: Lifetime comparisons of $k$-out-of-$n$ systems with i.i.d. DFR and IFR component distributions.

### Survival analysis and reliability

Organizer: Organizer: Maik Döring (Room 103)

1. Ann-Kathrin Bott: Nonparametric estimation of a conditional density.
2. Ewa Strzalkowska-Kominiak: Kaplan-Meier estimator based on ranked set samples.
3. Hong Chen: Model selection using Cramér-von Mises distance.
4. Harro Walk: Nonparametric quantile estimation by importance sampling.

**Empirical processes in stochastic optimization**
Organizer: Dietmar Ferger
Room 201

| Title | Presenter |
|---|---|
| On the construction of scenario trees based on the multistage empirical process. | Georg Pflug |
| Regularizing Linear Programming Estimation for Nonregular Regression Models. | Keith Knight |
| Universal Confidence Sets in Multiobjective Optimization. | Silvia Vogel |
| On the convergence of Arginf-sets and infimizing points of multivariate stochastic processes with cadlag trajectories. | Dietmar Ferger |

| Time | Event | Place |
|---|---|---|
| 16.00-16.30 | Coffee break | CSTI D-21 - Hall |
| 16.30-18.00 | Invited Sessions | CSTI D-21 |

**Acceptance Sampling**
Organizer: Wolfgang Kössler
Room 102

| Title | Presenter |
|---|---|
| Quantile Graphical Modelling of Point Processes. | Matthias Eckardt |
| Inspection plans for populations with unknown continuous distributions. | Wolfgang Kössler |
| Self-concordant profile empirical likelihood ratio tests for the population correlation coefficient: a simulation study. | Thorsten Dickhaus |

**Nonparametric Statistics for Image Analysis (part I)**
Organizer: Hajo Holzman, Mirosław Pawlak
Room 103

| Title | Presenter |
|---|---|
| ptimal classification and nonparametric regression for functional data. | Alexander Meister |
| Statistical Inference for Signal Symmetries. | Mirosław Pawlak |
| Nonparametric quantile estimation using importance sampling. | Reinhard Tent |
| Nonparametric Regression for latent Variables. | Florian Müller |

**Modeling Dependence Using Copulas (part I)**
Organizers: Piotr Jaworski, Eckhard Liebscher
Room 201

| Title | Presenter |
|---|---|
| Ultramodularity in the construction of binary copulas. | Erich Peter Klement |
| Semi-parametric Estimation of Income Mobility with D-vines using Bivariate Penalized Splines. | Christian Schellhase |
| Copulas of self-similar Ito diffusions and Girsanov transformation. | Marcin Krzywda |
| Time Varying Tail Dependence, Copulas and Marginal Expected Shortfall. | Oliver Grothe |

# Wednesday, 18.02.2015

| Time | Event | Place |
|---|---|---|
| 8.50-10.30 | Invited Sessions | CSTI D-21 |

**Statistical Genetics and Biostatistics**
Organizer: Josef Hoegel
Room 102

| Title | Presenter |
|---|---|
| Joint Genotype- and Ancestry-based Genome-wide. | Małgorzata Bogdan |
| Selection of candidate genes after genome-wide screening - a challenging problem. | Josef Hoegel |
| Use of a generalized multivariate gamma distribution based on copula functions in the average bioequivalence. | Roberto Molina de Souza |

**Disorder Detection**
Organizers: Elzbieta Ferenstein, Krzysztof Szajowski
Room 103

| Title | Presenter |
|---|---|
| On Some Distributed Disorder Detection. | Krzysztof Szajowski |
| Compund Poisson multiple disorder problem with disorder-related. | Elzbieta Ferenstein |
| The epsilon-complexity of continuous functions. | Boris Darkhovsky |
| Methodology for segmentation of time series with arbitrary generating mechanisms via $\epsilon$-complexity. | Alexandra Piryatinska |

**Experiment design (part I)**
Organizers: Rainer Schwabe, Dariusz Uciński
Room 201

| Title | Presenter |
|---|---|
| On the Impact of Correlation on the Optimality of Product-type Designs in SUR Models. | Moudar Soumaya |
| An Algorithm for Construction of Constrained D-Optimum Designs. | Dariusz Uciński |
| Optimal Designs for Steady-State Kalman Filters. | Guillaume Sagnol |
| Application of optimal designs for the methane flux in troposphere. | Kinga Sikolya |

| Time | Event | Place |
|---|---|---|
| 10.30-11.00 | Coffee break | CSTI D-21 - Hall |
| 11.00-13.05 | Invited Sessions | CSTI D-21 |

**Estimation and prediction in some stochastic reliability models (part I)**
Organizers: Ryszard Magiera
Room 102

| Title | Presenter |
|---|---|
| Interval Prediction for the Trend-Renewal Process. | Alicja Jokiel-Rokita |
| Estimation for the Modulated Power Law Process. | Krzysztof Boczkowski |
| Conditional Γ-minimax prediction in doubly stochastic Poisson process. | Daniel Lazar |
| Estimation of the Ratio of the Geometric Process. | Rafał Topolnicki |
| Bayes Estimation of the Weibull Power Law Process Parameters. | Ryszard Magiera |

**Statistical Process Control of Dependent Time Series**
Organizer: Wolfgang Schmidt
Room 103

| Title | Presenter |
|---|---|
| On hitting times for Markov time series of counts with applications to quality control. | Manuel Carbal Morais |
| Simultaneous surveillance of means and covariances of spatial models. | Philipp Otto |
| Control charts for long-memory processes. | Liubov Rabyk |
| Control Charts for State-Space Models. | Taras Lazariv |

**Modeling Dependence Using Copulas (part II)**
Organizers: Eckhard Liebscher, Piotr Jaworski
Room 201

| Title | Presenter |
|---|---|
| A study on robustness in the optimal design of experiments for copula models. | Elisa Perrone |
| Testing the truncation invariance. | Piotr Jaworski |
| Modeling and approximation of copulas using Cramér-von Mises statistic. | Eckhard Liebscher |
| Imprecise copulas. | Radko Mesiar |

| Time | Event | Place |
|---|---|---|
| 13.05-14.30 | Lunch | CSTI D-21 - Hall |
| 14.30-15.15 | Plenary session | CSTI D-21, r.007 |

| Title | Presenter |
|---|---|
| Some recent results in change-point analysis. | Marie Huskova |

| Time | Event | Place |
|---|---|---|
| 15.15-18.30 | Social event: Trip | TBA |
| 17.00-18.30 | QZS Meeting | C-3, room 208 |
| 19.00-22.00 | Conference Dinner | A-1, Aula |

# Thursday, 19.02.2015

| Time | Event | Place |
|---|---|---|
| 8.20-10.00 | Invited Sessions | CSTI D-21 |

**Statistical Methods in Engineering (part I)**
Organizer: Mirosław Pawlak
Room 102

| Title | Presenter |
|---|---|
| Wavelet algorithm for hierarchical pattern recognition. | Urszula Libal |
| Modelling and Forecasting Electricity Spot Prices Using Lasso Methods. | Florian Ziel |
| On Hammerstein system nonlinearity identification algorithms based on order statistics and compactly supported functions. | Przemysław Śliwiński |
| Stochastic Model Of Cognitive Agents Learning To Cross A Highway. | Anna T. Lawniczak |

**Survival analysis and reliability (part II)**
Organizer: Maik Döring
Room 103

| Title | Presenter |
|---|---|
| Odds algorithm in detection of occurrence of last aftershock in sequence. | Marek Skarupski |
| The Multivariate Kaplan-Meier Estimator. | Winfried Stute |
| Mixture and Non-Mixture Cure Rate Model Considering The Burr XII Distribution. | Jorge Alberto Achcar |
| Risk-Averse Equilibrium Modeling and Social Optimality of Cap-and-Trade Mechanisms. | Cristian Pelizzari |

**Poster presentation**
Room 201

| Title | Presenter |
|---|---|
| Capture-recapture type model for Estimating Elusive Events with Tag Loss. | Danjuma Jibasen |
| Optimality Theory analysis of frozen and non-frozen Binomials in Annang Language. | Imoh U. Moffat |
| Geo-Additive Modelling of Family Size in Nigeria. | Oluwayemisi Oyeronke Alaba |
| Existence of solutions for stochastic functional differential equations driven by G-Brownian motion with discontinuous coefficients. | Faiz Faizullah |

| Time | Event | Place |
|---|---|---|
| 10.00-10.45 | Plenary session | CSTI D-21, r.007 |

| Title | Presenter |
|---|---|
| Large deviation properties of $f$-divergences restricted to partitions. | László Györfi |

| Time | Event | Place |
|---|---|---|
| 10.45-11.15 | Coffee break | CSTI D-21 - Hall |
| 11.15-13.00 | Invited Sessions | CSTI D-21 |

## Change detection, estimation and testing (Part I)

Organizers: Ewaryst Rafajłowicz, Ansgar Steland (Room 102)

1. Ansgar Steland:Large sample approximations for inference and change-point analysis of high dimensional data.

2. Wolfgang Stummer: Change-point analysis tools by means of scaled Bregman distances.

3. Ewa Skubalska-Rafajłowicz: Change-point detection of the mean vector with fewer observations than the dimension using instantaneous normal random projections.

4. Jacek Leśkow: Relative Measures and Their Application to Inference for Time Series and Signals.

## Nonparametric Statistics for Image Analysis (Part II)

Organizers: Hajo Holzman, Mirosław Pawlak (Room 103)

1. Thomas Hotz: Non-asymptotic confidence regions for spherical means with applications to shape analysis.

2. Katharina Proksch: Simultaneous Confidence Bands in Nonparametric Regression - With Applications to Image Analysis.

3. Gerrit Eichner: Rank Transformed Kernel Density Estimation: The $L^2$-Approach.

4. Timo Aspelmeier: Statistical challenges for superresolution fluorescence microscopy.

**Experiment design (part II)**

Organizers: Sven Knoth, Reiner Schwabe, Dariusz Uciński

Room 201

| Title | Presenter |
|---|---|
| Trajectory selection for reconstruction and optimization of performance function in UMV. | Eva Riccomagno |
| Taking account of covariance estimation uncertainty in spatial sampling design for prediction with trans-Gaussian random fields. | Gunter Spöck |
| Poisson Model with Three Binary Predictors: When are Saturated Designs Optimal? | Heinz Holling |
| On optimal crossover designs in a model with carryover-effects which are proportional to direct effects. | Joachim Kunert |

| Time | Event | Place |
|---|---|---|
| 13.00-14.30 | Lunch | CSTI D-21 - Hall |
| 14.30-16.00 | Invited sessions | CSTI D-21 |

**Change detection, estimation and testing (part III)**
Organizers: Ewaryst Rafajłowicz, Ansgar Steland
Room 102

| Title | Presenter |
|---|---|
| Detecting changes in spatial-temporal image data. | Annabel Prause |
| Long-run variance estimation for spatial data under change-point alternatives. | Beatrice Bucchia |
| Testing for a change in the correlation of time series. | Christoph Heuser |
| Detection of essential changes in spatio-temporal processes with applications to camera based quality control. | Ewaryst Rafajłowicz |

**Statistics in Energy (part I)**
Organizer: Rafał Weron
Room 103

| Title | Presenter |
|---|---|
| Review of electricity price models used in practice by a power utility. | Clemence Alasseur |
| GEFCom2014 and probabilistic electricity price forecasting. | Jakub Nowotarski |
| Forecasting renewable energy generation: from simple approaches to high-dimensional distributed learning. | Pierre Pinson |

**Experiment design (part III)**
Organizers: Reiner Schwabe, Dariusz Uciński
Room 201

| Title | Presenter |
|---|---|
| Optimal designs for survival models. | Stefanie Biederman |
| On the Optimality of Harmonic Excitation As Input Signals for the Characterization of Smart Materials. | Tom Lahmer |
| Computing D-optimal experimental designs for estimating treatment contrasts under the presence of a nuisance time trend. | Radoslav Harman |
| Decentralized time-constrained scheduling for sensor network in identification of distributed parameter systems. | Maciej Patan |

| Time | Event | Place |
|---|---|---|
| 16.00-16.30 | Coffee break | CSTI D-21 - Hall |
| 16.30-18.00 | Invited Sessions | CSTI D-21 |

**Discrete-Valued Time Series**
Organizer: Christian H. Weiß
Room 102

| Title | Presenter |
|---|---|
| On the Time-Reversibility of Integer-Valued Autoregressive Processes of General Order. | Sebastian Schweer |
| Threshold models for integer-valued time series with infinite and finite range. | Tobias Möller |
| The Marginal Distribution of Compound Poisson INAR(1) Processes. | Christian H. Weiß |
| Combining Time Series Forecasting. Methods for Internet Traffic. | Christos Katris |

## Statistics in Energy (part II)
Organizer: Organizer:Rafał Weron (Room 103)

1. Almut E. D. Veraart: The impact of wind power production on electricity prices.
2. Alessandro Sapio: The impact of renewables on electricity prices and congestion in a regime switching model: Evidence from the Italian grid.
3. Matylda Jabłonska-Sabuka: Periodic models for hydrological storage reservoir levels. Case Study of New Zealand.
4. Daniel Ambach: Obtaining Superior Wind Power Predictions from a Periodic and Heteroscedastic Wind Power Prediction Tool.

**Control Charts and Applications**
Organizers: Reiner Schwabe, Dariusz Uciński
Room 201

| Title | Presenter |
|---|---|
| An Exact Formula for the Average Run Length to False Alarm of the Generalized Shiryaev–Roberts Procedure for Change-Point Detection under Exponential Observations. | Aleksey S. Polunchenko |
| Synthetic Control Charts and Diverse Steady-State ARL Concepts. | Sven Knoth |

# Friday, 20.02.2015

| Time | Event | Place |
|---|---|---|
| 9.50-11.30 | Invited Sessions | CSTI D-21 |

**Nonparametric Estimation and Its Applications**
Organizer: Adam Krzyżak
Room 102

| Title | Presenter |
|---|---|
| Smoothed Nonparametric Derivative Estimation Based on Sequences Weighted Difference. | Kris De Brabanter |
| Adaptive density estimation from data containing bounded measurement errors. | Adam Krzyżak |
| Risk of selection of irrelevant features from high-dimensional data with small sample size. | Henryk Maciejewski |
| Learning with localized support vector machines. | Ingo Steinwart |

## Statistics in Energy (part III)
Organizer: Organizer:Rafał Weron (Room 103)

1. Kai Erik Dahlen: ORisk Modelling of Energy Futures: A comparison of RiskMetrics, Historical Simulation, Filtered Historical Simulation, and Quantile Regression.

2. Michael Schürle: A spot-forward model for electricity prices with regime shifts.

3. Olivier Féron: Modeling spot, forward and option prices of several commodities: a regime switching approach.

4. Florentina Paraschiv: Optimization of hydro storage systems and indifference pricing of power contracts.

5. Carlo Lucheroni: Thermal and Nuclear Energy Portfolio Selection using stochastic LCOE risk measures.

**Probabilistic Modelling**
Organizer: Krzysztof Szajowski
Room 201

| Title | Presenter |
|---|---|
| Joint calibration of temperature and wind speed forecasts using Bayesian Model Averaging. | Sándor Baran |
| Detection of Change Points in Earthquakes data; A Bayesian approach. | Fahimah Al-Awadhi |
| Kernel estimation of Wiener-Hammerstein system nonlinearity. | Grzegorz Mzyk |

| Time | Event | Place |
|---|---|---|
| 11.30-12.00 | Coffee break | CSTI D-21 - Hall |
| 12.00-12.30 | Closing ceremony | CSTI D-21 - Hall |
| 12.30-14.30 | Lunch | CSTI D-21 - Hall |
| 14.30-17.25 | Invited sessions | CSTI D-21 |

## Statistics in Energy (part IV)

Organizer: Organizer:Rafał Weron (Room 103)

1. Kai Erik Dahlen: ORisk Modelling of Energy Futures: A comparison of RiskMetrics, Historical Simulation, Filtered Historical Simulation, and Quantile Regression.
2. Michael Schürle: A spot-forward model for electricity prices with regime shifts.
3. Olivier Féron: Modeling spot, forward and option prices of several commodities: a regime switching approach.
4. Florentina Paraschiv: Optimization of hydro storage systems and indifference pricing of power contracts.
5. Carlo Lucheroni: Thermal and Nuclear Energy Portfolio Selection using stochastic LCOE risk measures.
6. Paolo Falbo: Approximating Markov Chains for Bootstrapping and Simulation in Electricity Markets.
7. Katarzyna Maciejowska: Fundamental and speculative shocks - structural analysis of electricity markets.
8. Takashi Kanamura: Dynamic Price Linkage and Volatility Structure Model between Carbon Markets.

# Contents

# Mixture and Non-Mixture Cure Rate Model Considering The Burr XII Distribution

**Jorge Alberto Achcar** *Social Medicine, Medical School , University of São Paulo , Brazil*
**Emílio Augusto Coelho-Barros** *Social Medicine, Medical School , University of São Paulo , Brazil*
**Josmar Mazucheli** *Social Medicine, Medical School , University of São Paulo , Brazil*

**Abstract:** This paper presents estimates for the parameters included in long-term mixture and non-mixture lifetime models, applied to analyze survival data when some individuals may never experience the event of interest. We consider the case where the lifetime data have a three-parameter Burr XII distribution, which includes the popular Weibull mixture model as a special case.

# Geo-Additive Modelling of Family Size in Nigeria

**Oluwayemisi Oyeronke Alaba** *Department of Statistics, University of Ibadan, Nigeria and Department of Statistics, University of South Africa*
**J. O. Olaomi** *Department of Statistics, University of South Africa*

**Abstract:** The 2013 Nigerian Demographic Health Survey (NDHS) data was used to investigate the determinants of family size in Nigeria using the geo-additive model. The fixed effect of categorical covariates were modelled using the diffuse prior, P-spline with second-order random walk for the non-linear effect of continuous variable, spatial effects followed Markov random field priors while the exchangeable normal priors were used for the random effects of the community and household. The Negative Binomial distribution was used to handle over dispersion of the dependent variable. Inference was fully Bayesian approach. Results showed a declining effect of secondary and higher education of mother, Yoruba tribe, Christianity, family planning, mother giving birth by caesarean section and having a partner who has secondary education on family size. Big family size is positively associated with age at first birth, number of daughters in a household, being gainfully employed, married and living with partner, community and household effects.

# Review of electricity price models used in practice by a power utility

**Clemence Alasseur** *EDF R& D, France*

**Abstract:** Due the particular nature of electricity, power markets are organized through different prices for different maturities: forward markets, spot, intraday, adjustment markets... This quite complex structure of electricity markets make it challenging to model as a whole. In this talk, I will briefly describe their major characteristics focusing mainly on French organization. Power companies are faced with several applications for which electricity price models are required such as physical portfolio and risk management, trading or even investment decisions. A unique price model cannot be satisfactory for this various topics and I will make a review of the different types of price models we used in practice. I will also emphasize on qualities models should exhibit depending on the application.

# Detection of Change Points in Earthquakes data; A Bayesian approach.

**Fahimah A. Al-Awadhi** *Department of Statistics and Operations Research, Kuwait University, Kuwait*
**D. Al-Hulail** *Department of Statistics and Operations Research, Kuwait University, Kuwait*

**Abstract:** In this study, we applied the Bayesian hierarchical model to detect single and multiple change points for daily earthquake body wave magnitude. The change point analysis is used in both backward (off-line) and forward (on-line) statistical research. In this study, it is used with the backward approach. Different types of change parameters are considered (mean, variance or both). The posterior model and the conditional distributions for single and multiple change points are derived and implemented using BUGS software. The model is applicable for any set of data. The sensitivity of the model is tested using different prior and likelihood functions. Using Mb data, we concluded that during January 2002 and December 2003, three changes occurred in the mean magnitude of Mb in Kuwait and its vicinity.

# Obtaining Superior Wind Power Predictions from a Periodic and Heteroscedastic Wind Power Prediction Tool

**Daniel Ambach** *Department of Statistics, European University Viadrina, Frankfurt (Oder), Germany*
**Carsten Croonenbroeck** *European University Viadrina, Frankfurt (Oder), Germany*

**Abstract:** The Wind Power Prediction Tool (WPPT) has successfully been used for accurate wind power forecasts in the short to medium term scenario (up to 12 hours ahead). Since its development about a decade ago, a lot of additional stochastic modeling has been applied to the interdependency of wind power and wind speed. We improve the model in three ways: First, we replace the rather simple Fourier series of the basic model by more general and flexible periodic Basis splines (B-splines). Second, we model conditional heteroscedasticity by a threshold-GARCH (TGARCH) model, one aspect that is entirely left out by the underlying model. Third, we evaluate several distributional forms of the model's error term. While the original WPPT assumes gaussian errors only, we also investigate whether the errors may follow a Student's t-distribution as well as a skew t-distribution. In this article we show that our periodic WPPT-CH model is able to improve forecasts' accuracy significantly, when compared to the plain WPPT model.

# Statistical challenges for superresolution fluorescence microscopy

**Timo Aspelmeier** *Institute for Mathematical Stochastics, Georg-August University of Göttingen, Germany*

**Abstract:** Conventional light microscopes have been used for centuries for the study of small length scales down to about 250nm. Due to fundamental physical limitations, this is the smallest accessible length scale of optical microscopes. In recent years, however, it has become possible to circumvent this inherent resolution limit for fluorescence microscopes and to achieve resolutions of down to about 20nm. The methods which are able to resolve such small length scales introduce new statistical challenges as the images are often acquired as abstract data which need to be analysed and processed by statistical means in order to reconstruct useable images. Here I will present some of these microscopic techniques, the specific statistical problems encountered and show some results for statistical image reconstruction.

# Stochastic dynamics of G-protein-coupled cell-surface receptors

**Michał Balcerek** *Hugo Steinhaus Center, Department of Mathematics, Wroclaw University of Technology, Poland*
**Aleksander Weron** *Hugo Steinhaus Center, Department of Mathematics, Wroclaw University of Technology, Poland*

**Abstract:** The field of bio-medicine has seen immense increase in single particle tracking techniques and experimental results. We present the analysis of the data obtained from experiment described by D. Calebiro et al. [1] describing the motion of fluorescently labeled G-protein-coupled cell-surface receptors. Our study revealed that some proteinsâĂŹ trajectories do not have Gaussian increments. By using various like: p-variation analysis ([3, 8]), dynamical functional analysis ([4, 9, 10]), MSD analysis ([3, 4, 5]), we attempt to narrow down possible models of particles in biological system. For more methods used in analysis (and their description), yet not included in this talk, see [6].

**General information**

In this talk we discuss our results for two data sets containing single molecule coordinates of fluorescently labeled G-protein-coupled receptors.
While the first data set consisted of 4111 trajectories measured in 400 time frames, the second data set consists of 6345 trajectories, also measured in 400 time frames (we will mostly focus on the first data set, though the second data set is quite similar). Both data sets are highly irregular, due to fluorescence blinking and fading out the measured trajectories have gaps, they are of uneven length and usually they are very short (more information about the experiment itself can be found in [1]).
Our study revealed that some of scrutinized trajectories' one-dimensional increments (i.e. $dX_t = X_t - X_{t-1}$ and $dY_t = Y_t - Y_{t-1},\ t = 1, \ldots, 400$) did not present Gaussian behaviour. This is typical for anomalous subdiffusion in biological cells, see for example [3, 5]. We focused mostly on those trajectories, and due to statistical purposes we analysed only those trajectories which were measured in over 70 continuous (without gaps) time frames; those are referred to as the "longer trajectories". Unfortunately there are only 102 such trajectories in the first data set and 99 in the second data set. All trajectories' increments show stationary behaviour (e.g. by plotting quantile lines), a property which is essential for further presented analysis.
Behaviour of all trajectories and those trajectories that increments do not follow Gaussian law can be seen in the left and the right part of Figure 1 respectively.

# References

[1] Calebiro D et al. (2013), Proc. Nat. Acad. Sci., vol. 110, no. 2: 743-748.

[2] Calebiro D et al. (2014), Curr. Opin. Cell Biol., 27:87âĂŞ93, doi: 10.1016/j.ceb.2013.11.009.

[3] Burnecki K and Weron A (2010), Phys. Rev. E **82**, 021130.

[4] Burnecki K et al. (2012), Biophys. J., Vol. 103: 1839âĂŞ1847.

[5] Burnecki K, Sikora G and Weron A (2012), Phys. Rev. E **86**, 041912.

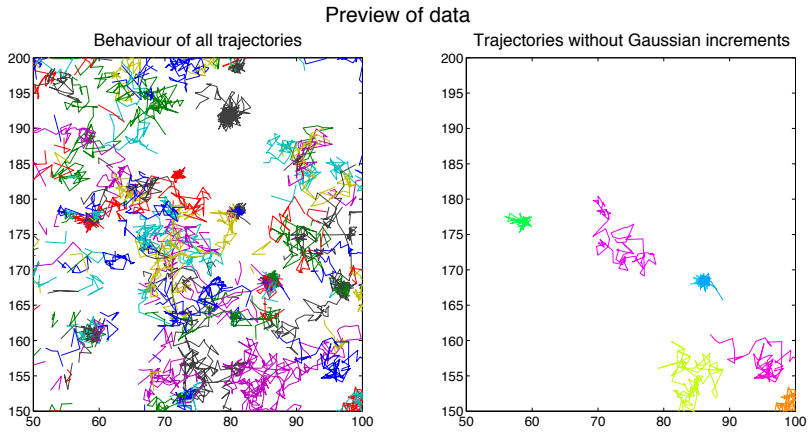



Figure 1: Behaviour of all trajectories in the first data set (left panel) compared to behaviour of trajectories without Gaussian increments (right panel).

[6] Burnecki K and Weron A (2014), Algorithms for testing of fractional dynamics: a practical guide to ARFIMA modelling, to appear in J.Stat.Mech.

[7] Burnecki K, Wyłomańska A et al. (2012) Phys. Rev. E 85, 056711.

[8] Magdziarz M, Weron A, Burnecki K and Klafter J (2009), Phys. Rev. Lett. 103, 180602.

[9] Magdziarz M, Weron A (2011), Ann. Phys. **326**: 2431âĂŞ2443.

[10] Magdziarz M, Weron A (2011), Phys. Rev. E **84**, 051138.

[11] Lasota A and Mackey MC (1994) Chaos, Fractals and Noise: Stochastic Aspects of Dynamics. Springer-Verlag, New York.

[12] Janicki A and Weron A (1994), Simulation and Chaotic Behaviour of $\alpha$-Stable Stochastic Processes. Marcel Dekker, New York.

# Joint calibration of temperature and wind speed forecasts using Bayesian Model Averaging

**Sándor Baran** *Department of Applied Mathematics and Probability Theory, University of Debrecen, Hungary*
**Anette Möller** *Department of Animal Sciences, University of Göttingen, Germany*

**Abstract:** The evolution of the weather can be described by deterministic numerical weather forecasting models. Multiple runs of these models with different initial conditions result in forecast ensembles which are used for estimating the distribution of future atmospheric variables. However, these ensembles are usually under-dispersive and uncalibrated, so post-processing is required.

We present a bivariate Bayesian Model Averaging (BMA) model [3] for joint calibration of wind speed and temperature forecasts based on the bivariate truncated normal distribution. It extends the univariate truncated normal BMA model [1] designed for post-processing ensemble forecast of wind speed by adding a normally distributed temperature component with a covariance structure representing the dependency among the two weather quantities.

The method is applied to wind speed and temperature forecasts of the eight-member University of Washington mesoscale ensemble and of the eleven-member ALADIN-HUNEPS ensemble of the Hungarian Meteorological Service and its predictive performance is compared to that of the general Gaussian copula method [2]. The results indicate improved calibration of probabilistic and accuracy of point forecasts in comparison to the raw ensemble and the overall performance of this model is able to keep up with that of the Gaussian copula method.

**Acknowledgement**
Research was partially supported by the TÁMOP-4.2.2.C-11/1/KONV-2012-0001 project. The project has been supported by the European Union, co-financed by the European Social Fund.

## References

[1] Baran, S. (2014). Probabilistic wind speed forecasting using Bayesian model averaging with truncated normal components. *Comput. Stat. Data Anal.* 75: 227–238.

[2] Möller, A., Lenkoski, A., Thorarinsdottir, T. L. (2013). Multivariate probabilistic forecasting using ensemble Bayesian model averaging and copulas. *Q. J. R. Meteorol. Soc.* 139: 982–991.

[3] Raftery, A. E., Gneiting, T., Balabdaoui, F., Polakowski, M. (2005). Using Bayesian model averaging to calibrate forecast ensembles. *Mon. Wea. Rev.* 133: 1155–1174.

# Optimal designs for survival models

**Stefanie Biedermann** *University of Southampton, UK*
**Maria Konstantinou** *Ruhr-Universität Bochum, Germany*
**Alan Kimber** *University of Southampton, UK*

**Abstract:** Censoring occurs in many industrial or biomedical 'time to event' experiments. Finding efficient designs for such experiments can be problematic for various reasons:

1. The statistical models involved may be nonlinear, making the optimal choice of design parameter dependent;
2. In addition, there may be uncertainty about the form of the model;
3. More flexible semiparametric models may be used, for which only limited theory on optimal design is available.

We provide analytical characterisations of locally $D$- and $c$-optimal designs for a popular class of models. Different censoring mechanisms are incorporated and the robustness of designs against parameter misspecification is assessed. We then consider optimal designs for the situation where the true model is within a neighbourhood of the assumed model. We illustrate our results using the natural proportional hazards parameterisation of the exponential regression model. Finally we will present some results on optimal designs for Cox's proportional hazard model (Cox, 1972), and show a relationship with optimal designs for parametric models.

# References

[1] Cox, D.R.: Regression models and life tables. J. R. Stat. Soc. Ser. B Stat. Methodol., **34**, 187–220 (1972)

[2] Konstantinou, M., Biedermann, S. and Kimber, A.C.: Optimal designs for two-parameter nonlinear models with application to survival models. Statist. Sinica, **24**, 415–428 (2014)

[3] Konstantinou, M., Biedermann, S. and Kimber, A.C.: Optimal designs for full and partial likelihood information - with application to survival models. Under revision.

[4] Konstantinou, M., Biedermann, S. and Kimber, A.C.: Minimax optimal designs for approximately exponential regression models. preprint.

# Estimation for the Modulated Power Law Process

**Krzysztof Boczkowski** *Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*
**Alicja Jokiel-Rokita** *Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*

**Abstract:** The modulated power law process (MPLP) has been proposed in [2] as a compromise between the non-homogeneous Poisson process and the renewal process models. This model is a special case of the inhomogeneous gamma process (IGP) introduced in [1]. Since the class of trend renewal processes (TRP's), introduced by Lindqvist in [3], includes IGP, the MPLP is also a special case of TRP. The MPLP is often used to model failure data from repairable systems, when both renewal type behaviour and time trend are present. It is also useful in analyzing duration dependence in economic and financial cycles (see for example [4] and [5]. In the paper we consider a problem of estimation for the MPLP under failure truncated sampling scheme. We propose methods for estimating the expected value of the next failure time. They are based on the generalized method of moments and on the least squares method. We compare the obtained estimators with the maximum likelihood ones.

## References

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

[2] Lakey M. J. and Rigdon S. E. (1992). The modulated power law process. In *Proceedings of the 45th Annual Quality Congress.*, pages 559–563, Milwaukee, WI. American Society of Quality Control.

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

[4] Zhou H. and Rigdon S. E. (2008). Duration dependence in us business cycles: An analysis using the modulated power law process. *J. Econ. Finan.*, 32:25–34.

[5] Zhou H. and Rigdon S. E. (2011). Duration dependence in bull and bear stock markets. *Modern Economy*, 2:279–286.

# Joint Genotype- and Ancestry-based Genome-wide Association Studies in Admixed Populations

**Małgorzata Bogdan** *Department of Mathematics, Wroclaw University of Technology, Poland*
**Florian Frommlet** *Department of Medical Statistics, Medical University of Vienna, Austria*
**Piotr Szulc** *Department of Mathematics, Wroclaw University of Technology, Poland*
**Hua Tang** *Departments of Genetics and Statistics, Stanford University, USA*

**Abstract:** Genome-wide association studies (GWAS) have become a popular approach for mapping loci which influence complex traits. The complementary design of admixture mapping allows to identify loci which underlie population-level phenotypic differences. The purpose of this talk is to introduce a method that jointly models genotype and ancestry information for population-based GWAS. To this end a modified version of the Bayesian Information Criterion is developed, which accounts for the differential correlation structure due to linkage disequilibrium and admixture linkage disequilibrium. Simulation studies are performed to compare the efficiency of the joint model and conventional single-marker models.

# SLOPE – Adaptive Variable Selection via Convex Optimization

**Małgorzata Bogdan** *Department of Mathematics, Wroclaw University of Technology, Poland*
**Ewout van den Berg** *IBM T.J. Watson Research Center, USA*
**Chiara Sabatti** *Departments of Health Research and Policy and of Statistics, Stanford University, USA*
**Weijie Su** *Department of Statistics, Stanford University, USA*
**Emmanuel J. Candès** *Departments of Mathematics and of Statistics, Stanford University, USA*

**Abstract:** We introduce a new estimator for the vector of coefficients $\beta$ in the linear model $y = X\beta + z$, where $X$ has dimensions $n \times p$ with $p$ possibly larger than $n$. SLOPE, short for Sorted L-One Penalized Estimation, is the solution to

$$\min_{b\in\mathbb{R}^p} \quad \frac{1}{2}\|y - Xb\|_{\ell_2}^2 + \lambda_1|b|_{(1)} + \lambda_2|b|_{(2)} + \ldots + \lambda_p|b|_{(p)},$$

where $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_p \geq 0$ and $|b|_{(1)} \geq |b|_{(2)} \geq \ldots \geq |b|_{(p)}$ are the decreasing absolute values of the entries of $b$. This is a convex program and we demonstrate a solution algorithm whose computational complexity is roughly comparable to that of classical $\ell_1$ procedures such as the lasso. Here, the regularizer is a sorted $\ell_1$ norm, which penalizes the regression coefficients according to their rank: the higher the rank—i. e. the stronger the signal—the larger the penalty. This is similar to the Benjamini-Hochberg procedure (BH), which compares more significant p-values with more stringent thresholds. One notable choice of the sequence $\{\lambda_i\}$ is given by the BH critical values $\lambda_{BH}(i) = z(1 - i \cdot q/2p)$, where $q \in (0, 1)$ and $z(\alpha)$ is the quantile of a standard normal distribution. SLOPE aims to provide finite sample guarantees on the selected model; of special interest is the false discovery rate (FDR), defined as the expected proportion of irrelevant regressors among all selected predictors. Under orthogonal designs, SLOPE with $\lambda_{BH}$ provably controls FDR at level $q$. Moreover, it also appears to have appreciable inferential properties under more general designs $X$ while having substantial power, as demonstrated in a series of experiments running on both simulated and real data.

# Nonparametric estimation of a conditional density

**Ann-Kathrin Bott** *Fachbereich Mathematik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt, Germany*
**Michael Kohler** *Fachbereich Mathematik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt, Germany*

**Abstract:** The goal is to estimate a conditional density. In contrast to standard results in the literature in this context we assume that for each observed value of the covariate we observe a sample of the corresponding conditional distribution of size larger than one. A density estimate is defined taking into account the data from all the samples by computing a weighted average using weights depending on the covariates. The error of the density estimate is measured by the $L_1$–error. Results concerning consistency and rate of convergence of the estimate are presented. Furthermore the estimate is applied to a problem in fatigue analysis.

# Long-run variance estimation for spatial data under change-point alternatives

**Beatrice Bucchia** *Department of Mathematics, University of Cologne, Germany*

**Abstract:** In this talk, we consider the problem of estimating the long-run variance of an $\mathbb{R}^p$-valued multiparameter stochastic process $\{X_{\mathbf{k}}\}_{\mathbf{k}\in[1,n]^d}$, $(n, p, d \in \mathbb{N},\ p, d$ fixed) whose mean-function has an abrupt jump. This is modeled in the form

$$X_{\mathbf{k}} = Y_{\mathbf{k}} + \mu + I_{C_n}(\mathbf{k})\Delta,$$

where $I_C$ is the indicator function for a set $C$, the change-set $C_n \subset [1, n]^d$ is a finite union of rectangles and $\mu, \Delta \in \mathbb{R}^p$ are unknown parameters. We assume that the centered weakly stationary process $\{Y_{\mathbf{k}}\}_{\mathbf{k}\in\mathbb{Z}^d}$ fulfills a weak invariance principle and some moment conditions. Due to the non-constant mean, kernel-type long-run variance estimators using the arithmetic mean of the observations as a mean estimator have an unbounded error for changes $\Delta$ that do not vanish for $n \to \infty$. To reduce this effect, we use a mean estimator which is based on an estimation of the set $C_n$.

# On the Asymptotic Behavior of Systems Based on Sequential Order Statistics

**Marco Burkschat** *Institute of Statistics, RWTH Aachen University, Germany*
**Jorge Navarro** *Facultad de Matemáticas, Universidad de Murcia, Spain*

**Abstract:** Sequential order statistics can be used to describe the successive failure times of components in a system, where failures may affect the performance of remaining components. In the talk, coherent systems consisting of corresponding failure-dependent components are considered. The limiting behavior of the hazard rate of the system lifetime is examined and related results for the system survival function are given. Furthermore, applications to the comparison of the performance of different systems in the long run and to characteristics in a signature-based representation of the residual system lifetime are presented.

# On hitting times for Markov time series of counts with applications to quality control

**Manuel Cabral Morais** *CEMAT and Instituto Superior Técnico, Universidade de Lisboa, Portugal*
**António Pacheco** *CEMAT and Instituto Superior Técnico, Universidade de Lisboa, Portugal*

**Abstract:** Examples of time series of counts arise in several areas, for instance in epidemiology, industry, insurance and network analysis. Several time series models for these counts have been proposed and some are based on the binomial thinning operation, namely the integer-valued autoregressive (INAR) model, which mimics the structure and the autocorrelation function of the autoregressive (AR) model.

The detection of shifts in the mean of an INAR process is a recent research subject and it can be done by using quality control charts. Underlying the performance analysis of these charts, there is an indisputable popular measure: the run length (RL), the number of samples until a signal is triggered by the chart. Since a signal is given as soon as the control statistic falls outside the control limits, the RL is nothing but a hitting time.

In this paper, we use stochastic ordering to assess:

- the ageing properties of the RL of charts for the process mean of Poisson INAR(1) output;
- the impact of shifts in model parameters on this RL.

We also explore the implications of all these properties, thus casting interesting light on this hitting time for a Markov time series of counts.

# Model selection using Cramér-von Mises distance

**Hong Chen** *Department of Applied Mathematics and Statistics, University of Hohenheim, Germany*

**Abstract:** In this paper we consider a model selection problem for the distribution function of lifetimes in the presence of covariates. We propose a new model selection method by defining the closeness between two distribution functions by the Cramér-von Mises distance. This distance is used mostly in the literature to conduct goodness of fit tests. Given a set of data and two competing classes of parametric distribution functions, we define a test statistic, to decide which class approximates the underlying distribution better. This approach is extended to the selection between a parametric model and the proportional hazard model. With increasing sample size the asymptotic normality property of our test statistic is shown under suitable conditions. As an example, we apply our method to a real data set of lifetimes of DC-motors, which depend on the covariate *load*. A simulation study reveals that the test has good finite-sample property.

# Statistical method to estimate a regime-switching Lévy model

**Julien Chevallier** *Université Paris 8 and IPAG Business School (IPAG Lab), France*
**Stéphane Goutte** *Université Paris 8 and ESG Management School (ESG MS), France*

**Abstract:** A regime-switching Lévy model combines jump-diffusion under the form of a Lévy process, and Markov regime-switching where all parameters depend on the value of a continuous time Markov chain. We start by giving general stochastic results. Estimation is performed following a two-step procedure. The EM-algorithm is extended to this new class of jump-diffusion regime-switching models. An empirical application is dedicated to the study of Asian equity markets.

# Bias Calculations for Adaptive Generalised Linear Models

**Steve Coad** *School of Mathematical Sciences, Queen Mary, University of London, U.K.*

**Abstract:**
A generalised linear model is considered in which the design variables may be functions of previous responses. Interest lies in estimating the parameters of the model. Approximations are derived for the bias and variance of the maximum likelihood estimators of the parameters. The derivations involve differentiating the fundamental identity of sequential analysis.

**Introduction**

An adaptive normal linear model was considered in [1] in which the design variables may be functions of the previous responses and/or auxiliary randomisation. Approximations were derived for the bias and variance of the maximum likelihood estimators of the parameters. The aim of the present work is to extend these ideas to the class of generalised linear models.

**Adaptive generalised linear models**

Consider an adaptive generalised linear model in which the $k$th response has probability distribution

$$f(y_k;\theta) = \exp[\{y_k\eta_k - a(\eta_k) + b(y_k)\}/\phi]$$

for $k = 1, 2, \ldots$, where $\theta$ is a $p$-vector, $\eta_k = h(x_k^T\theta)$, $x_k$ is a $p$-vector of design variables and $\phi$ is known [2]. The model is adaptive in the sense that

$$x_k = x_k(y_1, \ldots, y_{k-1})$$

for $k = 1, 2, \ldots$.

The likelihood function based on $(x_1, y_1), \ldots, (x_n, y_n)$ is

$$L_n(\theta) \propto \exp\left[\frac{1}{\phi}\left\{\sum_{k=1}^{n} y_k\eta_k - \sum_{k=1}^{n} a(\eta_k) + \sum_{k=1}^{n} b(y_k)\right\}\right]$$

for all $\theta$. So the gradient with respect to $\theta$ of the log-likelihood function is

$$\nabla \log L_n(\theta) = \frac{1}{\phi}\sum_{k=1}^{n}\{y_k - a'(\eta_k)\}h'(x_k^T\theta)x_k$$

for all $\theta$.

The Hessian with respect to $\theta$ is

$$\nabla^2 \log L_n(\theta) = -\frac{1}{\phi}\sum_{k=1}^{n} a''(\eta_k)h'(x_k^T\theta)^2 x_k x_k^T + O_p(1)$$

for all $\theta$. Note that

$$\sum_{k=1}^{n} x_k a''(\eta_k)h'(x_k^T\theta)^2 x_k^T = X_n^T W_n X_n,$$

where $X_n = (x_1, \ldots, x_n)^T$, $W_n = \mathrm{diag}(w_1, \ldots, w_n)$ and $w_k = a''(\eta_k)h'(x_k^T\theta)^2$.

**Bias and variance approximations**

Let $P_\theta$ denote the probability measure under which the adaptive generalised linear model holds. The maximum likelihood estimator of $\theta$ is denoted by $\hat{\theta}_n$. Further, let $M_n = (X_n^T \hat{W}_n X_n)^{-1}$ and $M(\theta) = E_\theta(M_n)$, where $\hat{W}_n$ is the maximum likelihood estimator of $W_n$.

By the fundamental identity of sequential analysis [3],

$$E_\theta(M_{nij}) = \int M_{nij} dP_\theta = \int M_{nij} L_n(\theta) dP_0$$

for $i, j = 1, 2, \ldots, p$. Differentiation and a Taylor series expansion yield

$$E_\theta(\hat{\theta}_n) = \theta + \phi M^{\#}(\theta)\mathbf{1} + o\left(\frac{1}{n}\right),$$

where $M_{ij}^{\#}(\theta) = \partial M_{ij}(\theta)/\partial\theta_j$ for $i, j = 1, 2, \ldots, p$ and $\mathbf{1}$ is the unit $p$-vector. This approximation for the $O(1/n)$ bias generalises the one given in [4]. Using similar arguments, an approximation for the matrix of second moments may be obtained.

# References


[1] Coad, D. S. and Woodroofe, M. B. (1998). Approximate bias calculations for sequentially designed experiments, *Sequential Analysis* 17: 1-31.

[2] Rosenberger, W. F. and Hu, M. (2002). On the use of generalised linear models following a sequential design, *Statistics and Probability Letters* 56: 155-161.

[3] Woodroofe, M. (1982). *Nonlinear Renewal Theory in Sequential Analysis*, Society for Industrial and Applied Mathematics: Philadelphia.

[4] Cordeiro, G. M. and McCullagh, P. (1991). Bias correction in generalised linear models, *Journal of the Royal Statistical Society Series B* 53: 629-643.

# Risk Modelling of Energy Futures: A comparison of RiskMetrics, Historical Simulation, Filtered Historical Simulation, and Quantile Regression

**Kai Erik Dahlen** *Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Norway*
**Ronald Huisman** *Erasmus School of Economics, and affiliated researcher at IEB*
**Sjur Westgaard** *Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Norway*

**Abstract:** Prices of energy commodity futures often display high volatility and changes in return distribution over time, making accurate risk modelling both important and challenging. Non-complex risk measuring methods that work quite well for financial assets perform worse when applied to energy commodities. More advanced approaches have been developed to deal with these issues, but either are too complex for practitioners or do not perform consistently as the work for one commodity but not for another. The goal of this paper is to examine, from the viewpoint of a European energy practitioner, whether some non estimation complex methods for calculating Value-at-Risk can be found to provide consistent results for different energy commodity futures. We compare RiskMetrics$^{TM}$, historical simulation, filtered historical simulation and quantile regression applied to crude oil, gas oil, natural gas, coal, carbon and electricity futures.
We find that historical simulation filtered with an exponential weighted moving average (EWMA) for recent trends and volatility performs best and most consistent among the commodities in this paper.

# The epsilon-complexity of continuous functions

**Boris Darkhovsky** *Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Norway*
**Alexandra Piryatinska** *Erasmus School of Economics, and affiliated researcher at IEB*

**Abstract:** This is the first part of our joint talk named "Novel methodology of change-point detection for time series with arbitrary generated mechanisms".

Our approach based on novel conception, namely, *$\epsilon$-complexity of continuous functions*([2]). This conception is in line with Kolmogorov's idea [1] about "complexity" of objects.

Here are main definitions and results concerning the $\epsilon$-complexity.

Let $x(\cdot)$, $\|x(\cdot)\|_C = R > 0$ be a continuous function defined on the unit cube in $\mathbb{R}^k$. Let $\hat{x}(\cdot)$ be an approximation of the function constructed by its values at the nodes of a uniform grid with spacing $h$ by one of the allowable methods from collection $\mathcal{F}$.

The function $x(\cdot)$ is called *$\mathcal{F}$-nontrivial (correspondingly, totally nontrivial)* if it can not be recovered with arbitrary small error by methods $\mathcal{F}$ (correspondingly, by any enumerable collection of methods) for any $h > 0$. Put

$$\delta_x^{\mathcal{F}}(h) = \inf_{\hat{x}(\cdot)\in\mathcal{F}} \|x(\cdot) - \hat{x}(\cdot)\|_\infty.$$

The function $\delta_x^{\mathcal{F}}(h)$ is called *absolute recovery error of $x(\cdot)$ by methods $\mathcal{F}$*. Put $(\forall \epsilon \geq 0)$

$$h_x^*(\epsilon, \mathcal{F}) = \begin{cases} \inf\{h \leq 1 : \delta_x^{\mathcal{F}}(h) > \epsilon R\}, & \text{if } x(\cdot) \text{ is } \mathcal{F}-\text{nontrivial function} \\ 1, & \text{in opposite case} \end{cases}$$

**Definition.** *The number*

$$\mathbb{S}_x(\epsilon, \mathcal{F}) = -\log h_x^*(\epsilon, \mathcal{F})$$

*is called the $(\epsilon, \mathcal{F})$-complexity of an individual continuous function $x(\cdot)$.*

Let $\mathcal{T}$ be a set of totally nontrivial functions satisfying Hölder condition.

**Theorem.** *For any $x(\cdot)$ from some dense subset of $\mathcal{T}$, and any (sufficiently small) $\alpha > 0$, $r > 0$, $\gamma > 0$ there exist real numbers $\Delta > 0$, $\mathbb{A}$, $\mathbb{B}$, $|\mathbb{B}| \geq b\,(x(\cdot)) > 0$, collection of approximation methods $\mathcal{F}^*$, functions $\theta(\epsilon), \zeta(\epsilon)$ and set $M \subset [\alpha, \alpha + \Delta]$ with Lebesgue measure $\mu(M) > \Delta - r$ such that on the set $M$ for all approximation methods $\mathcal{F} \supseteq \mathcal{F}^*$ the following relations hold:*

$$\mathbb{S}_x(\epsilon, \mathcal{F}) = \mathbb{A} + \mathbb{B}\log\epsilon + \theta(\epsilon)\log\epsilon + \zeta(\epsilon), \quad \sup_{\epsilon\in M} \max(|\theta(\epsilon)|, |\zeta(\epsilon)|) \leq \gamma.$$

Let a function satisfying Hölder condition is given by its $n$ values on a uniform grid. Choose 0 Using the remaining values we approximate the values at the discarded points by the set of approximation methods $\mathcal{F}$ and find the best approximation.

**Corrolary.** *For any $x(\cdot)$ from dense subset of $\mathcal{T}$, any (sufficiently small) $\kappa > 0, \delta > 0$, and $n \geq n_0(x(\cdot))$ there exist set of approximation methods $\mathcal{F}^*$, numbers $0 < \alpha\,(n, x(\cdot)) < \beta\,(n, x(\cdot)) < 1$, functions $\rho(S), \xi(S)$ and set $N \subset Q = [\alpha(\cdot), \beta(\cdot)], \mu(N) > \mu(Q) - \delta$ such that for all $\mathcal{F} \supseteq \mathcal{F}^*$ and $S \in N$ the following relations hold:*

$$\log\epsilon = A + (B + \rho(S))\log S + \xi(S), \ \sup_{S\in N} \max(|\rho(S)|, |\xi(S)|) \leq \kappa.$$

## References

[1] A.N. Kolmogorov, *Combinatorial foundations of information theory and the calculus of probability*, Uspekhi Matematicheskikh Nauk **38** (1983), 27–36.

[2] B.S.Darkhovsky and A.Piryatinska, *A new approach to the problem of segmentation of time series of arbitrary nature*, Proc. Steklov Inst. Math **287** (2014), 61-74 (in Russian).

# Smoothed Nonparametric Derivative Estimation Based on Weighted Difference Sequences

**Kris De Brabanter** *Department of Statistics and Department of Computer Science, Iowa State University, USA*
**Yu Liu** *Department of Statistics and Department of Computer Science, Iowa State University, USA*

**Abstract:** We present a simple but effective fully automated framework for estimating derivatives nonparametrically based on weighted difference sequences. Although regression estimation is often studied more, derivative estimation is of equal importance. For example in the study of exploration of structures in curves, comparison of regression curves, analysis of human growth data, etc. Via the introduced weighted difference sequence, we approximate the true derivative and create a new data set which can be smoothed by any nonparametric regression estimator. However, the new data sets created by this technique are no longer independent and identically distributed (i.i.d.) random variables. Due to the non-i.i.d. nature of the data, model selection methods tend to produce bandwidths (or smoothing parameters) which are too small. In this paper, we propose a method based on bimodal kernels to cope with the non-i.i.d. data in the local polynomial regression framework.

# Self-concordant profile empirical likelihood ratio tests for the population correlation coefficient: a simulation study

**Thorsten Dickhaus** *Weierstrass Institute for Applied Analysis and Stochastics, Berlin, Germany*

**Abstract:** We present results of a simulation study regarding the finite-sample type I error behavior of the self-concordant profile empirical likelihood ratio (ELR) test for the population correlation coefficient. Three different families of bivariate elliptical distributions are taken into account. Uniformly over all considered models and parameter configurations, the self-concordant profile ELR test does not keep the significance level for finite sample sizes, albeit the level exceedance monotonously decreases to zero as the sample size increases. We discuss some potential modifications to address this problem.

## References

[1] Owen AB (1990) Empirical likelihood ratio confidence regions. Ann Stat 18(1):90–120

[2] Owen AB (2013) Self-concordance for empirical likelihood. Can J Stat 41(3):387–397

[3] Wilks SS (1938) The large-sample distribution of the likelihood ratio for testing composite hypotheses. Ann Math Stat 9:60–62

# Asymmetric Cusp Estimation in Regression Models

**Maik Döring** *Faculty of Statistics, TU Dortmund University, Germany*

**Abstract:** We consider the problem of estimating the location of an asymmetric cusp $\theta_0$ in a regression model. That means, we focus on regression functions, which are continuous at $\theta_0$, but the degree of smoothness from the left $p_0$ could be different to the degree of smoothness from the right $q_0$. The degrees of smoothness have to be estimated as well. We investigate the consistency with increasing sample size $n$ of the least squares estimates. It turns out that the rates of convergence of $\hat{\theta}_n$ depend on the minimum $b$ of $p_0$ and $q_0$ and that our estimator converges to a maximizer of a Gaussian process. In the regular case, i.e. for $b$ greater than $1/2$, we have a rate of $\sqrt{n}$ and the asymptotic normality property. In the non-regular case, we have a representation of the limit distribution of $\hat{\theta}_n$ as maximizer of a fractional Brownian motion with drift.

# Quantile Graphical Modelling of Point Processes

**Matthias Eckardt** *Department of Computer Science, Humboldt Universität zu Berlin, Germany*

**Abstract:** We introduce a novel graphical model termed *quantile dependence graph* capturing the dependence structure of a multivariate point process. Our nonparametric approach is based on quantile spectral properties. While vertices correspond to component processes the edge set encodes relations between components at given quantiles.

Graphical models are an efficient approach of dealing with highly complex or highly dimensional data. An introduction is given in [6]. [1, 2] and [3] derived graphical models related to stochastic point processes in the frequency domain. We will define a novel graphical model whose dependence structure is related to conditional spectral properties of a finite set of randomly occurring points of different types in time. Let $\mathbf{Z}(t), t \geq 0$ be a $d$-variate point process generating $d$ different types of points which we call events. The realizations of this point process can then be represented as a $d$-variate counting process $\mathbf{N}_V(t)$ with index set $V = \{1, \ldots, d\}$ consisting of components $N_i(t),\ i \in V$, counting the number of events of type $i$ up to time $t \in T$. Additionally, let $dN_i(t) = N_i(t + dt) - N_i(t)$ be the number of observed events of type $i$ within a infinitesimal time interval.

Instead of focussing on the mean intensity of process $N_i$ [8, 9, 10] have presented different quantile extensions with respect to censored data analysis beyond mean regression. For location $\tau \in [0, 1]$ let $N_{i,q_\tau}(t)$ denote the corresponding counting process for quantile $q_\tau$ with respect to the event of type $i$ up to time $t \in T$. Similar to [4, 5] and [7] we define the quantile cross-covariance as

$$\gamma_{ij,q_\tau}(u) = \mathrm{COV}\{\mathbf{I}(dN_i(t)t.$$

such that the quantile cross-spectra at frequency $\omega$ is given as

$$f_{ij,q_\tau}(\omega) = \int \gamma_{ij,q_\tau}(u) \exp(-\iota\omega^T u)du.$$

We denote the partialized version hereof as $f_{ij|V\setminus\{i,j\},q_\tau}(\omega)$ which can efficiently be calculated by

$$f_{ij|V\setminus\{i,j\},q_\tau}(\omega) = f_{ij,q_\tau}(\omega) - f_{aV\setminus\{i,j\},q_\tau}(\omega) f_{V\setminus\{i,j\}V\setminus\{i,j\},q_\tau}(\omega)^{-1} f_{bV\setminus\{i,j\},q_\tau}(\omega).$$

Then, the quantile spectra coherence follows as

$$R_{ij|V\setminus\{i,j\},q_\tau}(\omega) = \frac{f_{ij|V\setminus\{i,j\},q_\tau}(\omega)}{\left[f_{ii|V\setminus\{i,j\},q_\tau}(\omega) f_{jj|V\setminus\{i,j\},q_\tau}(\omega)\right]^{\frac{1}{2}}}.$$

Let $G = (V, E)$ denote a graph with $V = \{v_1, \ldots, v_k\}$ as finite set of *vertices* and $E \subseteq V \times V$ as set of *edges* where $E_{q_\tau} \subset E$ contains all edges related to quantile $q_\tau$. A *quantile dependence graph* is an undirected graphical model with possibly multiple edges joining the vertices such that $(v_i, v_j) \notin E_{q_\tau} \Leftrightarrow R_{ij|V\setminus\{i,j\},q_\tau}(\omega) = 0$. Hence, two components are conditional independent at quantile $q_\tau$ if the edge is not in $E_{q_\tau}$. Additionally, $G_{q_\tau} = (V, E_{q_\tau})$ is an undirected subgraph of $G$ at given $q_\tau$ with at most one edge joining two vertices.

# References


[1] Brillinger, D.R. (1996). Remarks Concerning Graphical Models for Time Series and Point Processes, *Revista de Econometrica*, 16: 1-23.

[2] Dahlhaus, R., Eichler, M. and Sandkühler, J. (1997). *Identification of Synaptic Connections in Neural Ensembles by Graphical Models*, Maastricht University: Maastricht.

[3] Eichler, M., Dahlhaus, R. and Sandkühler, J. (2003). Partial Correlation Analysis for the Identification of Synaptic Connections, *Biological Cybernetics* 89: 289-302.

[4] Hagemann, A. (2013). Robust Spectral Analysis, *arXiv:1111.1965*.

[5] Kley, T., Volgushev, S., Dette, H. and Hallin, M. (2014). Quantile Spectral Processes: Asymptotic Analysis and Inference, *arXiv:1401.8104*.

[6] Lauritzen, S. (1996). *Graphical Models*, Oxford University Press: Oxford.

[7] Li, T.-H. (2012). Quantile Periodograms, *Journal of the American Statistical Society*, 107: 765-776.

[8] Peng, L. and Huang, Y. (2008). Survival Analysis with Quantile Regression Models, *Journal of the American Statistical Association* 103: 637-649.

[9] Portnoy, S. (2003). Censored Quantile Regression, *Journal of the American Statistical Association* 98: 1001-1012.

[10] Powell, JL. (1986). Censored Regression Quantiles, *Journal of Econometrics* 32: 143-155.

# Rank Transformed Kernel Density Estimation: The $L^2$-Approach

**Gerrit Eichner** *Mathematical Institute, Justus-Liebig-University Giessen, Germany*
**Winfried Stute** *Mathematical Institute, Justus-Liebig-University Giessen, Germany*

**Abstract:** In [1] we studied a rank transformed kernel density estimator, which achieved the same efficiency as the Epanechnikov kernel estimator but also provides a smooth estimator which allows a reliable bandwidth selection. In the present talk we study the $L^2$-performance of this estimator. It turns out that the bias and variance term can be handled jointly and need not dealt with separately.

## References

[1] Eichner, G., Stute, W. (2013): Rank transformations in Kernel density estimation, *Journal of Nonparametric Statistics*: 25:2, 427-445.

# Existence of solutions for stochastic functional differential equations driven by G-Brownian motion with discontinuous coefficients

**Faiz Faizullah** *Department of Basic Sciences and Humanities, College of E and ME, National University of Sciences and Technology (NUST) Pakistan*

**Abstract:** In this article the existence theory for stochastic functional differential equations driven by G-Brownian motion (G-SFDEs) with discontinuous coefficients is developed. It is shown that under some suitable conditions the G-SFDEs have more than one solutions. The Heaviside and Satooth functions are used as coefficients of scalar G-SFDEs to indicate the importance of above mentioned theory in engineering and sciences.

# Approximating Markov Chains for Bootstrapping and Simulation in Electricity Markets

**Roy Cerqueti**
*Department of Economics and Law, University of Macerata, Italy*
**Paolo Falbo** *Department of Economics and Management, University of Brescia, Italy*
**Gianfranco Guastaroba** *School of Mathematics, University of Technology, Sydney, Australia*
**Cristian Pelizzari** *Department of Economics and Management, University of Brescia, Italy* **Abstract:**

In this work we develop a bootstrap method based on the theory of Markov chains. The method moves from the two competing objectives that a researcher pursues when performing a bootstrap procedure: (i) to preserve the structural similarity – in statistical sense – between the original and the bootstrapped sample; (ii) to assure a diversification of the latter with respect to the former. The original sample is assumed to be driven by a Markov chain.
The approach we follow is to implement an optimization problem to estimate the memory of a Markov chain (i.e. its order) and to identify its relevant states. The basic ingredients of the model are the transition probabilities, whose distance is measured through a suitably defined functional.
The bootstrap procedure advanced here works similarly to that of Anatolyev and Vasnev [1], who propose a Markov chain bootstrap where states correspond to the intervals resulting from a partition of the state space (of an observed time series) into a fixed number of quantiles.
However, differently from that work, our proposal places much greater care in identifying the states of the Markov chain. In particular, the approach we propose is based on the joint estimation of the relevant states and of the order of a Markov chain through an optimization problem. The solution identifies the partition which groups the states with the most similar transition probabilities. In this way the resulting groups emerge as the relevant states, that is the states which significantly influence the conditional distribution of the process.
We also show that the minimization of the objective function represented by the distance measure of the partitions, which is based on the transition probabilities of the states, corresponds to the minimization of the information loss function in the sense of Kolmogorov [3].
We apply the method to simulate the electricity prices of the Spanish market. The results confirm that the method proposed here performs better with respect to a well established bootstrap approach, such as the Variable Length Markov Chain (VLMC) bootstrap of Buhlmann and Wyner [2], in particular in reproducing the dependence among data.

## References

[1] Anatolyev S., Vasnev A. (2002). Markov chain approximation in bootstrapping autoregressions. *Econ Bull*, 3(19), pp. 1-8

[2] Buhlmann P., Wyner A.J. (1999) Variable length Markov chains. *Ann Stat*, 27(2), pp. 480-513

[3] Kolmogorov A.N. (1965). Three approaches to the quantitative definition of information. *Probl Inf Transm*, 1(1), pp. 3-11

# Compund Poisson multiple disorder problem with disorder-related penalty cost functions

**Elżbieta Z. Ferenstein** *Faculty of Mathematics and Information Science, Warsaw University of Technology, Poland*
**Adam Pasternak-Winiarski** *Faculty of Mathematics and Information Science, Warsaw University of Technology, Poland*

**Abstract:** An extension of a standard Compound Poisson disorder problem is analyzed. Two independent Compound Poisson processes are considered. Each process is subject to a disorder which can occur at an unobservable, random time. As a result of the disorder the characteristics of the process (intensity and distribution of jumps) change. The aim of the decision-maker is to derive a stopping rule which would minimize a pre-defined, nonlinear cost function. The structure of the cost function depends on the number of disorders which have occurred and its aim is to penalize the decision maker for stopping both too early and too late.

# On the convergence of Arginf-sets and infimizing points of multivariate stochastic processes with cadlag trajectories

**Dietmar Ferger** *Department of Mathematics, Technische Universität Dresden, Germany*

**Abstract:** For some fixed natural number $d$ let $X = \{X(t) : t \in \mathbb{R}^d\}$ be a real-valued stochastic process defined on some probability space $(\Omega, \mathcal{A}, \mathbb{P})$ with trajectories in the *multivariate Skorokhod-space* $D = D(\mathbb{R}^d)$ which is defined as follows. If $R = (R_1, \ldots, R_d) \in \{<, \geq\}^d$ is a ordered list of the usual relations $<$ and $\geq$ in $\mathbb{R}$ and $t = (t_1, \ldots, t_d) \in \mathbb{R}^d$ is a point in the euclidean space then

$$Q_R := Q_R(t) := \{s \in \mathbb{R}^d : s_i R_i t_i, 1 \leq i \leq d\}$$

is the *R-quadrant of t*. Given a function $f : \mathbb{R}^d \to \mathbb{R}$ the quantity

$$f(t+R) := \lim_{s \to t, s \in Q_R(t)} f(s)$$

is called the *R-quadrant-limit of f in t*. Then $D(\mathbb{R}^d)$ consists of all functions $f$ such that for each $t \in \mathbb{R}^d$ it is guaranteed: (1) $f(t+R)$ exists for all $R \in \{<, \geq\}^d$ and (2) $f(t+R) = f(t)$ for $R = (\geq, \ldots, \geq)$. Relations (1) and (2) extend the notions „limits from below" and „continuous from above" from the univariate case (d=1) to the multivariate one. Therefore it is convenient to call $f \in D$ a *cadlag function* (continue à droite limite à gauche). $D(\mathbb{R}^d)$ endowed with the *Skorokhod-metric* s is a complete separable metric space and the pertaining Borel-$\sigma$-algebra $\mathcal{D}$ is generated by the sets of all cylinders, whence $X$ can be considered as a random element $X : (\Omega, \mathcal{A}) \to (D, \mathcal{D})$.

The main object in our talk is the random set $\mathrm{Arginf}(X)$ of all *infimizers* of $X$, where

$$\mathrm{Arginf}(f) \equiv A(f) := \{t \in \mathbb{R}^d : \min_{R \in \{<, \geq\}^d} f(t+R) = \inf_{s \in \mathbb{R}^d} f(s)\}, \quad f \in D.$$

We will see that $\mathrm{A}(f)$ is a closed subset of $\mathbb{R}^d$ (possibly empty). Let $\mathcal{F} = \mathcal{F}(\mathbb{R}^d)$ denote the family of all closed subsets of $\mathbb{R}^d$ (including the empty set $\emptyset$) and let $\mathcal{F}$ be equipped with some appropriate topology $\tau$ and the pertaining Borel-$\sigma$-algebra $\mathcal{B}$. It turns out that $\mathrm{A}(X)$ is a random element in the space $(\mathcal{F}, \mathcal{B})$. We focus on the following problem:

If $(X_n)$ is a sequence of random elements in $(D, \mathcal{D})$ converging to some limit $X$ in distribution or almost surely, respectively, then under which conditions does this entail the corresponding convergence of the Arginf-sets? In other words we want to formulate versions of the Continuous Mapping Theorem for the Arginf-functional $A : D \to \mathcal{F}$.

Let $D'$ be the collection of all $f \in D$ with $A(f) \neq \emptyset$. Then by the axiom of choice for every $f \in D'$ we can chose a fixed infimizing point of $f$ and denote it by $a(f) \equiv \mathrm{arginf}(f)$. Once again the question arises which types of Continuous Mapping Theorems are valid for the functional $a : D' \to \mathbb{R}^d$.

The motivation for considering these problems stems from statistics. Here, the well-known principle of *M-estimation* yields estimators $\hat{\theta}_n$ defined as infimizing point of some random criterion function $M_n(t), t \in \mathbb{R}^d$, that is $\hat{\theta}_n := a(M_n)$ estimates a parameter $\theta = a(M)$ where $M$ is some theoretical criterion function. In nonparametric statistics the involved criterion functions typically are cadlag and its tempting to conclude as follows: If $M_n \to M$ a.s. or in probability then hopefully $\mathrm{a}(M_n) \to \mathrm{a}(M)$ and $\mathrm{A}(M_n) \to \mathrm{A}(M)$ a.s. or in probability, respectively. Clearly, we wish the convergence $M_n \to M$ to be as weak as possible and in case of set-convergence

the topology on the *hyper-space* $\mathcal{F}$ to be as large as possible. It turns out that epi-convergence seems to be the minimal setup to make the above conclusions to become true as long as a certain compactness condition is fulfilled. In applications to establish epi-convergence of the stochastic processes $M_n$ is rather intractable. In contrast, the Skorokhod-convergence is much easier to handle. As a crucial result we find that convergence in the Skorokhod-metric implies epi-convergence, whence we immediately obtain sufficient and manageable criterions for proving consistency of $(\hat{\theta}_n)$.

For the construction of confidence regions one needs convergence in distribution, i.e. $\Gamma_n(\hat{\theta}_n - \theta) \xrightarrow{\mathcal{L}} \xi$ for some suitable $d \times d$-matrices and identification of the limit variable $\xi$. The basic idea here is to introduce *rescaled* $M_n$-processes defined as

$$X_n(t) = \gamma_n\{M_n(\theta + \Gamma_n^{-1}t) - M_n(\theta)\},\ t \in \mathbb{R}^d$$

with some *normalizing* sequence $(\gamma_n)$ of positive real numbers. As a consequence of the transformation in time one obtains that $\Gamma_n(\hat{\theta}_n - \theta) = a(X_n)$ and that $\Gamma_n(A(M_n) - \theta) = A(X_n)$. Thus if $X_n \xrightarrow{\mathcal{L}} X$ in $(D, s)$ entails distributional convergence of $a(X_n)$ and $A(X_n)$ we have a powerful tool to find the limit distributions of $M$-estimators of Euclidean parameters.

# Modelling spot, forward and option prices of several commodities: a regime switching approach

**Olivier Féron** *EDF Research and Development and Finance for Energy Market Research Center, Clamart Cedex, France*
**Alain Monfort** *Centre de Recherche en Economie et Statistiques and University of Maastricht, Malakoff, France*

**Abstract:** We propose a joint modelling of spot, forward and option prices of several commodities in the Energy market, using recent developments in discrete time asset pricing methods based on the notions of stochastic discount factor and of Compound Autoregressive (or affine) stochastic processes. We show that this approach provides quasi-explicit formulae for forward and spread option prices, while allowing for a large flexibility in the modelling of dynamics, spikes and seasonality, both in the historical and the risk neutral worlds. This work is a direct extension of [2] in which this approach is applied on the electricity prices. In this work we model jointly the electricity prices as well as fuel prices, taking into account the storability properties of the latter by introducing the convenience yield. The proposed model is therefore a multivariate model with discrete latent variable for the regime switching representation, and also continuous latent variable (the convenience yield). In this context we propose an iterative approach for calibrating the model and we show an illustration in the UK Market with a model on power and gas prices.

## References

[1] C. Gourieroux and A. Monfort, "Econometric specifications of stochastic discount factor models", *Journal of Econometrics*, 136(2): 509–530, 2007.

[2] A. Mofort and O. Féron, "Joint econometric modelling of spot electricity prices, forwards and options", *Review of derivatives research*, 15(3):217–256, 2012.

[3] A. Monfort and F. Pegoraro, "Switching VARMA term structure models". *Journal of Financial Econometrics*, 5(1): 105–153, 2007.

# Time Varying Tail Dependence, Copulas and Marginal Expected Shortfall

**Tobias Eckernkemper,** *University of Cologne, Germany*
**Oliver Grothe,** *Institute of Econometric and Statistic, University of Cologne, Germany*

**Abstract:** Recently, Brownlees and Engle (2012) proposed a framework for modeling the Marginal Expected Shortfall based on a DCC-GARCH model. The correlation between marketâĂŹs and institutionâĂŹs innovations is generated by a one-factor model and they allow for additional, non-linear types of dependence (like tail dependence). While their approach is very flexible and performs well in different applications, it assumes that the non-linear dependence stays constant over time. In this paper, a copula-based alternative is proposed which embeds main elements of the Brownlees and Engle model but captures dynamic effects of linear and non-linear dependence structures. The copula parameters are modeled with the Generalized Autoregressive Score model of Creal et al. (2014).

# Large deviation properties of $f$-divergences restricted to partitions

**László Györfi** *Department of Computer Science and Information Theory, Budapest University of Technology and Economics, Hungary*

**Abstract:** We discuss Chernoff-type large deviation results for the total variation, for the I-divergence and for the $\chi^2$-divergence errors on partitions.

**Total variation error**

We consider the problem of testing hypotheses

$$H_0 : \nu = \mu \text{ versus } H_1 : \nu \neq \mu$$

by means of test statistics $T_n = T_n(X_1, \ldots, X_n)$ where $X_1, X_2, \ldots$ are independent and identically distributed $\mathbb{R}^d$ valued random vectors along $\nu$. Therefore under $H_0$ the random vectors $X_1, \ldots, X_n$ have the probability distribution $\mu$. Let $\mu_n$ denote the empirical measure, and let $\mathcal{P}_n = \{A_{n,1}, \ldots, A_{n,m_n}\}$ be a finite partition of $\mathbb{R}^d$.

Introduce the test statistic

$$J_n = \sum_{j=1}^{m_n} |\mu(A_{n,j}) - \mu_n(A_{n,j})|,$$

Beirlant et al. [1] proved that

$$\mathbf{P}\{J_n > \epsilon\} = e^{-n(g(\epsilon)+o(1))},$$

where

$$g(\epsilon) = \inf_{0<p<1-\epsilon/2} \left( p \ln \frac{p}{p+\epsilon/2} + (1-p) \ln \frac{1-p}{1-p-\epsilon/2} \right),$$

$(0 < \epsilon < 2)$. Notice that $g(\epsilon) = \frac{\epsilon^2}{2}(1 + o(1))$ as $\epsilon \to 0$.

Biau and Györfi [2] proved the upper bound

$$\mathbf{P}\{J_n > \epsilon\} \leq 2^{m_n} e^{-ng(\epsilon)}.$$

This upper bound implies strongly consistent tests for homogeneity and for independence (cf. Biau and Györfi [2], and Gretton and Györfi [3]).

**The information divergence**

The I-divergence statistic is defined by

$$I_n = \sum_{j=1}^{m_n} \mu_n(A_{n,j}) \ln \frac{\mu_n(A_{n,j})}{\mu(A_{n,j})}.$$

Kallenberg [4] and Quine and Robinson [5] proved that

$$\mathbf{P}\{I_n > \epsilon\} = e^{-n(\epsilon+o(1))}.$$

**The $\chi^2$-divergence**

The $\chi^2$ or Pearson statistic is given by

$$\chi_n^2 = \sum_{j=1}^{m_n} \frac{(\mu(A_{n,j}) - \mu_n(A_{n,j}))^2}{\mu(A_{n,j})}.$$

If the restriction of $\mu$ to $\mathcal{P}_n$ is uniform then Quine and Robinson [5] proved that

$$\mathbf{P}\{\chi_n^2 > \epsilon\} = e^{-\frac{n \ln m_n}{\sqrt{m_n}}(\sqrt{\epsilon}/2 + o(1))}.$$

We extend this sub-exponential rate of convergence. Put

$$M_n := \frac{1}{\min\{\mu(A_{n,j}); j = 1, \ldots, m_n\}} < \infty.$$

Then for all $\epsilon > 0$

$$\mathbf{P}\{\chi_n^2 > \epsilon\} = e^{-\frac{n \ln M_n}{\sqrt{M_n}}(\sqrt{\epsilon}/2 + o(1))}.$$

# References


[1] Beirlant, J., Devroye, L., Györfi, L., Vajda, I. (2001). Large deviations of divergence measures on partitions. *J. Statist. Plann. Inference*, **93**, 1–16.

[2] Biau, G., Györfi, L. (2005). On the asymptotic properties of a nonparametric $L_1$-test of homogeneity. *IEEE Trans. Information Theory*, **51**, 3965–3973.

[3] Gretton, A., Györfi, L. (2010). Consistent nonparametric tests of independence. *Journal of Machine Learning Research*, **11**, 1391–1423.

[4] Kallenberg, W. C. M. (1985). On moderate and large deviations in multinomial distributions. *Annals of Statistics*, **13**, 1554–1580.

[5] Quine, M.P., Robinson, J. (1985). Efficiencies of chi-square and likelihood ratio goodness-of-fit tests. *Annals of Statistics*, **13**, 727–742.

# Computing D-optimal experimental designs for estimating treatment contrasts under the presence of a nuisance time trend

**Radoslav Harman** *Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovakia*
**Guillaume Sagnol** *Zuse Institut Berlin, Germany*

**Abstract:** There are two main approaches to computing exact optimal designs of statistical experiments - heuristic methods and enumeration algorithms. The heuristic methods are usually simple and rapid, but the advantage of the enumeration algorithms is that they can provide solutions with guaranteed optimality. In the talk, we will propose a branch-and-bound enumeration algorithm for computing exact D-optimal designs for estimating treatment contrasts under the presence of a nuisance time trend. The crucial component of the algorithm is a novel mathematical programming characterization of approximate partial D-optimality under general linear constraints.

# Testing for a change in the correlation of time series

**Christoph Heuser** *Mathematical Institute, University of Cologne, Germany*

**Abstract:** In this talk, we consider a two dimensional stochastic process $\{(X_i, Y_i)\}_{i\in\mathbb{N}}$, satisfying some near-epoch dependence and moment assumptions, and investigate its correlation coefficients $\{\rho_i\}_{i\in\mathbb{N}}$.
We present an a-posteriori and a sequential test procedure for detecting possible changes in the correlation coefficients. More precisely, we want to test the null hypothesis

$$H_0 : \rho_0 = \rho_i, \qquad \text{for } i = 1, \ldots, n, \tag{1}$$

with some unknown $\rho_0 \in (0, 1)$, against

$$H_1^{(1)} : \rho_1 = \ldots = \rho_{k^\star} \neq \rho_{k^\star+1} = \ldots = \rho_n \tag{2}$$

in the a-posteriori case, or against

$$H_1^{(2)} : \rho_1 = \ldots = \rho_n = \ldots = \rho_{n+k^\star} \neq \rho_{n+k^\star+1} = \ldots \tag{3}$$

in the sequential case, where $k^\star$ is an unknown change-point.
The test statistics will be based on weighted CUSUM detectors and require the estimation of the long-run variance (LRV). In particular, we investigate two types of LRV estimators - a Bartlett-type kernel estimator and a modification thereof which takes the change into account. We analyze the limit behavior of the LRV estimators and of the test statistics for $n \to \infty$ under the null as well as under both alternative hypotheses. Finally, we present some simulation results to illustrate the finite sample behavior of our procedures.

# Selection of candidate genes after genome-wide screening - a challenging problem

**Josef Hoegel** *Institute for Human Genetics, University of Ulm, Germany*
**Christiane Maier** *Department of Urology, University Hospital Ulm, Germany*
**Manuel Luedeke** *Department of Urology, University Hospital Ulm, Germany*

**Abstract:** We will give an overview of statistical (and molecular) methods in the detection of genetic sequence variants. Some approaches and ideas for the prioritization of suspected DNA variants obtained from next-generation-sequencing studies will be presented and illustrated using prostate cancer as an example.

An introductory outline of methods for the detection of genetic sequence variants associated with complex diseases (as a counterpart to monogenic phenotypes) will cover genome-wide approaches as linkage and association studies as well as exome-wide sequencing. The choice of methods will be discussed. It depends amongst other things on the frequency of DNA variants assumed to increase susceptibility for the disease, and their inherent magnitude of risk.

The problem of prioritizing suspected DNA variants obtained from next-generation-sequencing studies, in order to select the most promising ones for further functional research, is crucial, bearing in mind that an "average" individual shows thousands to tens of thousands deviations from the so-called reference genome. Prioritization is in general based on scoring real or predicted characteristics of detected variants in several dimensions. Thus, the respective variant is assessed in relation to the quality of its calling from the raw data, its sample frequency in comparison to controls, and its estimated pathogenicity. Further, the gene that harbors a variant is the object of scoring. We may distinguish between genes that are prone to lower or higher "mutability" and thus may attach, e.g., higher priority to variants with elevated sample frequency in genes with low mutation rates in the population. Gene annotation, e.g. in terms of "Gene-Ontology" (GO), may be helpful, both for case by case examination of gene function as well as for automatized scoring based on measuring the "complexity" of gene description. GO annotation and similar compilations may also serve to cluster genes and thus be used for the simultaneous identification of variants with a deeper relationship between each other.

We will illustrate the application of (some of) the above principles in a sample of 50 exome sequences obtained from 25 male sibpairs, all of them affected by prostate cancer.

# Poisson Model with Three Binary Predictors: When are Saturated Designs Optimal?

**Ulrike Graßhoff** *School of Business and Economics, Humboldt University Berlin, Germany*
**Heinz Holling** *Institute of Psychology, University of Münster, Germany*
**Rainer Schwabe** *Institute for Mathematical Stochastics, University of Magdeburg, Germany*

**Abstract:** In this paper, Poisson regression models with three binary predictors are considered. These models are applied to rule-based tasks in educational and psychological testing. To efficiently estimate the parameters of these models locally $D$-optimal designs will be derived. Eight out of all 70 possible saturated designs are proved to be locally $D$-optimal in the case of active effects. Two further saturated designs which are the classical fractional factorial designs turn out to be locally $D$-optimal for vanishing effects.

# Non-asymptotic confidence regions for spherical means with applications to shape analysis

**Thomas Hotz** *Institut für Mathematik, Technische Universität Ilmenau, Germany*
**Florian Kelma** *Institut für Mathematik, Technische Universität Ilmenau, Germany*

**Abstract:** For data on spheres, their mean is defined by averaging in the ambient Euclidean space and projecting back. We show how non-asymptotic confidence regions for this mean can be constructed. Viewing projective spaces as subsets of spheres via Veronese-Whitney embeddings, these results can be applied to shape analysis. In particular, we present examples for planar similarity shapes and projective shapes, the latter having applications in computer vision.

# Some recent results in change-point analysis

**Marie Hušková** *Charles University, Prague, Czech Republic*

**Abstract:** Change-point analysis is a fast developing area with many theoretical results as well as numerous applications. After a short introduction the talk will focus on results on detection of changes in *panel data* and in *time series of counts*. While for panel data we consider *retrospective setup* (i.e. all observations are available at the beginning of statistical analysis) the part on time series of counts will concerns *sequential one*.

Results on testing and estimating in panel data when a change in the mean can occur during the observation period will be presented. It is assumed that both the number of panels as well as the number of the observations in each panel are large.

The last part will deal with sequential tests for detection of changes in time series of counts with special emphasis to the popular models of integer autoregression and Poisson autoregression.

Asymptotic properties of the suggested procedures will presented. Also results of simulation studies and applications to a real data sets will be showed.

The talk is based on joint works with L. Horváth, Š. Hudecová, S. Meintanis and some others.

# Periodic models for hydrological storage reservoir levels. Case Study of New Zealand

**Matylda Jabłońska-Sabuka** *Lappeenranta University of Technology, Department of Mathematics and Physics, Finland*
**Agnieszka Wyłomańska** *Wrocław University of Technology, Department of Mathematics, Poland*

**Abstract:** Many electricity markets across the world are strongly hydro-generation-dependent, and ability to predict hydrological storage levels is of key importance in generation planning and risk management. The purpose of this work is to introduce models reproducing periodic and irregular behavior of reservoir levels in New Zealand. The case study covers the period from January 2002 until July 2008. Two approaches are proposed here, namely, continuous time random walk with periodic probability of jumps and periodic autoregressive model. Results show that both models are capable of reproducing statistical features of the original data and provide a supporting tool for market analysts and generation planners.

# Testing the truncation invariance

**Piotr Jaworski** *Institute of Mathematics, University of Warsaw, Poland*

**Abstract:** We study the dependence between random phenomena when one of them is achieving extreme values e.g. heavy losses. In many popular models we observe the stabilization of the conditional interdependence. In more details, let $X$ and $Y$ be two random variables, we deal with the conditional (truncated) distribution $(X,Y)|X \leq q$, where $\mathbb{P}(X \leq q)$ is positive but small. To fix the notation we assume that extremely bad means extremely small, i.e. if $L$ denotes the size of the loss we put $X = -L$. If $C_{[\gamma]}$ denotes the copula of the conditional (truncated) distribution $(X,Y)|X \leq q$, where $\gamma = \mathbb{P}(X \leq q)$, then in most of the models there exists the limit when $\gamma$ tends to 0

$$\lim_{\gamma \to 0} C_{[\gamma]} = C_{[0]}.$$

Hence the dependence between random variables truncated to the sufficiently small tail can be approximated with the help of the limiting copula $C_{[0]}$.

Limiting copulas $C_{[0]}$ are invariant with respect to conditioning (truncation), i.e. if pair of the uniformly on $[0,1]$ distributed random variables $(U,V)$ serves as representer of the copula $C_{[0]}$ then it is a copula of the truncated distribution $(U,V)|U \leq \gamma$ for any $\gamma \in (0,1]$. This leads to a practical question, to which extend the empirical data support the choice of a model with stable truncated interdependence, and is the motivation of our research. The goal is to construct a test of truncation invariance of copulas, which would help to check whether the approximation of the dependence between the truncated variables by a truncated invariant copula is statistically significant.

We base on the following fact: let random variables $X$ and $Y$ with invariant copula $C$ have continuous univariate distribution functions $F_X$ and $F_Y$ and joint distribution function $F_{XY}$, then the random variables $X$ and $Z$,

$$Z = \frac{F_{XY}(X,Y)}{F_X(X)},$$

are independent. In my talk I will provide several tests based on the above and discuss their asymptotic and finite sample properties.

# References

[1] Durante,F., Jaworski,P.: Invariant dependence structure under univariate truncation, *Statistics* **46**, 263-277 (2012).

[2] Durante,F., Jaworski,P., Mesiar,R.: Invariant dependence structures and Archimedean copulas. *Statistics and Probability Letters* **81**, 1995-2003 (2011).

[3] Jaworski,P.: Invariant dependence structure under univariate truncation: the high-dimensional case. *Statistics* 47 (2013) 1064-1074.

[4] Jaworski,P.: The limiting properties of copulas under univariate conditioning, In: Copulae in Mathematical and Quantitative Finance, P.Jaworski, F.Durante, W.K.Härdle (Eds.), Springer 2013, pp.129–163.

[5] Durante,F., Jaworski,P., Di Lascio,F.: A test for truncation invariant bivariate copula models, ***in preparation***.

# Capture-recapture type model for Estimating Elusive Events with Tag Loss

**Danjuma Jibasen** *Department of Statistics and Operations Research Modibbo Adama University of Technology, Yola, Nigeria*

**Abstract:** Capture-recapture (C-R) methods were originally applied to animal populations in which sequence of samples were taken from a well-defined population; any animal found without a tag in a particular sample were given a unique tag before returning that sample to the population. That way, estimate of the population size and other relevant parameters are obtained. These methods have now been applied extensively to epidemiological and public health events with the aim of estimating the incidence and prevalence of such events (Seber et al, 2000). When there are only two samples, the method is called the Petersen method (or the Lincoln index).

In practice, C-R methods can be applied to any situation in which records of individuals from the same population are kept in at least two different but incomplete lists. Thus "being on list "âĂİ can be equated to "being on sample ". The problem is to estimate those missing from both lists. These lists can come from different units or department of the same agency (e.g. Doctors' and Pharmacists' record), or different agencies (e.g. The Police Force and the Prison Services records). When applied to list, the Petersen method is known by the nomenclature; Dual System Methods (DSM); Dual System Estimation (DSE) or Dual Record Systems (DRS), IWGDMF (1995); El-khorazaty, Imrey, Koch, and Wells (1976) and Ericksen and Kadane (1985).

The assumptions required for this estimate to be valid can be spelt out in a number of ways. However the key ingredients are: (1) the population is closed, that is, the population has a constant size for the entire period of the study, (2) the lists are independent, (3) each member of the population has the same chance of being on a given list, and (4) individuals are matched correctly, that is, individuals will not change their identity, in the terminology of C-R, no tags loss.

Assumption (1) holds if the experiment is conducted within a reasonably short period of time. For (2) the listing systems may not be independent, since addicts can be referred across systems for rehabilitation or treatment; the NDLEA usually refer addicts to Psychiatric centre for treatment, likewise, Psychiatric centre too refer psychoactive patients to the NDLEA for rehabilitation. We assumed that addicts have similar behaviour, hence assumption (3) holds, that is, addicts have the same probability of being on a given list. Assumption (4) will completely be false; matching will depend on the quality of records, the truthfulness of the information and the uniqueness of the tags used. Addicted individuals are likely to give false information about their identity deliberately to avoid stigmatization or arrest, or even unconsciously under the effect of intoxicant. These make matching difficult. Hence, being on list 1 may tends to decrease the chance of being on list 2, this yields negative dependence (IWGDMF, 1995). According to Pollock (1991), the loss or overlooked of marks (tags) can be serious, he suggested that one way to estimate tag loss is to use double marks. Pollock, et al (1990) stated that, if tag loss is likely to occur, an attempt should be made to estimate rate of loss and that if individuals lose their tags, N will be overestimated; this situation is refers to as positive biased (IWGDMF,1995).

The objective is therefore to develop a model suitable for estimating the number of drugs addicts who are likely to change their identity on reference.

# References


[1] International Working Group for Disease Monitoring and Forecasting (IWGDMF) (1995). Capture-Recapture and Multiple-Record Systems Estimation I: History and Theoretical Development. Am. J. Epidemiol. **142**, 1047–58.

[2] El-Khorazaty, M. N., Imrey, P. B., Koch G.G and Wells, H. B. (1976). A Review Of Methodological Strategies For Estimating The Total Number Of Events With Data From Multiple-Record. University of North Carolina Institute of Statistics Mimeo Series No. 1095. Chapel Hill, N.C.

[3] Erickson, E.P. and Kadame, J. B. (1985). Estimating the population in a census year. Journal of the American Statistical Assoc. **80**, 98–109.

[4] Pollock, K.H., Nichols, J.D., Brownie, C. and Hines, J.E. (1990). Statistical inference from capture-recapture experiment. Wildlife Monographs **107**, 1-97

[5] Pollock, K. H. (1991). Modelling capture, recapture, and removal statistics for estimation demographic parameters for fish and wildlife populations: past, present and future. Journal of the American Statistical Association **86**, 225-238

# Interval Prediction for the Trend-Renewal Process

**Jürgen Franz** *Department of Mathematics, Technical University of Dresden, Germany*
**Alicja Jokiel-Rokita** *Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*
**Ryszard Magiera** *Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*

**Abstract:** Let $N(t)$ denote the number of jumps (failures) in the time interval $(0,t]$ and let $T_i$ be the time of the $i$th failure. The observed sequence $\{T_i, i = 1, 2, \ldots\}$ of occurrence times $T_1, T_2, \ldots$ (failure times) forms a point process, and $\{N(t), t \geq 0\}$ is the corresponding counting process. Let $\lambda(t), t \geq 0$, be a nonnegative function, and let $\Lambda(t) = \int_0^t \lambda(u)du$. The counting process $\{N(t), t \geq 0\}$ is called a trend-renewal process (TRP) with a renewal distribution function $F(t)$ and a trend function $\lambda(t)$ if the time-transformed process $\Lambda(T_1), \Lambda(T_2), \ldots$ is a renewal process (RP) with the renewal distribution function $F$, i.e. if the random variables

$$W_i = \Lambda(T_i) - \Lambda(T_{i-1}), \quad i = 1, 2, \ldots,$$

where $T_0 = 0$, are independent and identically distributed with cumulative distribution function $F$. The TRP was introduced and investigated first in [2] and [3]. TRP's, whose realizations depend on a renewal distribution as well as on a trend function, comprise the non-homogeneous Poisson and renewal processes and serve as useful reliability models for repairable systems.

In the talk some results contained in [1] will be presented, namely some ideas and methods for constructing prediction intervals for the next failure time of the TRP. The case when the renewal distribution $F$ of a TRP is unknown will be also considered. Conclusions from simulations, conducted to compare the prediction intervals for a TRP with completely unknown renewal distribution with the corresponding results for the TRP with a Weibull renewal distribution and power law type trend function, will be presented. The prediction methods will be also applied to some real data.

## References

[1] Franz, J., Jokiel-Rokita, A. and Magiera, R. (2014). Prediction in trend-renewal processes for repairable systems. *Statistics & Computing*, 24:633-649.

[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.

[3] Lindqvist B. H., Kjønstad G. A. and Meland N. (1994). Testing for trend in repairable system data. In *Proceedings of ESREL'94*, La Boule, France.

# Incomplete Maintenance in Degradation Processes

**Waltraud Kahle** *Institute of Mathematical Stochastics, Otto-von-Guericke-University Magdeburg, Germany*

**Abstract:** In Kijimas incomplete repair model the impact of repair after a failure is not minimal as in the homogeneous Poisson process and not "as good as new" as in renewal processes but lies between these boundary cases. In this research, we use this model to consider incomplete preventive maintenance in degradation processes.

We consider a Wiener process with drift for degradation modelling. To estimate the process parameters inspections are carried out. At each inspection point the actual state of the process can be observed. Basing on this observation, the estimates of the process parameters can be updated. Further, at each inspection point, a decision about preventive maintenance actions (replace the system by a new one, let it as it is, ore make an incomplete repair with some degree) is possible. The costs of preventive maintenance actions depends on the degree of repair and are smaller than the costs of failure. Further, the next inspection point can be defined. In the talk, we consider a sequential technique which minimizes the average costs per time unit.

Further, we consider the impact of the degree of repair to the behaviour of the degradation process.

# Dynamic Price Linkage and Volatility Structure Model between Carbon Markets

**Takashi Kanamura** *Graduate School of Advanced Integrated Studies in Human Survivability (GSAIS), Kyoto University, Japan*

**Abstract:** This paper investigates the dynamic price linkage and volatility structure between two leading carbon markets of EU allowance (EUA) and secondary certified emission reduction (sCER). We propose a correlation model between EUA and sCER price returns using the marginal abatement cost (MAC) curve and the emission reduction volume. The model reflects twohold market observations: financial playersâĂŹ EUA-sCER swap transaction in carbon price boom periods and stronger energy price impacts on EUA prices than sCER prices. The model demonstrates that the volatilities are affected by the MAC curve shape and the emission reduction volume while the correlations are indifferent from the MAC curve shape and affected by the emission reduction behavior. The model also suggests that the EUA-sCER price correlations increase when the swap transaction increases or energy prices fall, translated into the opposite EUA price movements of EUA price rise or fall, respectively.

# Combining Time Series Forecasting. Methods for Internet Traffic.

**Christos Katris** *Department of Electrical & Computer Engineering, University of Patras, Greece*
**Sophia Daskalaki** *Department of Electrical & Computer Engineering, University of Patras, Greece*

**Abstract:** The aim of this work is to explore whether forecasts from individual forecasting models can be improved with the use of combination rules. Working with Internet traffic data, first we use FARIMA, FARIMA with student-t innovations and Artificial Neural Networks as individual forecasting models, since each one of them explains some statistical characteristic of our data, and next we combine the forecasts using three different combination rules. Based on our experimental work simple combination rules may improve individual models. Finally, we consider a scheme where the selection of the model is based on the White's Neural Network test for non-linearity and compare with the results from the combination of forecasts.

# Ultramodularity in the construction of binary copulas.

**Erich Peter Klement** *Department of Knowledge-Based Mathematical Systems, Johannes Kepler University, Linz and Softwarepark Hagenberg, Austria*
**Anna Kolesárová** *Department of Information Engineering, Automation and Mathematics, Faculty of Chemical and Food Technology, Slovak University of Technology, Bratislava, Slovakia*
**Radko Mesiar** *Department of Mathematics and Descriptive Geometry, Faculty of Civil Engineering, Slovak University of Technology, Bratislava, Slovakia and*
*Centre of Excellence IT4 Innovations, Institute for Research and Applications of Fuzzy Modeling, University of Ostrava, Czech Republic*
**Susanne Saminger-Platz** *Department of Knowledge-Based Mathematical Systems, Johannes Kepler University, Linz, Austria*

**Abstract:** We discuss the role of ultramodularity in special constructions of copulas. We focus on a the so-called $D$-product of a copula and its dual and show that for each copula $D$ which is ultramodular and Schur concave on the left upper triangle of the unit square, this $D$-product of an arbitrary copula and its dual is again a copula. We give several examples and counterexamples and, finally, extend some of our results to the case of semicopulas and quasi-copulas.

### The $D$-Product of a copula and its dual

The dual of a binary copula $C\colon [0,1]^2 \to [0,1]$ can be characterized as a binary aggregation function $C^*\colon [0,1]^2 \to [0,1]$ having 0 as neutral element, 1 as annihilator and being *submodular*, i.e., for all $\mathbf{x}, \mathbf{y} \in [0,1]^2$ we have $C^*(\mathbf{x} \vee \mathbf{y}) + C^*(\mathbf{x} \wedge \mathbf{y}) \leq C^*(\mathbf{x}) + C^*(\mathbf{y})$.

Given an aggregation function $D$ and a 1-Lipschitz aggregation function $A$, consider the function $D(A, A^*)\colon [0,1]^2 \to [0,1]$ defined by

$$D(A, A^*)(x, y) = D(A(x, y), A^*(x, y))$$

and call it the *$D$-product of $A$ and its dual $A^*$*.

In many cases involving the three basic copulas $W$, $\Pi$ and $M$ this construction always yields a copula: for instance, for each copula $C$ we trivially get $W(C, C^*) = W$ and $M(C, C^*) = C$, and for each copula $D$ we have $D(W, W^*) = W$. However, there are copulas $C$ and $D$ such that the $D$-product $D(C, C^*)$ is not a copula.

### Main result

The ultramodularity and the Schur concavity of copulas on the upper left triangle $\{(x, y) \in [0,1]^2 \mid x \leq y\}$ provide a sufficient condition for the $D$-product to be a copula.

**Theorem** *Let $C$ be a binary copula and let $D$ be a binary copula which is ultramodular and Schur concave on the upper left triangle $\{(x, y) \in [0,1]^2 \mid x \leq y\}$. Then the function $D(C, C^*)$ is a copula.*

## References

[1] F. Durante and C. Sempi. Copulæ and Schur-concavity. *Int. Math. J.*, 3:893–905, 2003.

[2] F. Durante and C. Sempi. Semicopulæ. *Kybernetika (Prague)*, 41:315ï£¡–328, 2005.

[3] H. Joe. *Multivariate Models and Dependence Concepts*. Chapman & Hall, London, 1997.

[4] E. P. Klement, M. Manzi, and R. Mesiar. Ultramodular aggregation functions. *Inform. Sci.*, 181:4101–4111, 2011.

[5] E. P. Klement, M. Manzi, and R. Mesiar. Ultramodularity and copulas. *Rocky Mountain J. Math.*, 44:189–202, 2014.

[6] E. P. Klement, R. Mesiar, and E. Pap. *Triangular Norms*. Kluwer Academic Publishers, Dordrecht, 2000.

[7] M. Marinacci and L. Montrucchio. Ultramodular functions. *Math. Oper. Res.*, 30:311–332, 2005.

[8] M. Marinacci and L. Montrucchio. On concavity and supermodularity. *J. Math. Anal. Appl.*, 344:642–654, 2008.

[9] R. B. Nelsen. *An Introduction to Copulas*, *Lecture Notes in Statistics* 139. Springer, New York, second edition, 2006.

[10] B. Schweizer and A. Sklar. *Probabilistic Metric Spaces*. North-Holland, New York, 1983 (updated and reprinted under the same title by Dover Publications, Mineola, 2006).

# Regularizing Linear Programming Estimation for Nonregular Regression Models

**Keith Knight** *Department of Statistical Sciences, University of Toronto, Canada*

**Abstract:** We will consider estimation in regression models where the errors are non-regular; examples include models with positive errors, bounded errors, and errors whose densities have jump discontinuities. In such models, estimation based on linear programming arises naturally and, under appropriate regularity conditions, the resulting estimators typically converge in distribution to the solution of a linear program whose constraints are a random set determined by a Poisson process. However, if the errors are sufficiently non-homogeneous, linear programming estimation will break down in the sense that it will not be able to attain its optimal convergence rate. In this talk, we will discuss regularizing linear programming estimation using simple quadratic penalization in order to recover the optimal convergence rate as well as some computational methods.

# Synthetic Control Charts and Diverse Steady-State ARL Concepts

**Sven Knoth** *Department of Mathematics and Statistics, Helmut Schmidt University, University of the Federal Armed Forces Hamburg, Germany*

**Abstract:** The synthetic chart principle proposed by [6] – it is basically an extension of the Conforming Run Length (CRL) chart introduced by [1] – initiated a stream of publications in the control charting literature. Originally, it was claimed that the new chart has superior Average Run Length (ARL) properties. [2] indicated that the synthetic chart is nothing else than a runs rule chart – [4] recommended something similar, but much more simple. Moreover, they criticized the design of the performance evaluation and advocated to use the steady-state ARL. The latter measure was used then, e. g., in [5]. In most of the papers on synthetic charts that actually used the steady-state framework it was not rigorously described – see [3] as an exception, where it was mentioned that the cyclical steady-state design was considered. The aim of the talk is to present a careful steady-state analysis (cyclical and the more popular conditional) for the synthetic chart, the original 2 of $L+1$ ($L \geq 1$) runs rule chart, and competing two-sided EWMA charts with different types of control limits. For the EWMA chart some enlightening new results for the cyclical steady-state ARL are obtained. Finally it turns out that the EWMA chart has a uniformly (over a large range of potential shifts) better steady-state ARL performance than the synthetic chart.

## References

[1] Bourke P. D. (1991). Detecting a shift in fraction nonconforming using run-length control charts with 100% inspection. *Journal of Quality Technology* 23(3): 225-238.

[2] Davis R. D. and Woodall W. H. (2002). Evaluating and improving the synthetic control chart. *Journal of Quality Technology* 34(2): 200-208.

[3] Khoo M. B. C., Wong V. H., Wu Z. and Castagliola P. (2011). Optimal designs of the multivariate synthetic chart for monitoring the process mean vector based on median run length. *Quality and Reliability Engineering International* 27(8): 981-997.

[4] Klein M. (2000). Two alternatives to the Shewhart $\overline{X}$ control chart. *Journal of Quality Technology* 32(4): 427-431.

[5] Wu Z., Ou Y., Castagliola P. and Khoo M. B. (2010). A combined synthetic $\overline{X}$ chart for monitoring the process mean. *International Journal of Production Research* 48(24): 7423-7436.

[6] Wu Z. and Spedding T. A. (2000). A synthetic control chart for detecting small shifts in the process mean. *Journal of Quality Technology* 32(1): 32-38.

# Inspection plans for populations with unknown continuous distributions

**Wolfgang Kössler** *Institute of Computer Science, Humboldt-Universität zu Berlin, Germany*

**Abstract:** The ordinary variable inspection plans are sensitive to deviations from the normality assumption (cf. e.g. [2]). A variable inspection plan is constructed that can be used for populations with arbitrary continuous distributions. The peaks over threshold method is used, the tails are approximated by a generalized Pareto distribution, and their parameters and the fraction defective are estimated.
Several methods of estimates are investigated, the Maximum Likelihood method (ML, [3]), ordinary moment, probability weighted moment, elemental percentile estimates ([1]) and a moment estimate proposed in a similar form by [4] (SW estimate). It turns out that, for densities with medium to long tails, the ML method is the best, whereas for short tail densities the SW estimate is to be preferred. The other estimates are worse with respect to asymptotic and finite variances.
The estimates of the fraction defective are asymptotically normal. Their asymptotic variances do not differ very much for the various distributions regardless whether the ML or SW estimates are used. Therefore we may fix the variance and use the known asymptotic distribution for the construction of the inspection plans.
The sample sizes needed to satisfy the two-point conditions are much less than that for attribute plans. Finite sample properties are also investigated.

## References

[1] Castillo, E. and Hadi, A.S. (1997). Fitting the Generalized Pareto Distribution to Data, *J. Amer.Statist. Assoc.* Vol. 92: 1609-1620.

[2] Kössler, W. and Lenz, H.J. (1997). On the Non-Robustness of Maximum-Likelihood Sampling Plans by Variables, *Frontiers in Statistical Quality Control*, Vol. 5, Lenz, H.J. and Wilrich, P.Th., eds., pp. 38-52, Physica: Heidelberg.

[3] Smith, R.L. (1987). Estimating tails of probability distributions. *Annals of Statistics*, Vol. 15: 1174-1207.

[4] Smith, R.L. and Weissman, I. (1985). Maximum Likelihood estimation of the lower tail of a probability distribution. *J.Royal Statistical Society B*, Vol 47: 285-298.

# Copulas of self-similar Ito diffusions and Girsanov transformation

**Marcin Krzywda** *Institute of Mathematics and Computer Science , Jagiellonnian University in Krakow, Poland*

**Abstract:** We study two-dimensional self-similar Ito diffusions$(X, Y)$ whose margins are Brownian Motions. The characterisation of the distributions of the random pairs $(X_t, Y_t)$ for a given $t$ is described in terms of their copulas.Next we discuss the Girsanov transformation of the process in case of stochastic coefficients and show that then the copulas of the same stochastic process in risk neutral and objective measures may be different.Finally we show examples of how the model fits to the high-frequency quotes of the most liquid stocks at the Warsaw Stock Exchange.

The talk is based on the joint work with Prof Piotr Jaworski.

# Adaptive density estimation from data containing bounded measurement errors

**Tina Felber** *Fachbereich Mathematik, Technische Universität Darmstadt, Germany*
**Michael Kohler** *Fachbereich Mathematik, Technische Universität Darmstadt, Germany*
**Adam Krzyżak** *Department of Computer Science and Software Engineering, Concordia University, Monteral, Canada*

**Abstract:** We consider the problem of density estimation using noisy data containing small measurement errors. The only assumption on these errors is that the maximal measurement error is bounded by some real number converging to zero for sample size tending to infinity. We estimate the density by a standard kernel density estimate applied to the noisy data and propose data-dependent method for choosing its bandwidth.We derive an adaptation result for this estimate and analyze the expected $L_1$ error of our density estimate depending on the smoothness of the density and the size of the maximal measurement error.

# On optimal crossover designs in a model with carryover-effects which are proportional to direct effects

**Joachim Kunert** *Department of Statistics, TU Dortmund University, Germany*
**R. A. Bailey** *School of Mathematics and Statistics, University St Andrews, U.K.*

**Abstract:** We review results on the optimality of crossover designs in a model with proportional carryover effects. Some new results for the case that the proportionality factor is near 1 are added.

The talk deals with a model for crossover designs, where carryover effects are present. The carryover effects are assumed to be proportional to the corresponding direct effects. The proportionality factor lies within the interval $[-1, 1]$. Since $\lambda$ is unknown, this leads to a nonlinear model. Hence, the optimal designs for the estimation of the direct effects depend on the unknown parameter $\lambda$.

**Existing results.**

We consider the situation that the number of treatments $t$ is greater or equal to the number of periods $p$. It was shown by Bailey and Kunert (2006) that there is a $\lambda_0 > 0$, depending on $t$ and $p$, such that for all $\lambda \leq \lambda_0$ the A-optimal design in this model is a so-called totally balanced design. In a totally balanced design, each unit receives each treatment at most once. If $\lambda$ gets too large, however, then Bailey and Kunert (2006) found out that other designs, where some units receive a treatment more than once, will perform better.

Zheng (2013) considered the same model, but looked at other optimality criteria as well. In particular, Zheng (2013) found that the E-optimal design does not depend on the parameter $\lambda$, and is the same as the universally optimal design in the traditional model treated e.g. by Kushner (1997). This design has some units where the same treatment is given twice, in the last two periods. Most units, however, receive each treatment at most once.

**Some new results.**

The talk considers A-optimality and the situation where the proportionality factor $\lambda$ gets near 1. We use a generalization of Kushner's (1997) method to determine optimal designs for this case. It is shown that for $\lambda$ sufficiently near 1, all units in the optimal design will receive the same treatment in the last two units.

# References

[1] Bailey, R.A. and Kunert, J. (2006). On optimal crossover designs when carryover effects are proportional to direct effects, *Biometrika* 93: 613 - 625.

[2] Kushner, H.B. (1997). Optimal repeated measurements designs: the linear optimality equations, *Annals of Statistics* 25: 2328 - 2344.

[3] Zheng, W. (2013). Optimal Crossover Designs for the Proportional Model, *Annals of Statistics* 41: 2218 - 2235.

# On the Optimality of Harmonic Excitation As Input Signals for the Characterization of Smart Materials

**Tom Lahmer** *Institute of Structural Mechanics, Bauhaus University Weimar, Germany*
**Ewaryst Rafajłowicz** *Instytut Informatyki, Automatyki i Robotyki, Politechnika Wrocławska, Poland*

**Abstract:** In mechatronical systems different types of sensors and actuators are applied to convert signals from one physical field into signals of another physical field. Examples are piezoelectrically driven actuators for ultrasound generation, electro- magnetic transducers, microelectro-mechanical devices and so on. Generally, the design and development of these transducers is supported by means of models. A variety of models has been derived, which depending on the application, are formulated in 1, 2 or even 3 dimensions. Mostly, the effects are described by coupled systems of hyperbolic partial differential equations. Depending on the dimension, but also the material properties (isotropic or anisotropic) a series of material specific parameters needs to be known in order to make reliable predictions. Their determination is the content of many works, where often discrepancies between measured and simulated signals are systematically reduced by applying techniques of non-linear optimization. As most applications are dynamic, time-harmonic excitations are applied to excite the structures and to measure responses in dependency of the current excitation frequency. A series of responses, e.g. measured mechanical displacement magnitudes for different frequencies is used as input for parameter identification methods. In the contribution we will address optimality criteria for the designed experiments for smart materials and derive numerical procedures to optimally select sets of excitation frequencies.

# Stochastic Model Of Cognitive Agents Learning To Cross A Highway

**Anna T. Lawniczak** *Department of Mathematics and Statistics, University of Guelph, Ontario, Canada*
**Bruno N. Di Stefano** *Nuptek Systems Ltd, Toronto, Ontario, Canada*
**Jason B. Ernst** *School of Computer Science, University of Guelph, Ontario, Canada*

**Abstract:** We describe a stochastic model of simple cognitive agents ("creatures") learning to cross a highway. The creatures are capable of experiencing fear and/or desire to cross and they use an observational learning mechanism. Our simulation results are consistent with real life observations and are affected by the creaturesâĂŹ fears and desires, and the conditions of the environment. The transfer of the knowledge base acquired by creatures in one environment to the creatures operating in another one improves creatures success of crossing a highway.

# Conditional $\Gamma$-minimax prediction in doubly stochastic Poisson process

**Daniel Lazar** *Faculty of Fundamental Problems of Technology, Wrocław University of Technology, Poland*

**Abstract:** A stochastic marked point process model based on doubly stochastic Poisson process is considered in the problem of prediction for the total size of future marks in a given period, given the history of the process. A robust Bayesian approach is used to construct optimal predictors in the presence of uncertainty regarding the prior distribution. The underlying marked point process $(T_i, Y_i)_{i\geq 1}$, where $T_i$ is the time of occurrence of the $i$th event and the mark $Y_i$ is its characteristic (size), is supposed to be a non-homogeneous Poisson process on $\mathbb{R}_+^2$ with intensity measure $P \times \Theta$, where $P$ is known, whereas $\Theta$ is treated as a random measure of the total size of future marks in a given period. The prior distribution of $\Theta$ is presented by an unknown process from a family of gamma processes – $\Gamma$. The conditional $\Gamma$-minimax predictor with respect to this family of prior distributions is constructed under a precautionary loss function. A simulation study for comparison of Bayesian predictors and their robust versions is provided.

## References

[1] Betro, B., Ruggeri, F. (1992). *Conditional $\Gamma$-minimax actions under convex losses*, Comm. Statist. Theory Methods **21**, 1051–1066.

[2] Blackwell, D., MacQueen, J.B. (1973). *Ferguson distributions via Pólya urn schemes*, Ann. Statist. **1**, 353–355.

[3] Jokiel-Rokita, A., Lazar, D., Magiera, R. (2014). *Bayesian prediction in doubly stochastic Poisson process*, Metrika **77**(8), 1023–1039.

[4] Niemiro, W. (2006). *Bayesian prediction with an asymmetric criterion in a non-parametric model of insurence risk*, Statistics **40**(4), 353–363.

[5] Norstrøm, J.G. (1996). *The use of precautionary loss function in risk analysis*, IEEE Transactions on Reliability **45**(3), 400–403.

# Control Charts for State-Space Models

**Taras Lazariv** *Department of Quantitative Methods esp. Statistics, European University Viadrina, Germany*
**Wolfgang Schmid** *Department of Quantitative Methods esp. Statistics, European University Viadrina, Germany*

**Abstract:** The state-space model is a powerful instrument for modelling and forecasting dynamic systems. It is very widely used in engineering for a long time. Further applications were studied, e.g., in econometrics (Durbin and Koopman, 2001) or in environmental science (Bodnar and Schmid, 2010). The state-space representation is a very general tool and covers a huge variety of processes. Such processes, among the others, could be a linear trend, a random walk, different seasonal models, various time series (ARMA, ARIMA processes).

In SPC literature it is often assumed that the underlying process is stationary. However, this assumption is very restrictive and does not hold in many applications. Therefore, the control charts for non-stationary processes should be introduced. We use the state-space models to model the non-stationary processes. In the talk new control charts for the mean of the state-space models are presented, which are derived using the likelihood ratio, the sequential probability ratio test and the Shiryaev-Roberts approach (Lazariv et al. (2013)). For prediction the underlying process the Kalman filter is used (Brockwell and Davis, 1991).

Within a simulation study all proposed schemes are compared with each other. The behaviour of the charts is analysed for a stationary (autoregressive process of order 2) and for a non-stationary (random walk with autoregressive noise of order 2) process. As the measures of performance the average run length (ARL), the average delay (AD) and the probability of successful detection (PSD) are used.

## References

[1] Bodnar, O. and Schmid, W. (2010): Nonlinear locally weighted kriging prediction for spatio-temporal environmental processes, *Environmetrics* 21, 365-381.

[2] Brockwell, P. and Davis, R. (1991): *Time Series: Theory and Methods*, Springer.

[3] Durbin, J. and Koopman, S. (2001): *Time Series Analysis by State Space Methods*, University Press, Oxford.

[4] Lazariv, T., Schmid, W. and Zabolotska, S. (2013): On control charts for monitoring the variance of a time series, *Journal of Statistical Planning and Inference* 143, 1512-1526.

# Validation of positive quadrant dependence and visualization of dependence structure

**Teresa Ledwina** *Institute of Mathematics, Polish Academy of Sciences, Poland*

**Abstract:** Quadrant dependence is a useful dependence notion of two random variables, widely applied in reliability, insurance, and actuarial sciences. The interest in this dependence structure ranges from modeling it, throughout measuring its strength and investigations on how increasing the dependence effects of several reliability and economic indexes, to hypothesis testing on the dependence. In this talk, we focus on testing for positive quadrant dependence and measuring its strength.

We shall present two new tests for verifying positive quadrant dependence recently introduced in [1]. We shall also discuss interesting results on finite sample behavior of power function of one of the proposed tests. Next, we shall summarize simulation study performed to evaluate and compare the two new solutions with the best existing ones, including a recent construction described and studied in [2] and related papers. These comparisons demonstrate that the new solutions are slightly weaker in detecting positive quadrant dependence modeled by classical bivariate models such as Gaussian, Clayton or Gumbel, for example, and outperform the best existing solutions when some mixtures, regression and heavy-tailed models have to be detected. The new methods, introduced in the paper, shall be applied to real life insurance data, to assess the dependence and test them for positive quadrant dependence.

The approach that we proposed to construct one of the new tests for positive quadrant dependence naturally leads to a new function valued measure of dependence of two random variables; cf. [3]. The measure allows one to study and visualize explicit dependence structure, both in some theoretical models and empirically, without prior model assumptions. This provides a comprehensive view of association structure and makes possible much detailed inference than the one based on standard numeric measures of association. We shall present theoretical properties of the new measure of dependence. Some artificial and real data examples will illustrate the behavior and practical utility of the measure and its estimator.

## References

[1] Ledwina, T., Wyłupek, G. (2014). Validation of positive quadrant dependence, *Insurance Math Econom* 56: 38-47.

[2] Gijbels, I., Omelka, M., Sznajder, D. (2010). Positive quadrant dependence tests for copulas, *Canad J Statist* 38: 555-581.

[3] Ledwina, T. (2014). Visualizing association structure in bivariate copulas using new dependence function, *12th Workshop on Stochastic Models, Statistics and Their Applications*, February 16-20, 2015, Wrocław, Poland, Steland, A., Rafajłowicz, E., Szajowski, K., eds., Springer Proceedings in Mathematics and Statistics, Vol. 122, in press.

# Variable Selection via Lasso and Graphical Lasso

**Sangkyun Lee** *Computer Science Department, TU Dortmund University, Germany.*

**Abstract:** Variable selection in high dimensional settings is an essential step for finding relevant features in a variety of tasks including identifying sparse models in statistics and machine learning, and discovering biomarkers in computational biology, just to name a few.

Lasso, also known as the $\ell_1$-penalized regression, is a popular method for selecting individual features whilst fitting a linear model consisting of chosen features to minimize a loss function of interest. When the number of variables is large, obtaining a solution of lasso becomes a challenging problem in terms of (i) finding an accurate solution of a high-dimensional optimization problem, and (ii) finding a statistically reasonable (consistent) solution by choosing the value of a tuning parameter which determines how sparse a solution will be. The latter point is of a special interest in computational biology where the number of features is very large and choosing meaningful features can be crucial for the purpose of applications.

Graphical lasso is another form of variable selection performed on a graph representing the Gaussian Markov random field (GMRF). The GMRF consists of vertices representing random variables and edges representing conditional dependency between vertices. Graphical lasso searches for a sparse GMRF by selecting only relevant edges that may reveal the hidden high-order relations of features and thereby provide us a better understanding of a complex feature space. In high dimensions, however, the GMRF shares similar issues to the case of lasso.

In this talk, we will discuss recent methods and results for obtaining solutions efficiently and for finding statistically consistent solutions of lasso and graphical lasso, including some results on high-throughput computational biology studies.

# Relative Measures and Their Application to Inference for Time Series and Signals

**Jacek Leśkow** *Institute of Mathematics, Cracow Technical University, Poland.*

**Abstract:** The purpose of this talk is to show how the concept of relative measure introduced by Kac and Steinhaus [2] can be used in contemporary aspects of statistical inference for time series and signals. Such approach allows to bypass the cumbersome and largely unverifiable mixing assumptions while working on limiting properties of estimating procedures. Moreover, it is gaining popularity in signal processing as the fraction-of-time approach (see e.g. [1], [3]). The theoretical approach will be illustrated with examples from telecommunication signal processing and finance. The possibilities of introducing the resampling schemes in the fraction-of-time context will be also discussed.

**Introduction**

Most of the results addressing the asymptotic properties of estimators for time series are based on mixing assumptions, that approximate the joint distributions with marginal ones, while the time separation is increasing. Those assumptions can not be verified for non-gaussian time series. Therefore, while studying estimating procedures for time series, a fundamental question arises: do we have to construct a highly complex stochastic process model fulfilling the mixing assumption just to show a property like the convergence of the sample autocorrelation function for one realization $x(t)$ that we have on hand? Would it not be simpler to check certain analytical properties just for $x(t)$ to get the desired convergence?

In our presentation, an alternative approach will be proposed based on the concept of the relative measure $\mu_R$ ( see [5, 2]). The relative measure $\mu_R(A)$ of a Borel set $A \subseteq \mathbb{R}$ is defined to be the limit $\mu_R(A) = \lim_{T\to\infty} \frac{1}{T}\,\mu(\{t \in [-T/2, T/2] \cap A\})$, if it exists, where $\mu$ denotes the Lebesgue measure. In such case, $A$ is called *relatively measurable*. Given a single function of time $x(t)$, the relative measure of the set of values of $t$ such that $x(t) \leq \xi$, as a function of $\xi$ is a valid cumulative distribution function except for the right continuity property in the discontinuity points. This distribution function represents the fraction-of-time (FOT) probability [1] that the function $x(t)$ does not exceed the threshold $\xi$ and the expected value corresponding to such a distribution is the infinite-time average of $x(t)$.

**The goal of the research**

Our goal will be to characterize the relatively measurable functions $x(t)$ and show how the relative measure $\mu_R$ generated by such functions can serve as a starting point to construct relevant moment characteristics of the time series $x(t)$. The expectation and covariance operators will be constructed using the relative measurability and joint relative measurability of the signals $x(t)$ and $x(t), x(t+\tau)$, respectively. Then, the central limit theorem in the fraction-of-time context will be presented, given some analytic conditions on the sequence of signals. Finally, examples from telecommunication signals and financial times series will be dealt with using the proposed fraction-of-time approach. Finally, possibilities of getting resampling procedures in the fraction-of-time context will be presented, using the ideas from [4].

**Acknowledgement**

This research is supported by the grant from the Polish National Center of Science, grant number UMO - 2013/10/M/ST1/00096.

# References


[1] Gardner, W. (1991), Two alternative philosophies for estimation of the parameters of time series, IEEE Trans. Inform. Theory, 37, 216 - 218.

[2] Kac, M., Steinhaus, H. (1938), Sur les fonctions independantes IV, Studia Mathematica 7, pp. 1 - 15.

[3] Dehay, D., Leśkow, J. and Napolitano, A. (2013), 'Central Limit Theorem in the Functional Approach', IEEE Transactions on Signal Processing, Vol **61**, No. 16, pp. 4025 - 4037.

[4] Dehay, D., Dudek, A. and Leśkow, J. (2014), Subsampling for continuous-time almost periodically correlated processes, Journal of Statistical Planning and Inference, vol **150**, pp. 142 - 158.

[5] Leśkow, J., Napolitano, A. (2006), Foundations of the functional approach for signal analysis, Signal Processing, Vol **86**, pp. 3796-3825.

# Wavelet algorithm for hierarchical pattern recognition

**Urszula Libal** *Institute of Computer Engineering, Control and Robotics, Wroclaw University of Technology, Poland.*
**Zygmunt Hasiewicz** *Institute of Computer Engineering, Control and Robotics, Wroclaw University of Technology, Poland.*

**Abstract:** The idea, presented in this article, is based on a combination of hierarchical classifier with multiresolution representation of signals in the Daubechies wavelet bases. The paper concerns a multi-class recognition of random signals. It presents a multistage classifier with a hierarchical tree structure, based on a multiscale representation of signals in wavelet bases. Classes are hierarchically grouped in macro-classes and the established aggregation defines a decision tree. In each macro-class, the existence of deterministic pattern of signals is assumed. A global loss function with reject option is proposed for the multistage classifier and two strategies for the choice of loss function parameters are discussed. An analysis of risk is performed for a local (binary) attraction-limited minimum distance classifier for wavelet approximation of signals. This leads to proposals, relating to the upper estimate of the risk, called the guaranteed risk. Its value depends on the several parameters as the wavelet scale of signal representation, the support length of wavelet function, or the variance of the random noise in the macro-class. Finally, the guaranteed risk of the multistage classifier is derived.

# Modelling and approximation of copulas using Cramér-von Mises statistic

**Eckhard Liebscher** *Department of Computer Science and Communication Systems, University of Applied Sciences Merseburg, Germany*

**Abstract:**

When analysing multivariate data, it frequently happens that we cannot find an appropriate model for the multivariate distribution or the copula. Often all goodness-of-fit tests show then the result that the null hypothesis is rejected. The high complexity of the multivariate distribution is the reason for this behaviour. In this talk we present a way to overcome this problem. We search for a reasonable approximation of the sample copula instead for an exact fit. The aim is to find a copula from a parametric family which approximates best the sample copula.

Let us denote the copula of the sample by $C$. This copula is modeled by a parametric family $\mathcal{M} = \{C_\theta\}_{\theta\in\Theta}$ of copulas. $\Theta$ is the parameter space. Against the above background, we assume that $C$ does not belong to $\mathcal{M}$. Further we consider the *Cramér-von-Mises divergence* as a measure of discrepancy between the copula $C$ and the model class $\mathcal{M}$:

$$\mathcal{D}(C, \mathcal{M}) = \inf_{\theta\in\Theta} \mathcal{D}(C, C_\theta),$$

where

$$\begin{aligned} \mathcal{D}(C, C_\theta) &= \int_{[0,1]^d} \left(C(u) - C_\theta(u)\right)^2 \, dC(u) \\ &= \int_{\mathbb{R}^d} \left(H(x) - C_\theta(F(x))\right)^2 \, dH(x). \end{aligned}$$

The CvM divergence is estimated by

$$\widehat{\mathcal{D}}_n(C_\theta) = \frac{1}{n}\sum_{i=1}^{n} \left(\hat{H}_n(X_i) - C_\theta(\overline{F}_n(X_i))\right)^2.$$

The approximate minimum distance estimator $\hat{\theta}_n$ is an estimator satisfying

$$\widehat{\mathcal{D}}_n(C_{\hat{\theta}_n}) \le \min_{\theta\in\Theta} \widehat{\mathcal{D}}_n(C_\theta) + \varepsilon_n$$

with a sequence $\{\varepsilon_n\}$ of random numbers with $\varepsilon_n \to 0$ $a.s.$ Under certain regularity conditions, one can prove that $\hat{\theta}_n$ is a consistent estimator for

$$\theta_0 = \arg\min_{\theta\in\Theta} \mathcal{D}(C, C_\theta)$$

and it is asymptotically normally distributed (see [2]). It should be pointed out that the best parameter $\theta_0$ depends heavily on the approximation measure. There is no "true parameter" at all. As a key result, we obtain asymptotic normality of $\widehat{\mathcal{D}}_n(C_{\hat{\theta}_n})$ with a certain variance which can be estimated in a suitable way (estimator $\hat{\sigma}_1^2$). In the proof we use the fact that $\widehat{\mathcal{D}}_n(C_{\hat{\theta}_n})$ can be represented by a sum of a $U$-statistic and a remainder term which is asymptotically negligible. Let us consider the test

$$H_0 : \mathcal{D}(C, \mathcal{M}) \le M, \quad H_1 : \mathcal{D}(C, \mathcal{M}) > M$$

for a given $M > 0$. The test statistic is given by

$$\frac{\widehat{\mathcal{D}}_n(C_{\hat{\theta}_n}) - M}{\hat{\sigma}_1}.$$

In contrast to goodness-of-fit, this statistic is asymptotically normally distributed which leads to an-easier-to-handle test procedure.

The second part of the talk is devoted to comparisons between approximations by several parametric copulas. We introduce a measure for goodness-of-approximation:

$$\rho = 1 - \frac{\mathcal{D}(C, \mathcal{M})}{\mathcal{D}(C, \mathcal{M}_R)}$$

where $\mathcal{M}_R$ is a reference class of copula models. The quantity $\rho$ describes the quality of approximation. The case $\rho = 1$ corresponds to perfect approximation. At the end the use of the methods is illustrated by means of examples.

# References


[1] Lachout, P.; Liebscher, E. and Vogel, S. (2005). Strong convergence of estimators as $\varepsilon_n$-minimisers of optimisation problems. *Ann. Inst. Statist. Math.* 57:291-313.

[2] Liebscher, E. (2009). Semiparametric Estimation of the Parameters of Multivariate Copulas. *Kybernetika* 45:972-991.

# Thermal and Nuclear Energy Portfolio Selection using stochastic LCOE risk measures

**Carlo Lucheroni** *School of Sciences and Technologies, University of Camerino, Camerino (MC), Italy*
**Carlo Mari** *Dept. of Management and Business Administration, University of Chieti-Pescara, Pescara, Italy*

**Abstract:** We review a recently introduced stochastic Levelized Cost of Electricity (LCOE) technique for optimizing multi-asset risky energy portfolios, and extend it using improved dynamics and a new set of risk measures.

### Introduction

Investment decisions and assessment in electricity production are usually supported by a Levelised Cost of Energy (LCOE) analysis, which is a way to determine a unitary break-even cost of production for an electricity producing plant, in terms of the present value of its past and future construction and operation costs. Standard LCOE analysis is a deterministic technnique, in which future unknown costs are replaced by their expected values. For a given production technology $x$ (gas, coal, nuclear), this standard technique outputs a single number (the LCOE $P^{LC,x}$), to be compared to a sales price $P^E$, assumed fixed for all operational life of the plant. Only in cases beyond break-even, i.e. when $P^{LC,x} < P^E$, the business can be considered valuable. In [1] a stochastic extension of this technique was introduced, in which 1) future unknown fuel costs (i.e. fuel prices) are modelled as stochastic processes and 2) the analysis is applied to a pool of plants (i.e. an energy portfolio), in order to exploit synergies among them. This change of perspective transforms the portfolio LCOE to a stochastic variable $P^{LC,\vec{w}}(\omega)$, endowed with a distribution, dependent on price paths $\omega$, and controllable by the weights $\mathbf{w}$ assigned to the component technologies $\mathbf{x}$ (both seen as vectors). An optimal portfolio selection scheme 'à la Markowitz' can then be used to single out the combination of technologies that optimizes w.r.t. a chosen risk-return objective, wich is impossible in the standard (i.e. deterministic) LCOE technique case. Even without the assumption that fuel prices are correlated, just taking into account for each fuel cost the price to be paid for $CO_2$ emissions for the technology related to it, portfolio components $\mathbf{x}$ turn out to be correlated through the common $CO_2$ price process. In [1] four price processes (for coal, gas, nuclear and $CO_2$) were assumed geometric brownian motions, and variance was selected as risk measure. The stochastic LCOE scheme analysis can be pushed much further than this, and more interesting results can be obtained.

### The Method, and New Results

In [2] the vector $\mathbf{y}$ of price stochastic processes (and its distribution $p(\mathbf{y})$) was more accurately modelled using mean reversions and jumps, and CVaR

$$CVaR_\alpha^{\mathbf{w}}(f(\omega)) = \frac{1}{1-\alpha}\int_{f(\mathbf{w},\mathbf{y}(\omega))\geq VaR_{\mathbf{w}}^{\alpha}} f(\mathbf{w},\mathbf{y}(\omega))\, p(\mathbf{y})\, d\mathbf{y}(\omega) \tag{1}$$

(where $f$ is the portfolio loss function, $\mathrm{VaR}_{\mathbf{w}}^{\alpha}$ refers to the Value at Risk measure, $\alpha$ is a level of confidence) had to be added to the risk measure previously studied, since with the processes selected (but already with the geometric brownian motions used in [1]) the LCOE distributions have long asymmetric tails, to which variance is not sensitive.

CVaR is certainly a good complement to variance (i.e. standard deviation) as a risk objective for the stochastic LCOEs obtained in the simulations, but it has a major drawback. As it can be seen in Figure 1, where a selection of risk measures is plotted against LCOEs corresponding to different portfolios, it always selects a pure-gas strategy. In the talk it will be discussed why *generalized deviation measures*, like *CVaR Deviation* (or DVaR), are better suited to study the stochastic LCOE problem.

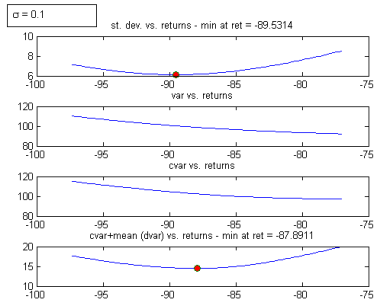



Figure 1: Four LCOE risk measures for different portfolio compositions

# References

[1] Mari, C. (2014). Hedging electricity price volatility using nuclear power, *Applied Energy*, 113, 615-621.

[2] Lucheroni, C., Mari, C. (2014). Stochastic LCOE for optimal electricity generation portfolio selection, EEM14 Proceedings (European Energy Market (EEM), 2014 11th International Conference on the), DOI 10.1109/EEM.2014.6861243.

# Risk of selection of irrelevant features from high-dimensional data with small sample size

**Henryk Maciejewski** *Institute of Computer Engineering, Control and Robotics, Wrocław University of Technology, Poland*

**Abstract:** In this work we demonstrate the effect of small sample size on the risk that feature selection algorithms will select irrelevant features when dealing with high-dimensional data. We develop a simple analytical model to quantify this risk; we verify this model by the means of simulation. These results (i) explain the inherent instability of feature selection from high-dimensional, small sample size data and (ii) can be used to estimate the minimum required sample size which leads to good stability of features. Such results are useful when dealing with data from high-throughput studies.

# Fundamental and speculative shocks - structural analysis of electricity markets

**Katarzyna Maciejowska** *Department of Operations Research, Wrocław University of Technology, Poland and CERGEEI, Praha, Czech Republic*

**Abstract:** In the paper, Structural Vector Autoregressive models (SVAR) are used to analyse effects of structural shocks on the electricity prices in UK. The shocks are identified via short run restrictions, which are imposed on the matrix of instantaneous effects. Two main types of shocks are considered: fundamental shocks, identified as demand and wind generation shocks and speculative shocks, which are associated solely with electricity prices. The results indicate that speculative shocks play an important role in the price setting process and account for more than 90the unexpected electricity price variability. Moreover, wind generation shocks have larger input to the electricity price variance than demand shocks, particularly when peak hours are considered.

**Acknowledgements**
Research supported by funds from the National Science Centre (NCN, Poland) through grants no. 2011/01/B/HS4/01077.

# Bayes Estimation of the Weibull Power Law Process Parameters

**Alicja Jokiel-Rokita** *Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*
**Ryszard Magiera** *Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*

**Abstract:** The problem of Bayes estimation of unknown parameters is considered for the stochastic model determined by the Weibull power law process (WPLP), i.e. the trend-renewal process (TRP) with a Weibull type renewal distribution and a power law trend function. The TRP model, introduced in [1] and investigated in [2], is defined to be a time-transformed renewal process, where the time transformation is given by a trend function. It comprises the non-homogeneous Poisson processes and renewal processes and serves as a useful reliability model for repairable systems (see, e.g. [3]). The WPLP is a very important representative of the TRP's. Besides the field of reliability, the WPLP's are also considered in many other fields, e.g. in the field of medicine [4]. The likelihood function of the WPLP depends on three unknown parameters and the problem is to estimate them using Bayesian approach. In the Bayes estimation problem considered for the WPLP, various noninformative prior distributions are used and their influence on properties of the estimators obtained is examined. Under mean squared and absolute estimation errors and for some prior distributions we show advantage of the Bayes estimators over the maximum likelihood estimators, especially when the number of observed failures in the WPLP is small. The Markov Chain Monte Carlo methods used can also be applied to predict future failure time.

## References

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

[2] Lindqvist B. H., Kjønstad G. A. and Meland N. (1994). Testing for trend in repairable system data. In *Proceedings of ESREL'94*, La Boule, France.

[3] Lindqvist B. H., Elvebakk G. and Heggland K. (2003). The trend-renewal process for statistical analysis of repairable systems. *Technometrics*, 45(1):31–44.

[4] Pietzner D. and Wienke A. (2013). The trend-renewal process: a useful model for medical recurrence data. *Statistics in Medicine*, 32(1):142–152.

# Optimal classification and nonparametric regression for functional data

**Alexander Meister**
*Institute for Mathematics, University of Rostock, Germany*

**Abstract:** We establish minimax convergence rates for classification of functional data and for nonparametric regression with functional design variables. The optimal rates are of logarithmic type under smoothness constraints on the functional density and the regression mapping, respectively. These asymptotic properties are attainable by conventional kernel procedures. The bandwidth selector is automatically adaptive. In this work the functional data are considered as realisations of random variables which take their values in a general Polish metric space. We impose certain metric entropy constraints on this space; but no algebraic properties are required.

## References

[1] Meister, A. (2014). Optimal classification and nonparametric regression for functional data, *under revision*.

# Imprecise copulas

**Radko Mesiar** *Faculty of Civil Engineering, Slovak University of Technology, Slovakia & Centre of Excellence IT4 Innovations - Division University of Ostrava - IRAFM, Czech Republic*

**Abstract:** In order to generalize the famous Sklar theorem for bivariate p–boxes, Montes et al. [2] have introduced imprecise copulas.

**Definition**
A pair $(A, B)$ of functions $A, B : [0,1]^2 \to [0,1]$ is called an imprecise copula if:

- both $A$ and $B$ are grounded;
- both $A$ and $B$ have 1 as a neutral element;
- the next 4 inequalities are satisfied for any rectangle $R = [x_1, x_2] \times [y_1, y_2] \subseteq [0,1]^2$:

$$A(x_2, y_2) + B(x_1, y_1) - A(x_1, y_2) - A(x_2, y_1) \geq 0, \quad \text{(CI-1)}$$

$$B(x_2, y_2) + A(x_1, y_1) - A(x_1, y_2) - A(x_2, y_1) \geq 0, \quad \text{(CI-2)}$$

$$B(x_2, y_2) + B(x_1, y_1) - A(x_1, y_2) - B(x_2, y_1) \geq 0, \quad \text{(CI-3)}$$

$$B(x_2, y_2) + B(x_1, y_1) - B(x_1, y_2) - A(x_2, y_1) \geq 0. \quad \text{(CI-4)}$$

We discuss and exemplify imprecise copulas, and introduce several construction methods. Observe that if $(A, B)$ is an imprecise copula, then both $A$ and $B$ are necessarily quasi–copulas [3], and $A \leq B$. A partial order $\leq$ on imprecise copulas can be introduced as $(A_1, B_1) \leq (A_2, B_2)$ whenever $A_2 \leq A_1$ and $B_1 \leq B_2$. Then the class of all imprecise copulas is an upper semilattice with a top element $(W, M)$ consisting of Fréchet – Hoeffding bounds, and its minimal elements are of the form $(C, C)$, where $C$ is a (bivariate) copula. Any family $(C_t)_{t \in T}$ of copulas [3], denoting $A = \bigwedge_{t \in T} C_t$ and $B = \bigvee_{t \in T} C_t$, defines an imprecise copula $(A, B)$. In general, any family $((A_t, B_t))_{t \in T}$ of imprecise copulas generates an imprecise copula $\left( \bigwedge_{t \in T} A_t, \bigvee_{t \in T} B_t \right)$.

For a quasi–copula $A : [0,1]^2 \to [0,1]$, and a rectangle $R = [x_1, x_2] \times [y_1, y_2] \subseteq [0,1]^2$, the $A$–volume of $R$ is given by

$$V_R(A) = A(x_2, y_2) + A(x_1, y_1) - A(x_1, y_2) - A(x_2, y_1).$$

Define $H_A, G_A : [0,1]^2 \to [0,1]$ by

$$H_A(x, y) = \inf \{ V_A(R) \mid (x, y) \text{ is a vertex of } R \text{ on the main diagonal} \},$$

$$G_A(x, y) = \inf \{ V_A(R) \mid (x, y) \text{ is a vertex of } R \text{ on the opposite diagonal} \}.$$

Obviously, $A$ is a copula if and only if $H_A \equiv 0$ and $G_A \equiv 0$.

**Proposition**
For any quasi–copula $A$, $A^\star = A - H_A$ and $A_\star = A + G_A$ are quasi–copulas.

**Theorem**
A pair of functions $(A, B)$, $A, B : [0,1]^2 \to [0,1]$, is an imprecise copula whenever $A, B$ are quasi–copulas and $B \geq A^\star$, $A \leq B_\star$.

Applying the corresponding construction methods for (quasi–) copulas, one can introduce flipping of imprecise copulas, survival imprecise copulas, ordinal sums of imprecise copulas, convex sums of imprecise copulas, etc. For more details see [1].

**Acknowledgment**
The work on this contribution was supported by the grant VEGA 1/0420/15 and by the European Regional Development Fund in IT4 Innovations Centre of Excellence Project (CZ.1.05/1.1.00/02.0070).

# References

[1] Dibala, M., Mesiar, R., Saminger–Platz, S.: Imprecise copulas. Working paper.

[2] Montes, I., Miranda, E., Pelessoni, R., Vicig, P.: Sklar's theorem in an imprecise setting. Fuzzy Sets and Systems, DOI: 10.1016/j.fss.2014.10.007

[3] Nelsen, R.B.: An introduction to copulas. Second Edition. Springer Series in Statistics, Springer-Verlag, New York (2006)

# Selection consistency of Generalized Information Criterion for sparse logistic model

**Jan Mielniczuk** *Institute of Computer Science, Polish Academy of Sciences and Warsaw University of Technology, Poland*

**Abstract:**

We consider selection rule for small-$n$-large-$P$ logistic regression which consists in choosing a subset of predictors minimizing Generalized Information Criterion (GIC) over all subsets of variables of size not exceeding $k_n$. Namely, for data $(Y, X)$ pertaining to a logistic model

$$GIC(s) = -2\ell(\hat{\beta}(s), Y|X(s)) + a_n|s|,$$

where $s \subseteq \{1, 2, \ldots, p_n\}$ is a given model containing $|s|$ predictors, $\ell$ the log-likelihood function, $\hat{\beta}(s)$ ML estimator for model $s$, $X(s)$ an experimental matrix with columns in $s$ and $a_n$ a chosen penalty. Let $s_0$ be the minimal true model and $\beta_0(s_0)$ the pertaining vector of coefficients. For $\mathcal{M} = \{s : |s| \leq k_n\}$, where $k_n$ is a certain non-decreasing sequence of integers

$$\hat{s}_0 = \arg\min_{s \in \mathcal{M}} GIC(s), \tag{1}$$

was introduced for $k_n = k$ and GLMs in [1]. As the selector makes sense for $k_n \geq |s_0|$ and $|s_0|$ is unknown it is natural to assume that $k_n \to \infty$. The following consistency result and its variants will be discussed. Assume that $a_n = o(n)$, $k_n \log p_n = o(a_n)$ and $k_n^2 \log p_n = o(n)$. Then $\hat{s}_0$ is consistent provided (i) there exist constants $0 < C_1, C_2 < +\infty$ such that for all $n$

$$C_1 \leq \min_{s \in A_1} \lambda_{min}(\frac{1}{n} H_n(\beta_0(s \cup s_0))) \leq \max_{s \in A_1} \lambda_{max}(\frac{1}{n} X'(s \cup s_0) X(s \cup s_0)) \leq C_2$$

and (ii) for any $\varepsilon > 0$ there exists $\delta > 0$ such that for sufficiently large $n$

$$\forall_{s:|s| \leq k_n} \forall_{||\beta(s \cup s_0) - \beta_0(s \cup s_0)|| \leq \delta} (1 - \varepsilon) H_n(\beta_0(s \cup s_0)) \leq H_n(\beta(s \cup s_0)) \leq (1 + \varepsilon) H_n(\beta_0(s \cup s_0)),$$

where $-H_n(\beta(s))$ is Hessian of the log-likelihood for model $s$ and $\lambda_{min}$ ($\lambda_{max}$) is the minimal (maximal) eigenvalue. In particular, results are valid for number of predictors much larger than the sample size.

In practice calculation of $\hat{s}_0$ is preceded by a screening stage in which predictors are ordered according to a specific variable importance measure and $\hat{s}_0$ is calculated for $\tilde{k}_n$ variables ranked highest, where $\tilde{k}_n$ is moderate. We discuss influence of several screening procedures on performance of $\hat{s}_0$ and compare it with a performance of selector being a maximizer of BIC for hierarchical family of submodels.

The talk is based on joint research with H. Szymanowski ([2] and its extensions).

## References

[1] Chen, J., Chen, Z. (2012). Extended BIC for small-n-large-p sparse GLM *Statist Sinica* 22; 555-574.

[2] Mielniczuk, J., Szymanowski, H. (2015). Selection consistency of Generalized Information Criterion for sparse logistic model. *12th Workshop on Stochastic Models, Statistics and Their Applications*, Rafajłowicz, E., Steland, A., Szajowski, K., eds., Springer Proceedings in Mathematics and Statistics, Vol. 122.

# Optimality Theory analysis of frozen and non-frozen Binomials in Annang Language

**Imoh U. Moffat** *Department of Mathematics & Statistics, University of Uyo, Nigeria*

**Abstract:** In this work, we address the issue of binomial formation, the process by which a language user determines the ordering of like-category conjoined items in a three-word phrase of the form A and B (e.g. Fruits and tree, i.e., mfro ne eto, in Annang language). Existing research using experimental, intuition-based, and corpus-based methods suggests that many factors can play a role under the right conditions, including the semantic relationship between the items, metrical and other phonological properties of the possible orderings, and relative item frequency. In Annang language, what remains unaddressed and poorly understood, however, are exactly how these factors interact, and how significant they function in naturally occurring data. Thus the study, which is corpus-based, considers frozen and non-frozen binomials, and deals with how the various constraints interact in three analytical frameworks of this variation: traditional Optimality Theory, stochastic Optimality Theory, and logistic regression. Our best models - using logistic regression âĂŞ predict over 75% of the binomial tokens and about 61% of types, and the remainder are predicted as less-frequent and ungrammatical - variants. These results imply that the semantic constraints outrank metrical constraints, which in turn outrank other phonological constraints in Annang language.

# Threshold models for integer-valued time series with infinite and finite range

**Tobias Möller** *Department of Mathematics and Statistics, Helmut Schmidt University, Germany*
**Christian H. Weiß** *Department of Mathematics and Statistics, Helmut Schmidt University, Germany*

**Abstract:** Threshold models are very popular in research and application. We survey threshold models for integer-valued time series with an infinite range and compare two of them in a real data example. In particular, we propose two new models for count data time series with a finite range.

**Introduction**

Threshold models as proposed by [6] have become very popular in research and application. Due to their attractive interpretability and ability to handle the nonlinearity found in real world data, these models arouse great interest especially in economics and finance, see [2] and [1], but also in other contexts like epidemiology, see [8]. For a long time, only threshold models for time series with a continuous state space have been in the focus of researchers, but recent developments also consider models for time series with a discrete state space. We present a brief survey of threshold models for integer-valued time series with an infinite range and introduce two new models for the case of a finite range.

**Survey of threshold models**

Beginning with the threshold autoregressive (TAR) models by [6] modifications have been made to transfer the idea of threshold models to integer-valued time series. We consider for the case of an integer-valued time series with an infinite range the SETINAR(2,1) model by [5] and [4] and the SETPAR model by [7]. We compare these two models by fitting them to a real data example of counts of heavy earthquakes.

**Threshold models for a finite range**

To the best of our knowledge there do not exist any threshold models for integer-valued time series with a finite range $\{0,\ldots,N\}$. Based on the binomial AR(1) model by [3] which is defined by the recursion

$$X_t = \alpha \circ X_{t-1} + \beta \circ (N - X_{t-1}), \tag{1}$$

where $0 < \alpha, \beta < 1$ and based on the binomial INARCH(1) model by [9] which is given by

$$X_t \overset{D}{=} Bin\left(N, a + b\frac{X_{t-1}}{N}\right), \tag{2}$$

where $0 < a, a+b < 1$, we newly propose extensions of these models with a self-exciting threshold (SET). For both models we consider stochastic properties, like conditional and unconditional moments and derive modifications of the models with restricted parameter sets. Further we compare the models in another real data example.

# References

[1] Chen C W S and So M K P and Liu F-C (2011) A review of threshold time series models in finance. Statistics and its interface 4:167–181

[2] Hansen B E (2011) Threshold autoregression in economics. Statistics and its interface 4:123–127

[3] McKenzie E (1985) Some simple models for discrete variate time series. JAWRA 21(4):645–650

[4] Monteiro M and Scotto M G and Pereira I (2012) Integer-Valued Self-Exciting Threshold Autoregressive Processes. Commun Stat-Theor M 41(15):2717–2737

[5] Thyregod P and Carstensen J and Madsen H and Arnbjerg-Nielsen K (1999) Integer valued autoregressive models for tipping bucket rainfall measurements. Environmetrics 10:395–411

[6] Tong H and Lim K S (1980) Threshold Autoregression, Limit Cycles and Cyclical Data. J R Stat Soc B Met 42(3):245–292

[7] Wang C and Liu H and Yao JF and Davis R A and Li W K (2014) Self-Excited Threshold Poisson Autoregression. J Am Stat Assoc 109(506):777–787

[8] Watier L and Richardson S (1995) Modelling of an Epidemiological Time Series by a Threshold Autoregressive Model. The Statistician 44(3):353–364

[9] Weiß C H and Pollett P K (2014) Binomial Autoregressive Processes With Density-Dependent Thinning. J Time Ser Anal 35(2):115–132

# Nonparametric Regression for latent Variables

**Florian Müller** *Technische Universität Darmstadt, Fachbereich Mathematik, Darmstadt, Germany*
**Michael Kohler** *Technische Universität Darmstadt, Fachbereich Mathematik, Darmstadt, Germany*
**Harro Walk** *Universität Stutgart, Fachbereich Mathematik, Stutgart, Germany*

**Abstract:** We consider the problem of estimating a regression function corresponding to latent variables given an independent and identically distributed sample of the observable variables. Focusing on the common factor model for latent variables, we define a non-parametric least squares estimate of the regression function. We show the strong consistency of the estimate under the assumption that the latent variables are subgaussian and that their characteristic functions vanish nowhere. Additionally we measured the performance of our estimator on simulated data.

# Kernel estimation of Wiener-Hammerstein system nonlinearity

**Grzegorz Mzyk** *Wrocław University of Technology, Poland*

**Abstract:** The problem of non-parametric estimation of the static characteristic in Wiener-Hammerstein (sandwich) system excited and disturbed by random processes will be discussed. The two kernel-based methods will be presented and compared. The proposed estimates are consistent under small amount of a priori information. An IIR dynamics, non-invertible static non-linearity, and non-Gaussian excitations are admitted. In the paper, the convergence of the estimates is proved for each continuity point of the static characteristic and the asymptotic rate of convergence is analysed. The results of computer simulations will be presented to illustrate the behaviour of the estimates for moderate number of observations.

## References

[1] G. Mzyk. *Combined Parametric-Nonparametric Identification of Block-Oriented Systems* Lecture Notes in Control and Information Sciences 454. Springer, 2014.

[2] G. Mzyk. A censored sample mean approach to nonparametric identification of nonlinearities in Wiener systems. *IEEE Transactions on Circuits and Systems âĂŞ II: Express Briefs*, 54(10):897âĂŞ901, 2007.

[3] W. Greblicki. Nonparametric input density-free estimation of the nonlinearity in Wiener systems. *IEEE Transactions on Information Theory*, 56(7):3575âĂŞ3580, 2010.

# GEFCom2014 and probabilistic electricity price forecasting

**Katarzyna Maciejowska,** *Department of Operations Research, Wrocław University of Technology, Poland*
**Jakub Nowotarski,** *Department of Operations Research, Wrocław University of Technology, Poland*
**Jakub Tomczyk,** *School of Mathematics and Statistics, University of Sydney, Australia*
**Rafał Weron,** *Department of Operations Research, Wrocław University of Technology, Poland*

**Abstract:** TEAM POLAND was ranked second in terms of the accuracy of probabilistic forecasts in the Price Forecasting track of the Global Energy Forecasting Competition 2014 (GEFCom2014). This success would not have been possible without developing a robust and efficient forecasting approach. In this paper we present the final outcome - a model which consists four major elements: (i) point forecasting and averaging, (ii) pre-filtering, (iii) quantile regression modelling and (iv) post-processing - and comment on its evolution throughout the twelve-week competition period culminating in December 2014.

# Simultaneous surveillance of means and covariances of spatial models

**Robert Garthoff** *European University Viadrina, Germany*
**Philipp Otto** *European University Viadrina, Germany*

**Abstract:**

This paper deals with the problem of statistical process control applied to multivariate spatial models. After introducing the target process that coincides with the spatial white noise, we concentrate on the out-of-control behavior taking into account both changes in means and covariances. Moreover, we propose conventional multivariate control charts either based on exponential smoothing or cumulative sums to monitor means and covariances simultaneously. Via Monte Carlo simulation the proposed control schemes are calibrated. Moreover, their out-of-control behavior is studied for specific mean shifts and scale transformation.

# Optimization of hydro storage systems and indifference pricing of power contracts

**Raimund M. Kovacevic** *ISOR Vienna, Austria*
**Florentina Paraschiv** *Institute for Operations Research and Computational Finance, University of St. Gallen, Switzerland*
**Michael Schürle** *Institute for Operations Research and Computational Finance, University of St. Gallen, Switzerland*

**Abstract:** In this paper, we aim at a mid-term planning model for hydropower production based on multistage stochastic optimization. We decide about one production schedule for a horizon of one year from the point of view of a producer that owns pumped-storage hydropower plants. These consist of large, seasonal connected reservoirs. We consider stochastic inflows, stochastic electricity prices and stochastic loads. The produced electricity is sold at the spot market. In addition, we follow an indifference pricing approach for non-standard power contracts to determine the price at which the producer is willing to deliver electricity to individual consumers.

# Decentralized time-constrained scheduling for sensor network in identification of distributed parameter systems

**Maciej Patan** *University of Zielona Góra, Poland*
**Adam Romanek** *University of Zielona Góra, Poland*

**Abstract:**

**Introduction**

Experimental design for spatio-temporal physical systems also called distributed parameter systems (DPSs) is often related to an optimal choice of measurement conditions in order to obtain the best information for estimating unknown parameters which can then be used, e.g., in optimal control. The impossibility to observe the system states over the entire spatial domain implies the question of where to locate discrete sensors and how to schedule the observations so as to accurately estimate the unknown system parameters. This is of vital importance in the context of recent advances in distributed sensor networks (SNs) which constitute a natural tools of monitoring distributed systems. [7, 1].

The main goal here is to develop the decentralized approach to scanning sensor configuration in the setting of sensor networks, where the observation system comprises multiple subnetworks and it is desired to activate only a subset of their nodes during a given time interval while the other sensors remain dormant. Additionally, the investigations include limitations on the power consumption of individual sensor nodes. Motivations come from technical limitations inherent to sensor nodes, which are supplied with power from batteries, and therefore their total time of active work is limited.

**Optimal experimental design problem in context**

Let $y = y(x, t; \theta)$ denote the scalar state of a given DPS at a spatial point $x \in \Omega \subset \mathbb{R}^d$ and time instant $t \in T = [0, t_f]$, $t_f < \infty$. Here $\theta$ represents an unknown $m$-dimensional parameter vector which must be estimated using observations of the system. Let assume that the state $y$ is observed directly by $N$ pointwise sensors, from among only $n$ are activated at time instants $0 < t_0 < t_1 < \cdots < t_K = t_f$ and will gather the continuous measurements for the duration of each subinterval $T_k = (t_{k-1}, t_k]$, $k = 1, \ldots, K$.

Since the covariance matrix of the least-squares estimator depends on the active sensor locations, therefore some measure quantifying the 'goodness' of different sensor configurations is required. Such criterion is customarily based on the concept of the *Fisher Information Matrix* (FIM) which is widely used in optimum experimental design theory for lumped systems [7] as its inverse constitutes a good approximation of covariance matrix.

The optimal sensor scheduling problem consists in seeking for each time subinterval $T_k$ the best subset of $n$ locations from among the $N$ given potential ones. More precisely, the problem is to divide for each time subinterval the $N$ available sensor nodes into $n$ active ones and the remaining $N - n$ dormant ones so as to maximize the criterion associated with the parameters to be estimated. However, since the available battery power for each node is limited, we impose the crucial constraints on total activation time for each individual sensor node in the form of the upper limit $L$ denoting the maximal number of time subintervals the sensor is allowed to be active.

**Decentralized multi-exchange algorithm**

To make the outlined idea useful in applications, a numerical algorithm has to be employed. Furthermore, the key property of the resulting procedure should be an efficient distribution of computations between the sensor nodes in a decentralized way. The general idea here is to construct a two-level structure of the network. First, we introduce the partitioning of network

into $G$ disjointed groups of sensors (subnetworks) with $N_p$ sensors in the $p$-th group, in such a way that $\sum_{p=1}^{G} N_p = N$. The resulting subnetworks are forming the lower level of our structure. Further, we assume that for each group we have the same superior entity, further called as ***master node***, responsible for observation schedule optimization within the scope of individual group. These master nodes form the higher level of network which serves as the routing layer for exchanging the data between subnetworks, stores the local activation schedules and finally performs all the computations. The network nodes at lower level within each group communicate only with their master node to upload sensor readings during the actual experiment. In such a way, we obtain the mixed structure: centralized at level of subnetworks and decentralized on the level of master nodes which are responsible for distributing computations.

# References


[1] Patan M (2012) Optimal sensor networks scheduling in identification of distributed parameter systems. Lecture Notes in Control and Information Sciences, vol. 425. Springer-Verlag, Berlin

[2] Uciński D (2005) Optimal Measurement Methods for Distributed-Parameter System Identification. CRC Press, Boca Raton, FL

# Statistical Inference for Signal Symmetries

**Mirosław Pawlak** *Department of Electrical and Computer Engineering, University of Manitoba, Canada*

**Abstract:** This paper formulates the problem of assessing the symmetry property of a function $f$ observed in the presence of noise. We consider both univariate and bivariate characteristics representing signal and image functions. First the problem of estimating a parameter defining the reflection symmetry is examined. This is followed by the question of testing the given symmetry type. The estimation/detection procedure is based on minimizing the $L_2$-distance between empirical versions of $f$ and its symmetrical version. For univariate functions this distance is estimated by the Fourier series type estimate. In the bivariate case we utilize a class of radial series. It is shown that the symmetry parameter can be recovered with the parametric optimal rate for all functions $f$ of bounded variation. The issue of the optimality of the proposed estimation and detection schemes is also discussed.

**Function Symmetry: Estimation and Detection**

Symmetry plays an important role in signal and image understanding. This includes object recognition, alignment, and segmentation [4]. The concept of symmetry is also important in the statistical inference, where efficient tests for distribution symmetry have been proposed [3]. In this paper, statistical aspects of signal symmetries are examined. We aiming at the fundamental problems of estimating symmetry parameters like the position of the axis of reflection symmetry and detection of symmetry type. For objects represented by a function $f$ that belongs to the space $\mathcal{F}$ one can define a symmetry class on $\mathcal{F}$ as follows: $\mathcal{S} = \{f \in \mathcal{F} : f = \tau_\theta f, \theta \in \Theta\}$, where $\tau_\theta$ is mapping $\tau_\theta : \mathcal{F} \to \mathcal{F}$ that represents the transformed version of $f$. The mapping $\tau_\theta$ is parametrized by $\theta \in \Theta$. Hence, the class $\mathcal{S}$ is a subset of $\mathcal{F}$ defining all objects from $\mathcal{F}$ that are symmetric with respect to the class of operations $\{\tau_\theta\}$ parametrized by $\theta \in \Theta$ . In the univariate case the reflection symmetry is characterized by the mapping $\tau_\theta f(x) = f(2\theta - x)$. For bivariate functions we have two basic symmetries, i.e., reflection and rotational symmetries.
In real-world applications we wish to assess the symmetry in $f$ based only on a training set of $n$ noisy and discrete observations. Hence, one needs to address the following fundamental issues: (1) Estimating the parameters characterizing the given type of symmetry, (2) Detection of the type of symmetry present in the original unobserved image. Since the signal function $f$ is not specified, the first question can be viewed as the semi-parametric estimation problem involving the true symmetry parameter $\theta_0$, along with an infinite-dimensional nuisance parameter $f \in \mathcal{F}$. The fact that $f$ remains unspecified implies a loss of efficiency with respect to estimating $\theta_0$. The detection issue can be consider as the nonparametric lack-of-fit testing problem as we wish to test the null hypothesis $H_0 : f = \tau_{\theta_0} f$, for some $\theta_0 \in \Theta$, against the alternative $H_a : f \neq \tau_\theta f$ for all $\theta \in \Theta$, where both $\theta_0$ and $f$ are not specified.
Our estimation and test statistics are constructed by expressing the symmetry condition in terms of restrictions on Fourier coefficients of the classical Fourier series (univariate case) or in terms of the radial moments for images. The estimation procedure is based on minimizing over $\theta \in \Theta$ the $L_2$-distance between empirical versions of $f$ and $\tau_\theta f$ defining the symmetry classes. Hence, let $\hat{f}_T$ denote the series estimate of $f$ based on the first $T$ terms of the series expansion. Then, we estimate the true parameter $\theta_0$ by $\widehat{\theta}_n = argmin_{\theta\in\Theta} \parallel \widehat{f}_T - \tau_\theta \hat{f}_T \parallel^2$,. The corresponding test

statistic for verifying $H_0$ has the form $D_T = \| \widehat{f}_T - \tau_{\widehat{\theta}_n} \widehat{f}_T \|^2$. The alternative form of $D_T$ would be $D_T = min_{\theta \in \Theta} \| \widehat{f}_T - \tau_\theta \widehat{f}_T \|^2$. We argue in this paper that the estimate $\widehat{\theta}_n$ converges to $\theta_0$ with the optimal $\sqrt{n}$ rate for all signals $f$ that are functions of bounded variation. Further, we establish asymptotic normality of $\widehat{\theta}_n$ assuming additional smoothness in $f$. The issue of the semi-parametric optimality is also examined. The detection method is proved to be consistent against all deviations from the symmetry assumption. Extensions to the statistical assessment of imperfect symmetries and symmetries that only hold locally are also discussed.

# References


[1] Bissantz, N., Holzmann, H., and Pawlak, M. (2009). Testing for image symmetries-with application to confocal microscopy, *IEEE Trans. Inf. Theory*, 55: 1841-1855.

[2] Bissantz, N., Holzmann, H., and Pawlak, M., (2010). Improving PSF calibration in confocal microscopic imaging - estimating and exploiting bilateral symmetry, *The Annals of Applied Statistics*, 4: 1871-1891.

[3] Inglot, T., Janic, A., and Józefczyk, J. (2012). Data driven tests for univariate symmetry, *Prob. and Math. Stat.*, 32: 323-358.

[4] Liu, Y., Hel-Or, H., Kaplan,C.S., and van Gool, L. (2010). *Computational Symmetry in Computer Vision and Computer Graphics*. Now Publishers, Boston.

[5] Pawlak, M. (2014). Moment invariants for image symmetry estimation and detection, *Moments and Moment Invariants*, Papakostas, G.A. ed., pp. 91-110, Science Gate Publisher, Greece.

# Risk-Averse Equilibrium Modelling and Social Optimality of Cap-and-Trade Mechanisms

**Paolo Falbo** *University of Brescia, Department of Economics and Management, Italy*
**Juri Hinz** *University of Technology, Sydney, School of Mathematics, Australia*
**Cristian Pelizzari** *University of Brescia, Department of Economics and Management, Italy*

**Abstract:** We present and explore a link between social optimality and risk neu- tral dynamics satisfied in the equilibrium of emission markets. Our contribution addresses market modeling in the setting of risk-averse market players and goes be- yond all existing models in this field, which neglect risk-aversion aspects at the cost of having a wide range of singularities.

# A study on robustness in the optimal design of experiments for copula models

**Elisa Perrone** *Department of Applied Statistics, Johannes Kepler University Linz, Austria*

**Abstract:** Copulas are a very flexible tool to highlight structural properties of the design for a wide range of dependence structures. In this work we introduce a procedure for checking the robustness of the D-optimal design with respect to slight changes of the marginal distributions in the case of copula models. To this end, we first provide a clear insight for the concept of "robustness" in our domain. Then, we define a stepwise method for the investigation of the design robustness. Finally, by reporting an example focused on comparison between the use of logistic margins and Gaussian margins, we put the usefulness of the analysis up.

**Introduction**

In many areas of applied statistics, copula functions are largely employed as a flexible tool to describe the behaviour of the dependence between random variables. However, the study of the design of the related experiment is still a neglected aspect.

A first step in this direction was made in the work of Denman et al. [1], a more complete and formal framework for copula models was described in our previous work [3], where a Kiefer-Wolfowitz type equivalence theorem was also provided. Despite the tools reported in [3] allow one to find the D-optimal design for any copula models, the computational complexity of the Fisher Information Matrix could represent a practical limitation due to the presence in the copula model of particular marginal distributions. Therefore, a natural question is whether the assumptions on the margins can be relaxed to gain in computational power with a consequently better understanding of the role of the dependence structure itself in the design.

In this work we provide a stepwise procedure to check whether a candidate auxiliary model with the same dependence structure but slightly different margins could be used to avoid some computational problems (all the details can be found in [2]).

**The procedure**

Let us consider the theoretical framework introduced in [3]. Then, $Y_1$ and $Y_2$ are two random variables whose dependence is described by the copula $C_\alpha$. We assume the "Model 1" being the true design model with margins $F_1(Y_1(x))$, $F_2(Y_2(x))$. We define for the vector $(Y_1, Y_2)$ a second model, named "Model 2", whose margins are $G_1(Y_1(x))$ and $G_2(Y_2(x))$. The procedure, that follows, is essentially composed of two parts: first, check the goodness (in the sense of D-efficiency) of the D-optimal designs found for a misspecified model with respect to the initial one (step 1-4); second, use the misspecified model to conduct a robustness study on the designs for a wider range of the association measure (step 5).

1. Find the pure impact of the marginals on the design by considering the product copula for the two models.
2. Find the optimal design by using the Fedorov-Wynn algorithm for both models. Calculate the D-efficiency by assuming that the Model 1 is the correct one.
3. Fix a copula $\tilde{C}_\alpha$. Select a set of parameters where the optimal designs for the Model 1 can be computed.
4. Find the optimal design for both models for the selected parameter set. Calculate the D-Efficiencies of the designs.

5. If the losses in the D-efficiencies in percent are lower than a given threshold, fix an enlarged set of parameters where the Model 1 has numerical problems and investigate the robustness of the design (in the sense of the copula) for the new parameter space by using the Model 2.

The robustness study presented in this work differs from other approaches whose aim is to provide robust designs with respect to misspecifications of the model assumptions. As a matter of fact, it just concerns the impact of the dependence structure on the designs. Essentially, to evidence the impact of the margins on the design, the analysis is carried out by slightly modifying the initial model. However, the new misspecified model has the same fixed dependence structure of the initial model, with different distributions of the random variables.

# References


[1] N. G. Denman, J. M. McGree, J.A. Eccleston, S.B. Duffull. Design of experiments for bivariate binary responses modelled by Copula functions. Computational Statistics and Data Analysis, vol **55**, (2011), pag. 1509-1520.

[2] E. Perrone. A study on robustness in the optimal design of experiments for copula models Proceeding of workshop on Stochastic Models, Statistics and Their Applications / 12th, February 16-20, 2015, WrocÅĆaw, Poland. Springer Proceedings in Mathematics and Statistics., Chapter 37, pag. 381-388.

[3] E. Perrone and W. G. Müller. Optimal Designs for Copula Models. arXiv:1406.2933.

# On the construction of scenario trees based on the multistage empirical process

**Georg Pflug**, *Department of Statistics and Operations Research, University of Vienna, Austria*

**Abstract:** In multistage decision making under uncertainty, the most used paradigm is to define the decision problem on a finite scneario tree, which should represent the stochastic scenario process in an optimal way. We demonstrate first that a good metric for the distance of processes on filtered spaces is the nested distance, a generalization of the well known Wasserstein distance. Then we consider the approximation of processes by finite processes, measured by this distance. Our estimators for the tree approximation are based on density and conditional density estimates, for which we formulate quality bounds and demonstrate unifrom consistency and asymptotic normality. The method was implemented and some results on practical use of the algorithms are presented.

# Forecasting renewable energy generation: from simple approaches to high-dimensional distributed learning

**Pierre Pinson** *Energy Analytics & Markets, Centre for Electric Power and Energy Technical University of Denmark, Electrical Engineering, Denmark*

**Abstract:** The deployment of renewable energy capacities is increasing at a rapid pace, also motivating the collection of large amount of data. This data originates from meteorological instruments, meteorological models, remote-sensing, and power measurement devices onsite. In parallel, the decision-making problems that require forecasts as input are becoming more numerous and diverse. While it could be seen as acceptable to predict aggregate power generation in a deterministic framework still a few years ago, now focus is given to predictive densities and space-time trajectories, permitting to make optimal decisions in a stochastic optimization framework. We will first motivate the need for more advanced forecasting products, also discussing the challenges related to their verification. Approaches to the generation of such trajectories will then be presented, with particular emphasis on combining nonparametric marginal densities and copulas for the space-time dependence structures. In a final part, new ideas related to distributed learning in renewable energy forecasting will be reviewed.

# Methodology for segmentation of time series with arbitrary generating mechanisms via $\epsilon$-complexity

**Boris Darkhovsky** *Institute for Systems Analysis, Moscow, Russia*
**Alexandra Piryatinska** *Department of Mathematics, San Francisco State University, San Francisco, CA, USA*

**Abstract:** This is the second part of our joint talk named "Novel methodology of change-point detection for time series with arbitrary generated mechanisms." In the first part the concept of $\epsilon$-complexity of continuous function was presented. In this part we utilize this concept to detect changes in a generating mechanism. In particular, we estimate $\epsilon$-complexity coefficients and use them as an input to the non-parametric change-point detection procedure. The proposed methodology is model-free and doesn't depend on the data generating mechanisms. The results of simulations, and application to EEG and stock market data, demonstrate the efficiency of our methodology.

**Algorithm for Segmentation of Time Series**

In this talk we propose to use the $\epsilon$-complexity of a continuous function as an "intrinsic" characteristic of a time series, which on the one hand allows us to perform segmentation into homogeneous increments and on the other hand doesn't depend on the type of data generating mechanism.

Let $X = \{x(t)\}_{t=1}^{N}$ be a time series with unknown moments of changes in generating mechanism (MCGM) $t_i, i = 2, \dots, k$ (it is unknown if there are changes or not). The type of generating mechanism is also unknown and can be stochastic, deterministic or mixed.

Any segment $[t_i, t_{i+1}]$, $t_1 = 1, \dots, t_{k+1} = N$, which is generated by the same mechanisms is called *homogeneous*. We assume that homogeneous segments are sufficiently long.

In the first part it was shown that $\epsilon$-complexity is uniquely characterized by a pair of parameters $\mathbb{R} = (A, B)$. For a given time series let us choose a window of size $n$ (we assume that $n \ll \min l_i(t_{i+1} - t_i)$). We can separate time series into disjoint intervals of length $n$ or consider a sliding window of size $n$. In case of disjoint intervals we calculate the $\epsilon$-complexity coefficients $\mathbb{R}(j)$ for $\{x(t)\}_{t=1+(j-1)n}^{jn}$, $j = 1, 2 \dots, p$(for a simplicity we suppose that $N/n = p$ and $p$ is an integer). As a result we obtain a new *diagnostic vector sequence* $\{\mathbb{R}(j)\}_{j=1}^{[N/n]}$. Similar vector sequence of the $\epsilon$-complexity coefficients can be also calculated for sliding window.

*The keystone of the proposed methodology* for segmentation of time series into homogeneous increments is a following Conjecture:

**Conjecture.** *At i-st segment of homogeneity $[t_i, t_{i+1}]$ of the time series $X$ for $t_i \le t$, $(t + n)$ satisfy the relation*

$$\mathbb{R}(j) = \mathbb{R}_i + \xi_i(j), \tag{1}$$

*where $\xi_i(j)$ is a random process with zero expectation.*

Thus, assuming the above Conjecture is true, the problem of a time series segmentation is reduced to the detection of changes in mathematical expectation of the vector diagnostic sequence $\mathbb{R}$.

To solve this problem we propose to use the following family of the statistics, which was introduced by Brodsky and Darkhovsky, see [1].

$$Y(n, \delta) = \left((\mathbb{N} - r)r/\mathbb{N}^2\right)^{\delta} \left( r^{-1} \sum_{k=1}^{r} z(k) - (\mathbb{N} - r)^{-1} \sum_{k=r+1}^{\mathbb{N}} z(k) \right), \tag{2}$$

where $0 \leq \delta \leq 1, 1 \leq r \leq \mathbb{N}-1, \mathbb{N} = [N/n]$, $Z = \{z(s)\}_{s=1}^{\mathbb{N}}$ is a diagnostic sequence. It can be shown (for details, see [1]) that the estimates of the change-points parameter $\vartheta = (\vartheta_2, \ldots, \vartheta_k)$, $t_i = [\vartheta_i N], i = 2, \ldots, k$, $0 < \theta_1 < \theta_2 < ...\theta_k < 1$ by using the family of statistics (2) under mild conditions are asymptotically minimax as $N \to \infty$ (here we apply the change-point detection procedure for each component of vector diagnostic sequence $\mathbb{R}$ separately).

The results of simulations and applications to the EEG (see, [2]) and Stock Market data will be presented.

# References


[1] Brodsky BE and Darkhovsky BS (2000) Non-parametric Statistical Diagnosis: Problems and Methods, Kluwer, Dordrecht.

[2] Darkhovsky B and Piryatinska A (2012) A new complexity-based algorithmic procedures for electroencephalogram (EEG) segmentation. Conf Proc IEEE Signal Processing in Medicine and Biology Symposium (SPMB) 2012. DOI: 10.1109/SPMB.2012.6469462 2012.

# Gaussian mixture decompositions for computation of features of protein spectral signals

**Andrzej Polański** *Institute of Informatics, Silesian University of Technology, Gliwice, Poland.*
**Michal Marczyk** *Data Mining Group, Institute of Automatic Control, Silesian University of Technology, Gliwice, Poland*
**Monika Pietrowska** *Department of Experimental and Clinical Radiobiology, Maria Sklodowska-Curie Memorial Cancer Center and Institute of Oncology, Branch in Gliwice, Poland*
**Piotr Widlak** *Department of Experimental and Clinical Radiobiology, Maria Sklodowska-Curie Memorial Cancer Center and Institute of Oncology, Branch in Gliwice, Poland*
**Joanna Polańska** *Data Mining Group, Institute of Automatic Control, Silesian University of Technology, Gliwice, Poland*

**Abstract:** We develop a methodology for processing proteomic mass spectra (MS) based on Gaussian mixture decomposition of the MS signal. We apply a version of the EM algorithm for Gaussian mixture decomposition of the proteomic mass spectral signal. Features of spectral signals are obtained on the basis of components of Gaussian mixture decomposition. We demonstrate efficiency of our method by comparing our approach to methods based on spectral peaks.

**Introduction**

A largest portion of the procedures for processing of proteomic mass profiles involves detection of individual peaks and their alignment between different spectra e.g., [1]. Once peaks have been determined numerically, they serve as features in the further data processing steps, e.g., designing classifiers for samples. Most frequently, when proteomic mass spectra are interpreted it is assumed that each spectral peak corresponds to a specific protein/peptide ion registered, and the composition of mass spectrum carries direct information on composition of the analyzed samples.

Another approach to computational processing of proteomic MS spectra is modeling spectral signals by mixtures of component functions. Most often the component functions are Gaussian distribution functions. Some results in this area were published e.g., in [2]. There are several advantages of using mixture modeling for protein MS spectra. In particular mixture models potentially allow for more accurate estimation of peptide concentrations in the proteomic samples as well as for more accurate estimation of their masses.

**The method**

Mixture models are fitted to data by application of the EM algorithm. However there is a difficulty in using mixture modeling approach stemming from computational issues, namely from difficulties in achieving convergence of iterations of the EM algorithm to solution of sufficiently high quality. We propose a method for computation of proteomic spectral features based on Gaussian mixture decomposition of the proteomic mass spectral signal. Features of spectral signals are obtained on the basis of components of Gaussian mixture decomposition. Gaussian mixture decomposition of the spectral signal is computed by application of EM algorithm combined with decomposition of the spectral signal into fragments.

**Results**

The proposed methodology has been applied to two MALDI-ToF mass spectra datasets, our own dataset comprising spectra of plasma samples obtained from 22 head and neck cancer

patients and 30 healthy donors, and the dataset from [3] including spectra of serum samples obtained from 47 ovarian cancer patients and 42 matched controls and. We have evaluated the developed methodology by performing experiments concerning quality of estimators of peptide species concentrations in proteomic samples and further to use these estimators as spectral features in cancer versus normal classifiers. Spectral features built of Gaussian masks were compared to those defined by spectral peaks. In cross validation experiments, classifiers based on spectral features defined by convolutions of Gaussian masks with spectral signals achieve lower average error rates than classifiers based on spectral peaks.

# References


[1] Baggerly K. A., Morris J. S., Coombes K. R., (2004), Reproducibility of SELDI-TOF protein patterns in serum: comparing datasets from different experiments, *Bioinformatics*, vol. 20., pp 777âĂŞ785.

[2] Dijkstra, M., Roelofsen, H., Vonk, R.J., Jansen, R.C. (2006) Peak quantification in surface-enhanced laser desorption/ionization by using mixture models. *Proteomics*, 6(19), 5106-16.

[3] Wu B., Abbott T., Fishman D., McMurray W., Mor G., Stone K., Ward D., Williams K., Zhao H., (2003), Comparison of statistical methods for classification of ovarian cancer using mass spectrometry data, *Bioinformatics*, vol. 19., pp. 1636âĂŞ1643.

# An Exact Formula for the Average Run Length to False Alarm of the Generalized Shiryaev–Roberts Procedure for Change-Point Detection under Exponential Observations

**Wenyu Du** *Department of Mathematical Sciences, State University of New York at Binghamton, U.S.A.*
**Grigory Sokolov** *Department of Mathematical Sciences, State University of New York at Binghamton, U.S.A.*
**Aleksey S. Polunchenko** *Department of Mathematical Sciences, State University of New York at Binghamton, U.S.A.*

**Abstract:** We derive analytically an exact closed-form formula for the standard minimax Average Run Length (ARL) to false alarm delivered by the Generalized Shiryaev–Roberts (GSR) change-point detection procedure devised to detect a shift in the baseline mean of a sequence of independent exponentially distributed observations. Specifically, the formula is found through direct solution of the respective integral (renewal) equation, and is a general result in that the GSR procedure's headstart is not restricted to a bounded range, nor is there a "ceiling" value for the detection threshold. Apart from the theoretical significance (in change-point detection, exact closed-form performance formulae are typically either difficult or impossible to get, especially for the GSR procedure), the obtained formula is also useful to a practitioner: in cases of practical interest, the formula is a function linear in both the detection threshold and the headstart, and, therefore, the ARL to false alarm of the GSR procedure can be easily computed.

# Monitoring changes in RCA models

**Zuzana Prášková** *Department of Probability and Mathematical Statistics, Charles University in Prague, Czech Republic*

**Abstract:** A sequential monitoring scheme is proposed to detect instability of parameters in a random coefficient autoregressive (RCA) time series model of general order p. A given set of historical stable observations is available that serves as a training sample. The proposed monitoring procedure is based on the quasi-likelihood scores and the quasi-maximum likelihood estimators of the respective parameters computed from the training sample, and it is designed so that the sequential test has a small probability of a false alarm and asymptotic power one as the size of the training sample is sufficiently large. The asymptotic distribution of the detector statistic is established under both the null hypothesis of no change as well as under the alternative that a change occurs.

# Detecting changes in spatial-temporal image data

**Annabel Prause** *Institute of Statistics, RWTH Aachen University, Germany*
**Ansgar Steland** *Institute of Statistics, RWTH Aachen University, Germany*

**Abstract:** We consider the problem to monitor a sequence of images that may be affected by spatial as well as temporal dependencies and present two different models to solve this problem. The underlying methods rely on results of the signal sampling theory and lead to different dectectors, for which we will derive the asymptotic distribution under the null hypothesis of no change and under general local alternatives.

**Introduction**

We study detection methods for three-dimensional signals under dependent noise, i.e. for signals in the space-time domain. We model these signals either as $f\colon \mathbb{R}^3 \to \mathbb{R}$ or as $\mathbf{f}\colon \mathbb{R} \to \mathbb{R}^{N_y \times N_x}$ for $N_x, N_y \in \mathbb{N}$. Examples for such signals are multifaceted. They include geographic and climatic data as well as image data, that are observed over a fixed time horizon.

As in practice in the presence of noise we usually cannot observe $f$ itself we work with a finite block of noisy samples $\{y_i : i \in \{1, \ldots, n\}\}$ following the model

$$y_i = f(i\tau) + \varepsilon_i.$$

Here, $f$ is the unknown signal that is either a map $f\colon \mathbb{R}^3 \to \mathbb{R}$ or a map $\mathbf{f}\colon \mathbb{R} \to \mathbb{R}^{N_y \times N_x}$, $\{\varepsilon_i\}$ is a zero mean noise process and $\tau$ is the sampling period that can attain different values in the case that $f\colon \mathbb{R}^3 \to \mathbb{R}$. We assume that it fulfills $\tau \to 0$ and $n\tau \to \overline{\tau}$, as $n \to \infty$.

**The method**

Our aim is to reconstruct the unknown signal $f$ on the basis of the sample $\{y_i\}$ and to detect changes from a given reference signal. Our approach is based on classical reconstruction procedures from the signal sampling theory, see also [3] and [4], leading to a sequential partial sum process as detector statistic. In the case that $\mathbf{f}\colon \mathbb{R} \to \mathbb{R}^{N_y \times N_x}$, in order to detect a change, we consider a detector based on linear combinations of quadratic forms, cf. [8], using results from [2].

In order to make these detector statistics applicable we need to determine proper critical values / control limits; thus, we show weak convergence towards gaussian processes under different assumptions on the dependence structure, allowing a wide applicability of the results. The main assumption that is needed for this purpose is an assumption on the noise process $\{\varepsilon_i\}$, namely that it fulfills a weak invariance principle, cf. [1]. After having established the limit distribution under the null hypothesis, where the signal corresponds to some reference signal, we also show weak convergence under local alternatives.

In all of our limit distributions a certain variance parameter, summing up all autocovariances of the noise process, appears. As this is in general unknown we also need a proper estimator for this parameter.

Finally, we also perform a simulation study regarding the power and error rates of one of our detection algorithms. This includes a subsampling procedure in order to appropriately determine some unknown parameters of the algorithm. More details regarding the presented methods can be found in [5], [6] and [7].

# References


[1] Deo, C. M. (1975). A functional central limit theorem for stationary random fields. *Ann Probab*, 3(4), 708–715.

[2] Pawlak, M. and Steland, A. (2013). Nonparametric sequential signal change detection under dependent noise. *IEEE T Inform Theory*, 59(6), 3514–3531.

[3] Pawlak, M. and Stadtmüller, U. (1996). Recovering band-limited signals under noise. *IEEE T Inform Theory*, 42(5), 1425–1438.

[4] Pawlak, M. and Stadtmüller, U. (2007). Signal sampling and recovery under dependent errors. *IEEE T Inform Theory*, 53(7), 2526–2541.

[5] Prause, A. and Steland, A. (2014). Sequential Detection of Three-Dimensional Signals under Dependent Noise. Preprint.

[6] Prause, A. and Steland, A. (2014). Sequential Detection of Three-Dimensional Signals under Dependent Noise – Some Simulation Results. Preprint.

[7] Prause, A. and Steland, A. (2014). Sequential Detection of Vector-Valued Signals under Dependent Noise. Preprint.

[8] Prause, A. and Steland, A. (2015). Detecting changes in spatial-temporal image data based on quadratic forms. Springer Proceedings.

# Simultaneous Confidence Bands in Nonparametric Regression - With Applications to Image Analysis

**Katharina Proksch** *Department of Mathematics, University of Siegen, Germany*

**Abstract:** In nonparametric regression, given a model such as

$$Y_j = m(x_j) + \varepsilon_j \quad j = 1, \ldots, n, \tag{1}$$

one aim is to recover the function $m$, which is observed corrupted with additive, random noise at $n$ design-points, from these observations. To account for the uncertainty in the reconstruction due to the random noise component, interval estimates are often employed to obtain error limits for specific points $m(x)$. In many settings, even global error limits for the whole curve of interest, that is, simultaneous confidence bands can be derived as well.

In this talk the construction of simultaneous confidence bands for the nonparametric additive error model (1) as well as for a Poisson-type regression model

$$Y_j \sim \text{Poisson}(m(x_j)) \quad j = 1, \ldots, n,$$

is discussed and the transfer of the results to inverse regression problems such as deconvolution, which is closely related to image analysis, or Radon-transformed data, is presented. Both, theoretical and numerical results are given.

# Control charts for long-memory processes

**Liubov Rabyk** *Department of Statistics, European University Viadrina, Frankfurt (Oder), Germany*
**Wolfgang Schmid** *Department of Statistics, European University Viadrina, Frankfurt (Oder), Germany*

**Abstract:** A lot of modified versions of Shewhart, EWMA and CUSUM control charts have been applied to correlated data following autoregressive moving average (ARMA) models that are often referred to as a short memory processes. This control charts have been found to be effective for monitoring stationary processes with autocorrelation functions decreasing exponentially and in a suitably fast manner. However, many empirically observed time series such as stock returns, wind speed, hydrological time series have been found to have autocorrelation functions decreasing slowly by hyperbola. Such processes are called long-memory processes. The class of autoregressive fractionally integrated moving average (ARFIMA) processes having fractional differencing parameter d is often used to characterize long-range dependent behavior. Since there are a lot of time series following ARFIMA models, they are of natural interest in quality control research.

In this talk EWMA control charts are introduced for detecting changes in the mean of long-memory processes. Also CUSUM variance charts for ARFIMA(p,d,q) processes using the likelihood ratio approach, the sequential probability ratio method and the Shiryaev-Roberts procedure were considered.

First we introduce the autoregressive fractionally integrated moving average (ARFIMA) processes. At the same time, the overview of control charts for dependent data will be given. Then, the moments of the EWMA statistics are calculated and CUSUM variance charts based on the likelihood ratio approach, the sequential probability ratio method and the Shiryaev-Roberts procedure for long-memory processes are introduced. The performance of the presented control charts is analyzed by simulations. As a measure of performance the average run length (ARL) was used. The target process is given by ARFIMA processes. ARFIMA(1,d,0), ARFIMA(0,d,1) and ARFIMA(1,d,1) processes were considered.

## References

[1] Beran, J., Feng, Y., Ghosh, S. and Kulik, R.: *Long-Memory Processes - Probabilistic Properties and Statistical Methods*. Springer, 2013.

[2] Brockwell, P. and Davis, R.: *Time series: theory and methods*. Springer, 1991.

[3] Granger, C. and Joyeux, R.: An introduction to long-range time series models and fractional differencing. *Journal of Time Series Analysis*, 1, 15-30, 1980.

[4] Granger, C.: Some properties of time series data and their use in econometric model specification. *Journal of Econometrics*, 16, 121-130, 1981

[5] Hosking, J.: Fractional differencing. *Biometrika*, 68, 165-176, 1981.

[6] Knoth, S. and Schmid, W.: Control charts for time series: A review. *Fronties in Statistical Quality Control*, eds. Lenz H.-J. and Wilrich P.-T. Physica, Vol.7, 210-236, 2004.

[7] Montgomery, D.: *Introduction to Statistical Quality Control (Sixth Edition)*. John Wiley & Sons, New York, 2009.

[8] Palma, W. *Long-Memory Time Series: Theory and Methods*. John Wiley & Sons, New York, 2007.

[9] Schipper, S. and Schmid, W.: Sequential methods for detecting changes in the variance of economic time series. *Sequential Analysis*, 20, 235-262, 2001.

[10] Schmid, W.: On the run length of a Shewhart chart for correlated data. *Statistical Papers*, 36, 111-130, 1995.

[11] Schmid, W.: On EWMA charts for time series. *Frontiers in Statistical Quality Control*, eds. Lenz H.-J. and Wilrich P.-T.

[12] Schmid, W.: CUSUM control schemes for Gaussian processes. *Statistical Papers*, 38, 191-217, 1997b.

[13] Sowell, F.: Maximum likelihood estimation of stationary univariate fractionally Physica, Vol.5, 115-137, 1997a. integrated time series models. *Journal of Econometrics*, 53, 165-188, 1992.

# Detection of essential changes in spatio-temporal processes with applications to camera based quality control

**Ewaryst Rafajłowicz** *Department of Automatic Control and Mechatronics, Wrocław University of Technology, Wrocław, Poland*

**Abstract:** The need for detection of essential changes in spatio-temporal processes arises in a large number of applications, when we observe a large number of parallel processes that may change in time. Our aim in this paper is to propose a simple detector of changes in time that is well suited for parallel use at a large number of spatial sites, since our main motivation is change detection in a sequence of images that are dedicated for quality control of continuously running industrial processes.

**Introduction**

To motivate our approach, consider a sequence of images provided by a camera that follows the quality of a certain production process. It is clear that the change at one pixel only is rather unimportant from the view point of the production quality control. We should rather concentrate on more massive changes that arise in a spatially concentrated area that arise at the same time or at time instants from a certain time interval that is not too large in comparison to the frame rate of image acquisition. From the statistical point of view quite similar change detection tasks arise when a bank observes the amount of money collected on accounts of its clients. In the same vain one can consider:

– a health care system, when the growing number of patients in a certain area should be detected as a possible indicator of an epidemia,

– a stock market – prices of shears of enterprises can fluctuate, but a rapid reduction of them at a certain area can be a symptom of certain economic changes.

Detecting changes simultaneously in time and space has not so rich bibliography as one might expect. The main contributions in this direction come from applications of image sequences processing and their applications in geoscience (see [1], [7], [2]). Quickest detection of significant changes in a sensor net that is based on a non-cooperative stopping game which is a model of the multivariate disorder detection has been proposed in [8].The approach proposed in [3] also covers spatio-temporal changes as a special case of detecting jumps of time series with values in a Banach space. The results on change detection in high-dimensional data streams [5], [6] may also be useful for spatio-temporal change detection.

We propose a simple change detector of changes in time that is well suited for parallel use at a large number of spatial sites. The idea is based on exponentially weighted moving average smoothing (EWMAS), but the detector itself is different than the one that is used in the classic EWMA chart. In particular, it allows to distinguish between jumps of a moderate size and those that are large. It keeps the main advantage of the classic EWMA chart, namely, there is no need to store historical data, i.e., for the current decision it suffices to have the present smoothed state and the current observation, which is crucial importance when we have to monitor millions of sites or pixels. The EWMAS is based on the idea of vertical weighting that was used for detecting changes in space (edges) in [4].

## References


[1] Ji M and Jensen JR (1999), Effectiveness of Subpixel Analysis in Detecting and Quantifying Urban Imperviousness from Landsat Thematic Mapper Imagery, Geocarto International 14(4): 33-41

[2] Megahed F M, Woodall W H and Camelio J A (2011) A review and perspective on control charting with image data. Journal of Quality Technology, 43(2): 83-98

[3] Pawlak M, Rafajłowicz E and Steland A (2004) On detecting jumps in time series: nonparametric setting, Journal of Nonparametric Statistics 16(3/4): 329-347

[4] Rafajłowicz E (2007) SUSAN edge detector reinterpreted, simplified and modified. In: International Workshop on Multidimensional (nD) Systems, Aveiro, Portugal, 69-74

[5] Skubalska-Rafajłowicz E (2011) Fast and efficient method of change detection in statistically monitored high-dimensional data streams. In: Proceedings of the 10th International Science and Technology Conference on Diagnostics of Processes and Systems, Zamość, Poland, pp. 256–260

[6] Skubalska-Rafajłowicz E (2013) Random projections and Hotellingï£¡s $T^2$ statistics for change detection in high-dimensional data streams. International Journal of Applied Mathematics and Computer Science 23(2):447–461

[7] Ristivojevic M and Konrad J(2006), Space-Time Image Sequence Analysis: Object Tunnels and Occlusion Volumes. IEEE Transactions On Image Processing 15(2): 364-376

[8] Szajowski K (2011) Multi-variate quickest detection of significant change process. In: Baras, J.S., Katz, J., Altman, E. (eds.) Decision and Game Theory for Security. Second international conference, GameSec 2011, College Park, MD, Maryland, USA, November 14âĂŞ15, 2011. Lecture Notes in Computer Science 7037: 56 - 66. Springer, Berlin

# Trajectory selection for reconstruction and optimization of performance function in UMV

**Massimo Caccia** *ISSIA, CNR Consiglio Nazionale delle Ricerche, Italy*
**Eva Riccomagno** *Dipartimento di Matematica, Universitá degli Studi di Genova, Italy*
**Eleonora Saggini** *Dipartimento di Matematica, Universitá degli Studi di Genova, Italy*

**Abstract:** A joint project between our two institutions relates to the definition and evaluation methods of performance indices during path-following and/or path-tracking tasks for unmanned marine vehicles. In the work we are presenting here, the performance is related to the tracking error (given by the reference path minus the observed/registered path) and, for sake of example, is chosen to be the integrals of the squared tracking error over a steady state time period, a settling period and the path approach and turn period, separately. For each time period, the design problem would consists in the choice of a suitable subset of reference trajectories at which to evaluate the tracking error in order to reconstruct the performance function or to maximise it. Our work is meant as a contribution to the current discussion on the establishment of new technological regulations for the introduction of autonomous robots in civilian applications.

**Introduction**

This work is part of a recent collaboration between CNR-ISSIA Istituto di Studi sui Sistemi Intelligenti per l'Automazione and Dipartimento di Matematica, Universitá di Genova on definition of good experimental methodologies and practices in marine robotics and establishing ground-truthing methodologies within an environment with a high degree of uncertainty. The introduction of autonomous robots (here UMV such as USV, ROV, gliders, AUV) in civilian applications requires new technological regulations, currently the focus is on weighing benefits against risks as the risks are largely unknown and difficult to quantify. Our project aims at providing real-time, adaptive and sequential algorithms to (automatic) control and optimize the dynamics of the vehicle with a view towards control and evaluation of manoeuvres performance. This paper within that project wants to deal with the limited task of describing a general method and its constraints of applicability for describing performance. Thus it deals with the description of vehicle performance rather than intervention on vehicle motion.

A path following experiment is defined as $n$ runs, corresponding to $n$ different paths that are executed sequentially in time; ideally runs are independent and each of the n paths is followed back and forth (at least one repetition). Repeatability is achieved through a suitable turning manoeuvre and performance is measured only while executing the "steady state" phase. The line is a path, that every vehicle is required to follow. Figure 1 shows the main parts of the manouvre: $H_{1\perp}, H_{1\parallel}$ and $H_2$ are Hausdorff distances and $A_1, A_2$ and $A_3^*$ areas between the target path and the followed path. Target paths are assumed to belong to low-dimensional parametric families. Here performance functions for different performance criteria are reconstructed based on simulation experiments for sinusoidal paths. These preliminary results provide insight on the definition of a suitable compound index of performance and on which paths to execute in order to estimate the compound index over the parameter region.

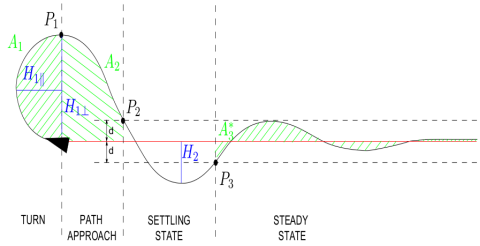



Figure 1: Classical path following manouvre.

# References

[1] M. Caccia et al (2013). Towards good experimental methodologies for unmanned marine vehicles, EUROCAST 2013, Part II, LNCS 8112 R. Moreno-Daz et al. eds., pp. 365372, Lecture Notes in Computer Science, Springer-Verlag Berlin Heidelberg.

[2] E. Saggini et al (2014). Performance indices for evaluation and comparison of unmanned marine vehicles guidance systems, in 19th IFAC World Congress, Cape Town, South Africa.

[3] E. Saggini et al (2014). Assessing path-following performance for Unmanned Marine Vehicles with algorithms from Numerical Commutative Algebra, in MED'14, 22nd Mediterranean Conference on Control and Automation, 16-19 giugno, Palermo, Italy, 8 pages.

# Lifetime comparisons of $k$-out-of-$n$ systems with i.i.d. DFR and IFR component distributions

**Tomasz Rychlik** *Institute of Mathematics, Polish Academy of Sciences, Poland*

**Abstract:** We present sharp upper bounds for the lifetime expectations of $k$-out-of-$n$ systems whose components have i.i.d. lifetime distributions belonging to the DFR and IFR families. The bounds are expressed in terms of mean and standard deviation of the single component lifetime. We numerically compare the bounds with their counterparts for other families of parent distributions.

Let $X_1, \dots, X_n$ denote random lifetimes of components of a $k$-out-of-$n$:$F$ system. Then the system lifetime coincides with the $k$th order statistic $X_{k:n}$. We assume that $X_1, \dots, X_n$ are i.i.d. whose common expectation and variance are $\mu \in \mathbb{R}$ and $0 < \sigma^2 < \infty$, respectively. Below we present sharp upper bounds on $\mathbb{E}(X_{k:n} - \mu)/\sigma$, when the parent distribution belongs to either DFR or IFR family. Let $f_{k:n}$ and $F_{k:n}$ denote the density and distribution functions of the $k$th order statistic from the standard uniform sample of size $n$.

**Theorem** (Danielak, 2003). *Suppose that $X_1, \dots, X_n$ are DFR, and put*

$$S(k,n) = \sum_{i=1}^{k} \frac{1}{n+1-i}, \qquad 1 \le k \le n.$$

*Then*

$$\frac{\mathbb{E}X_{k:n} - \mu}{\sigma} \le \begin{cases} 0, & if \quad S(k,n) \le 1, \\ S(k,n) - 1, & if \quad 1 < S(k,n) \le 2, \\ A = A(k,n), & if \quad S(k,n) > 2, \end{cases}$$

*for*

$$A^2 = \frac{(n!)^2}{(2n+1)!}\binom{2k-2}{k-1}\binom{2n-2k}{n-k}F_{2k-1:2n-1}(x_*) + (1-x_*)[2\alpha_*^2 + 2\alpha_* f_{k:n}(x_*) + f_{k:n}^2(x_*)] - 1,$$

*with*

$$\alpha_* = \alpha_*(x_*) = \frac{\sum_{i=1}^{k} S(k+1-i, n+1-i) f_{i:n+1}(x_*) - (n+1-k) f_{k:n+1}(x_*)}{2(n+1)(1-x_*)},$$

*and $x_*$ being the smallest positive zero of the polynomial*

$$\sum_{i=1}^{k-1} [2 - S(k+1-i, n+1-i)] f_{i:n+1}(x) - [n-k-1+S(1,n-k+1)] f_{k:n+1}(x).$$

**Theorem** (Goroncy, Rychlik, 2015). *Suppose that $X_1, \ldots, X_n$ have an IFR distribution. Then*

$$\frac{\mathbb{E}X_{k:n}-\mu}{\sigma} \leq \begin{cases} 0, & k=1, \\ \sqrt{\frac{\left[n^2(n-1)-\frac{(n^2-2n)2^{n-1}}{(n-1)^{4n-5}}\right]-1}{(2n-1)(2n-3)}}, & k=2, \\ \sqrt{(\gamma_*+\lambda_*)^2+\lambda_*^2(1-\alpha_*)^2-2\alpha_*\lambda_*\gamma_*-2\gamma_*(\lambda_*+\gamma_*)e^{-\alpha_*}}, & 3\leq k\leq n-1, \\ B=B(n), & k=n, \end{cases}$$

*where $0<\alpha_*<\infty$ is the unique zero of the function*

$$(1-2\alpha e^{-\alpha}-e^{-2\alpha})[1-e^{-\alpha}-F_{k:n}(1-e^{-\alpha})]+e^{-\alpha}(1-e^{-\alpha}-\alpha)\left[\sum_{i=1}^{k}\frac{F_{i:n}(1-e^{-\alpha})}{n-k+1}+e^{-\alpha}-1\right],$$

$$\gamma_*=\gamma_*(\alpha_*)=\frac{1-e^{-\alpha_*}-F_{k:n}(1-e^{-\alpha_*})}{e^{-\alpha_*}}, \qquad \lambda_*=\lambda_*(\alpha_*,\gamma_*)=\frac{-\gamma_*}{1-e^{-\alpha_*}-\alpha_*}.$$

*and*

$$\begin{aligned} B^2 &= [\Lambda(x_*)\ln(1-x_*)+nx_*^{n-1}]^2x_*+\frac{n^2}{2n-1}(1-x_*^{2n-1})-1 \\ &+ 2[\Lambda(x_*)\ln(1-x_*)+nx_*^{n-1}]\Lambda(x_*)[x_*+(1-x_*)\ln(1-x_*)] \\ &+ \Lambda^2(x_*)\{2x_*+(1-x_*)[\ln(1-x_*)-\ln^2(1-x_*)]\} \end{aligned}$$

*with $\frac{n-2}{n-1}<x_*<1$ minimizing the expression*

$$\begin{aligned} & \Lambda^2(x)[\ln^2(1-x)+2\ln(1-x)+2x] \\ - \; & 2\Lambda(x)\left[\sum_{i=1}^{n}\frac{x^i}{i}-nx^n-(nx^{n-1}-1)\ln(1-x)\right]+\frac{2n(n-1)^2}{2n-1}x^{2n-1} \end{aligned}$$

*for*

$$\Lambda(x)=\max\left\{\frac{\sum_{i=1}^{n}\frac{x^i}{i}-nx^n-(nx^{n-1}-1)\ln(1-x)}{\ln^2(1-x)+2\ln(1-x)+2x}, f_{n-1:n}(x)\right\}.$$

We can deliver attainability conditions for all the bounds presented above. The bounds will be numerically compared with ones valid for other classes of distributions.

# References


[1] Danielak, K. (2003). Sharp upper mean-variance bounds on trimmed means fromm restricted families. *Statistics* 37: 305-324.

[2] Goroncy, A. and Rychlik, T. (2015). Optimal bounds on expectations of order statistics and spacings from nonparametric families of distributions generated by convex transform order. ***Metrika***, to appear.

# Optimal Designs for Steady-State Kalman Filters

**Guillaume Sagnol** *Department of Optimization, Zuse Institut Berlin, Germany*
**Radoslav Harman** *Comenius University, Bratislava, Slovakia*

**Abstract:** We consider a stationary discrete-time linear process that can be observed by a finite number of sensors. The experimental design for the observations consists of an allocation of available resources to these sensors. We formalize the problem of selecting a design that maximizes the information matrix of the steady-state of the Kalman filter, with respect to a standard optimality criterion, such as $D-$ or $A-$optimality. This problem generalizes the optimal experimental design problem for a linear regression model with a finite design space and uncorrelated errors. Finally, we show that under natural assumptions, a steady-state optimal design can be computed by semidefinite programming.

We consider a stationary discrete-time linear process with a state vector $\mathbf{x}_t \in \mathbb{R}^n$:

$$\mathbf{x}_t = F\,\mathbf{x}_{t-1} + L\,\nu_t, \qquad (t = 1, 2, \ldots) \tag{1}$$

where $F$ is an $n \times n$ transition matrix, $L$ is an $n \times \ell$ noise selection matrix, and $\nu_t \sim \mathcal{N}(\mathbf{0}, \mathbf{I}_\ell)$ is a process noise. In addition, we assume $\mathbf{x}_0 \sim \mathcal{N}(\hat{\mathbf{x}}_0, \Sigma_0)$. Uncorrelated observations $\mathbf{y}_t^{(1)}, \ldots, \mathbf{y}_t^{(s)}$ of the process are available at each time step:

$$\forall i = 1, \ldots, s, \qquad \mathbf{y}_t^{(i)} = H_i \mathbf{x}_t + \mathbf{v}_t^{(i)} \tag{2}$$

where the $i^{\text{th}}$ observation matrix $H_i$ is $r_i \times n$ and the measurements errors satisfy $\mathbf{v}_t^{(i)} \sim \mathcal{N}(\mathbf{0}, \sigma_i^2 \mathbf{I}_{r_i})$. We can group the measurements at time $t$, which gives a multidimensional observation

$$\mathbf{y}_t = H\mathbf{x}_t + \mathbf{v}_t \tag{3}$$

of size $r = \sum_{i=1}^s r_i$, with $H = [H_1^T, \ldots, H_s^T]^T$, and $\mathbf{v}_t \sim \mathcal{N}(\mathbf{0}, R)$ where $R$ is the $r \times r$ block diagonal matrix whose $i^{\text{th}}$ diagonal block is $\sigma_i^2 \mathbf{I}_{r_i}$. The random vectors $\{\mathbf{x_0}, \nu_1, \ldots, \nu_t, \ldots, \mathbf{v}_1, \ldots, \mathbf{v}_t, \ldots\}$ are assumed to be mutually independent.

In this article, we are concerned with the case where the variance $\sigma_i^2$ depends on the quantity $w_i$ of resources dedicated to the $i^{\text{th}}$ observation. More precisely, we assume that $\sigma_i^2 = \frac{1}{\mu_i(w_i)}$, where $\mu_i$ is a nondecreasing, concave and continuous function mapping $\mathbb{R}_+$ onto itself, and such that $\mu_i(0) = 0$. The interpretation for $w_i = 0$ is that $\sigma_i^2 = +\infty$, meaning that $\mathbf{y}_t^{(i)}$ is unobserved if no resource is allocated to the $i^{\text{th}}$ observation point. The vector $\mathbf{w} = [w_1, \ldots, w_s] \in \mathbb{R}_+^s$ will be called a *measurement design*, or simply a *design* for the dynamic process (1)-(3).

The problem studied in this talk is the optimal allocation of resources to the $s$ observation points, when the resources are limited and the design $\mathbf{w}$ must be selected within a compact set $\mathcal{W} \subset \mathbb{R}_+^s$ prior to the beginning of the dynamic process.

The process described by Eq. (1)-(3) contains the natural ingredients to run a Kalman filter, which yields at each time $t$ an unbiased estimator $\hat{\mathbf{x}}_t$ of $\mathbf{x}_t$ that is linear with respect to the observations $\mathbf{y}_1, \ldots, \mathbf{y}_t$, and with Loewner-minimum covariance matrix in the class of all linear unbiased estimators of $\mathbf{x_t}$; see, e.g., [1, Section 5.2]. Under some standard assumptions, the information matrix $M_t$, which is defined as the inverse of the variance-covariance matrix $\Sigma_t$ of the error $(\hat{\mathbf{x}}_t - \mathbf{x}_t)$, converges to a constant matrix $M_\infty$. This limit depends only on the design $\mathbf{w}$ (and not on the initial state $\mathbf{x}_0$ or the measurements $\mathbf{y}_1, \mathbf{y}_2, \ldots$), and is the unique positive

definite solution $X$ of the discrete algebraic Riccati equation (written here in information form):

$$X = \left(FX^{-1}F^T + LL^T\right)^{-1} + M(\mathbf{w}), \tag{4}$$

where $M(\mathbf{w}) := \sum_{i=1}^{s} \mu_i(w_i) H_i^T H_i$. To stress this dependency, we denote by $M_\infty(\mathbf{w})$ the unique positive definite solution $X$ of (4). A natural approach hence consists in choosing $\mathbf{w} \in \mathcal{W}$ so as to maximize an appropriate scalarization $\Phi\big(M_\infty(\mathbf{w})\big)$ of the steady-state information matrix. Our main result shows that under natural conditions (in partcular, the pair $(F, L)$ must be *controllable* and the criterion $\Phi : \mathbb{S}_+^n \mapsto \mathbb{R}_+$ must be *isotonic*), then this problem can be reformulated as the following semidefinite programming problem.

$$\begin{array}{ll} \max\limits_{\substack{\mathbf{w}\in\mathbb{R}^s \\ X,U\in\mathbb{S}_n}} & \Phi(X) \\ \text{s.t.} & \begin{pmatrix} X - F^T U F & F^T U L \\ L^T U F & \mathbf{I}_\ell - L^T U L \end{pmatrix} \succeq 0 \\ & X = U + \sum\limits_{i=1}^{s} \mu_i(w_i) H_i^T H_i \\ & X \succeq 0 \\ & \mathbf{w} \in \mathcal{W}. \end{array}$$

# References


[1] Simon D (2006) Optimal state estimation: Kalman, $H_\infty$, and nonlinear approaches. Wiley

# The impact of renewables on electricity prices and congestion in a regime switching model: Evidence from the Italian grid

**Alessandro Sapio** *Department of Business and Economic Studies, Parthenope University of Naples, Italy*

**Abstract:** In this paper, the cross-zonal impact of renewable energy (RE) on electricity prices is assessed by means of a time-varying regime switching model, focusing on the highly congested line connecting Sicily with the Italian peninsula.

In the base regime, there is no congestion and the price in Sicily (which equals the system marginal price) depends on national electricity demand and RE supply. In the congested regime, the Sicilian price depends on the local electricity demand and RE supply, as well as on market power by local generators. The transition between regimes is modeled through a dynamic probit, including, as explanatory variables, the RE supply on both sides of the potentially congested line.

The regime switching model is estimated using hourly data from the Italian day-ahead electricity market for the year 2012. As shown by results, congestion is determined by the total amount of renewables in mainland Italy, but when the RE supply is disaggregated into different sources, one finds that congestion is mainly due to photovoltaics (from the peninsula) and hydropower (wherever located), whereas wind power has a negative effect on congestion regardless of localization.

# Semi-parametric Estimation of Income Mobility with D-vines using Bivariate Penalized Splines

**Christian Schellhase** *Centre for Statistics, Department of Business Administration and Economics, Bielefeld University, Germany*
**Torben Kuhlenkasper** *Pforzheim University, Germany*

**Abstract:** The article uses a semiparametric copula estimation approach for D-vines to evaluate the distribution of income mobility in Germany. We compare earning differentials on a micro level between four years in in the 1980's, 1990's and 2000's. We thereby separate with respect to the educational attainment of the individuals. We model income mobility by decomposing the multivariate distribution of individual incomes into its univariate margins with bivariate copulas. The latter is carried out by fitting D-vines in a flexible semi-parametric way. Whereas D-vines are commonly used to model serial dependence in multivariate time series. We employ penalized Bernstein polynomials as spline basis. The penalty induce smoothness of the fit while the high dimensional spline basis guarantees flexibility. We use the Sample of Integrated Labour Market Biographies (SIAB) as official empirical data from the German Federal Employment Agency. As result, we detect very low income mobility for the low educated workforce throughout the decades. For the high educated individuals, we detect significantly higher income mobility. Due to the assumptions of D-vines, the latter is visualized by the corresponding conditional probabilities of income changes throughout the time periods.

## Introduction

We investigate D-vines to evaluate the distribution of income mobility in Germany on a micro level between four years in in the 1980's, 1990's and 2000's. Throughout the article we investigate the income of the fourth, fifth, sixth and seventh year of each decade and build the differences between two following years to model income changes. We notate the change from the fourth to the fifth year with $\Delta_1$, the change from the fifth to the sixth year with $\Delta_2$ and the change from the sixth to the seventh year with $\Delta_3$. In general, we are interested to estimate the three dimensional distribution $F(\Delta_1, \Delta_2, \Delta_3)$ to model income mobility by decomposing the multivariate distribution of individual income changes into its univariate margins with bivariate copulas. Modelling and estimation of copulas has become extremely popular over the last decade, since its concept allows to decompose a multivariate distribution into its univariate margins and its interaction structure, expressed through the copula. Assuming the 3-dimensional random vector $(\Delta_1, \Delta_2, \Delta_3)$ with univariate marginal distributions $F_j(\Delta_j)$ for $j = 1, \dots, 3$ Sklar's theorem [2] states that the joint distribution can be written as

$$F(\Delta_1, \Delta_2, \Delta_3) = C\big(F_1(\Delta_1), F_2(\Delta_2), F_3(\Delta_3)\big). \tag{1}$$

Let $f(\Delta_1, \Delta_1, \Delta_3)$ be the corresponding multivariate density, which with Sklar's [2] theorem can be written as

$$f(\Delta_1, \Delta_2, \Delta_3) = c\{F_1(\Delta_1), F_2(\Delta_2), F_3(\Delta_3)\} \prod_{j=1}^{3} f_j(x_j) \tag{2}$$

where $c(.)$ is the copula density.

**The method**

Our aim is to estimate copula densities $c(\cdot)$ in a flexible, that is semi-parametric way as presented in [1]. Especially, we want to investigate the conditional copula density of income change for different decades and groups. Assuming the pair-copula assumption for Vines we can write the copula density as

$$\begin{aligned} f(\Delta_1, \Delta_2, \Delta_3) &= c(F(\Delta_1|\Delta_2), F(\Delta_3|\Delta_2)) \\ & \quad c(F(\Delta_1), F(\Delta_2))c(F(\Delta_2, \Delta_3)) \left( \prod_{j=1}^{3} f_j(\Delta_j) \right). \end{aligned} \tag{3}$$

Let therefore $u_{i|D} = F(\Delta_i|\Delta_D)$. We now approximate $c(\cdot, \cdot)$ with the representation $\tilde{c}(\cdot, \cdot)$, say, defined through

$$\begin{aligned} \tilde{c}(u_{i|D}, u_{j|D}; \boldsymbol{v}^{(i,j|D)}) &:= \sum_{k_1=0}^{K} \sum_{k_2=0}^{K} \phi_{Kk_1}(u_{i|D}) \phi_{Kk_2}(u_{j|D}) \boldsymbol{v}_{k_1,k_2}^{(i,j|D)} \\ &= \{\boldsymbol{\phi}_K(u_{i|D}) \otimes \boldsymbol{\phi}_K(u_{j|D})\} \boldsymbol{v}^{(i,j|D)} \end{aligned} \tag{4}$$

where the $\boldsymbol{v}^{(i,j|D)} = (v_{00}^{(i,j|D)}, \ldots, v_{0K}^{(i,j|D)}, \ldots, v_{KK}^{(i,j|D)})$ is subsequently called the coefficient vector and $\boldsymbol{\phi}_K(u) = (\phi_{K0}(u), \ldots, \phi_{KK}(u))$ is the bivariate base of Bernstein polynomials. We use quadratic programing with side constraints to estimate each copula and introduce a penalty to achieve a smooth fit.

# References


[1] Kauermann G., Schellhase C. (2014), Flexible Pair-Copula Estimation in D-vines with Penalized Splines, Statistics and Computing 24(6) 1081-1100.

[2] Sklar, A. (1959), Fonctions de repartition a n dimensions et leurs marges. Publ. Inst. Stat. Univ. Paris 8, 229-231.

# A spot-forward model for electricity prices with regime shifts

**Stein-Erik Fleten** *Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Trondheim, Norway*
**Florentina Paraschiv** *Institute for Operations Research and Computational Finance, University of St. Gallen, Switzerland*
**Michael Schürle** *Institute for Operations Research and Computational Finance, University of St. Gallen, Switzerland*

**Abstract:** We propose a novel regime-switching approach for the simulation of electricity spot prices that is inspired by the class of fundamental models and takes into account the relation between spot and forward prices. Additionally the model is able to reproduce spikes and negative prices. Market prices are derived given an observed forward curve. We distinguish between a base regime and an upper as well as a lower spike regime. The model parameters are calibrated using historical hourly price forward curves for EEX Phelix and the dynamic of hourly spot prices. We further evaluate different time series models such as ARMA and GARCH that are usually applied for modeling electricity prices and conclude a better performance of the proposed regime-switching model.

# On the Time-Reversibility of Integer-Valued Autoregressive Processes of General Order

**Sebastian Schweer** *Institute of Applied Mathematics, University of Heidelberg, Germany*

**Abstract:** Integer-valued autoregressive processes of a general order $p \geq 1$ (INAR(p) processes) are considered, and the focus is put on the time-reversibility of these processes. It is shown that for the case $p = 1$ the time-reversibility of such a process already implies that the innovations are Poisson distributed. For the case of a general $p \geq 2$, there exist two competing formulations for the INAR(p) process. Both of these formulations, that of [Alzaid and Al-Osh, 1990] and that of [Du and Li, 1991] are analyzed with respect to their behavior towards reversibility. While the INAR(p) process as defined in [Alzaid and Al-Osh, 1990] behaves analogously to the INAR(1) process, the INAR(p) process of [Du and Li, 1991] is shown to be time-irreversible in general.

## References

[Alzaid and Al-Osh, 1990] Alzaid, A. and Al-Osh, M. (1990). An integer-valued pth-order autoregressive structure (INAR(p)) process. *Journal of Applied Probability*, 27:314 – 324.

[Du and Li, 1991] Du, J.-G. and Li, Y. (1991). The integer-valued autoregressive (inar(p)) model. *Journal of Time Series Analysis*, 12(2):129–142.

# Application of optimal designs for the methane flux in troposphere

**Sándor Baran** *Department of Applied Mathematics and Probability Theory, University of Debrecen, Hungary*
**Kinga Sikolya** *Department of Applied Mathematics and Probability Theory, University of Debrecen, Hungary*
**Milan Stehlík** *Departamento de Matemática, Universidad Técnica Federico Santa María, Valparaíso, Chile*

**Abstract:** Measurement on the regular grid can be of interest for many important applications, e.g. measurement in chemistry. Our aims to contribute here for the case of methane modelling in troposphere, lowest part of atmosphere. We concentrate a realistic parametric model of covariance and provide theoretical and numerical results on optimal designs. We derive exact optimal designs for estimation of parameters of a shifted Ornstein-Uhlenbeck sheet [1, 2, 3] observed on a regular grid and a monotonic set. Moreover we study the optimal design problem for prediction of a shifted Ornstein-Uhlenbeck sheet with respect to integrated mean square prediction error and entropy criterion. Finally, we illustrate applicability of obtained designs for increasing/measuring the efficiency of the engineering designs for estimation of methane rate in various temperature ranges and under different correlation parameters. We show that in most situations the obtained designs have higher efficiency.

## References

[1] Baran, S., Sikolya, K., Stehlík, M. (2013). On the optimal designs for prediction of Ornstein-Uhlenbeck sheets, *Statist. Probab. Lett.* 83 1580–1587.

[2] Baran, S., Sikolya, K., Stehlík, M. (2014). Optimal designs for the methane flux in troposphere. *Chemometr. Intell. Lab. Syst.*, submitted (arXiv:1404.1839).

[3] Baran, S., Stehlík, M. (2014). Optimal designs for parameters of shifted Ornstein-Uhlenbeck sheets measured on monotonic sets, *Statist. Probab. Lett.* submitted.

# Odds algorithm in detection of occurrence of last aftershock in sequence

**Marek Skarupski**
*Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*

**Abstract:** In this talk we investigate the possibility of applying Odds algorithm developed by Bruss [1] in detecting the last aftershock in earthquake. Our aim is to predict the time after which there will be last (if any) aftershock of magnitude over some fixed level of magnitude. We create model based on Poisson arrivals where intensity function comes from Omori's law ([2, 3]). The model is applied to real data of Tohoku earthquake.

## References

[1] F.T.Bruss *Sum the odds to one and stop*, The Annals of Probability, Vol. 28 (2000), No.3, 1384-1391.

[2] F. Omori, *On after-shocks of earthquake*, J. Coll. Sci. Imper. Univ. Tokyo 7 (1894), 111.

[3] T. Utsu, Y. Ogata, R.S. Matsu'ura, *The centenary of the Omori formula for a decay law of aftershock activity*, Journal of Physics of the Earth 43 (1995), 1-33.

# Change-point detection of the mean vector with fewer observations than the dimension using instantaneous normal random projections

**Ewa Skubalska-Rafajłowicz** *Department of Computer Engineerig, Wrocław University of Technology, Wrocław, Poland*

**Abstract:** Our aim in this paper is to propose a simple method of a change-point detection of mean vector when the number of samples (historical data set) is smaller than the dimension. We restrict here our attention to the problem of monitoring independent individual observations under normality assumption. The presented approach is based on the Hoteling statistic. This statistic is applied to the data set projected onto a randomly chosen subspace of a sufficiently smaller dimension. We propose the procedure of normal random projection of data (historical data set and a new observation) instantaneously, just after a new observation appears. Next, we provide a model of the changes in the mean vector and derive the distribution of noncentrality parameter values. Further, a non-local power of the Hotelling test performed on projected samples is defined, which is the criterion for selecting the dimensionality of a projection subspace. Finally, simulation results are provided.

**Introduction**

It often happens that the dimension of observed data vectors is larger than the sample size and this case is referred to as small sample size, high dimensional data. Microarrays, medical imaging, text recognition, finance and chemometrics data analysis leads to such problems. (see [4] for a survey).

Although control charts based on the Hotelling statistic are very popular method for identifying a change in a multivariate normal process, their use is restricted to low dimensional problems and sufficiently large number of historical data samples. We propose a new approach for change-point detection of a mean vector when the number of observations is smaller than the dimension. A dimension of the problem is diminished by a linear singular projection onto a randomly chosen subspace of a sufficiently smaller dimension.

It is important to stress that this approach is different than the method proposed previously by the author in [2] and [3], where the projection matrix was generated only once as a starting point of the dimensionality reduction procedure. Here we propose to perform the procedure of random projection of data (historical data set and a new observation) instantaneously, just after a new observation appears. This means that Phase I and Phase II of the control chart design [1] is repeated consecutively.

The proposed chart is designed and investigated as follows:

- We describe the new version of a Hotelling control chart based on instantaneous normal random projections.
- We provide a model of the changes in the mean vector and the distribution of noncentrality parameter values.
- Assumption that this model is corect, we then define non-local power of the Hotelling test performed on projected samples.
- As a consequence we propose a method of optimal selecting the dimensionality of projection subspace which minimizes the non-local power of the test.

An illustrative example is also provided.

## References


[1] Mason RL Young JC (2002) Multivariate Statistical Process Control with Industrial Application. SIAM, Philadelphia

[2] Skubalska-Rafajłowicz E (2011) Fast and efficient method of change detection in statistically monitored high-dimensional data streams. In: Proceedings of the 10th International Science and Technology Conference on Diagnostics of Processes and Systems, Zamość, Poland, pp. 256–260

[3] Skubalska-Rafajłowicz E (2013) Random projections and Hotelling's $T^2$ statistics for change detection in high-dimensional data streams. International Journal of Applied Mathematics and Computer Science 23(2):447–461

[4] Srivastava MS (2009) A review of multivariate theory for high dimensional data with fewer observations In: SenGupta A (ed) Advances in Multivariate Statistical Methods 9, pp. 25–52, World Scientific, Singapore

# On Hammerstein system nonlinearity identification algorithms based on order statistics and compactly supported functions

**Zygmunt Hasiewicz** *Department of Control and Optimization, Institute of Computer Engineering, Control and Robotics, Wrocław University of Technology, Poland*
**Przemysław Śliwiński** *Department of Control and Optimization, Institute of Computer Engineering, Control and Robotics, Wrocław University of Technology, Poland*
**Paweł Wachel** *Department of Control and Optimization, Institute of Computer Engineering, Control and Robotics, Wrocław University of Technology, Poland*

**Abstract:** Nonparametric algorithms recovering the nonlinearity in Hammerstein systems are examined. The algorithms are based on ordered measurements and on compactly supported functions. The contribution of the note consists in that the probability density function of the input signal does not need to be strictly bounded from zero but can vanish in a finite number of points. In this setting, the convergence is established for nonlinearities being piecewise-Lipschitz functions. It is also verified that for p times locally differentiable nonlinearities, the algorithms attain the convergence rate $O(n^{-2p/(2p+1)})$, the best possible nonparametric one. Noteworthy, the rate is not worsened by irregularities of the input probability density function.

# Asymptotic expansions for SDE's with small multiplicative noise

**Sergio Albeverio** *Department of Applied Mathematics, University of Bonn, Germany*
**Boubaker Smii** *King Fahd University of Petroleum and Minerals, Dept. Math. and Stat., Saudi Arabia*

**Abstract:** Asymptotic expansions are derived as power series in a small coefficient entering a non-linear multiplicative noise and a deterministic driving term in a non-linear evolution equation. Detailed estimates on remainders are provided.

**Acknowledgements**
This work was supported by King Fahd University of Petroleum and Minerals. The authors gratefully acknowledge this support.

## References

[1] Albeverio. S, Di Persio. L, Mastrogiacomo. E and Smii. B. *A class of Lévy driven SDEs and their explicit invariant measures*, Preprint (2014).

[2] Albeverio. S, Mastrogiacomo. E and Smii. B. *Small noise asymptotic expansions for stochas-tic PDE's driven by dissipative nonlinearity and Lévy noise*, Stoch. Process. Appl. 123 (2013), 2084-2109.

[3] Albeverio. S and Smii. B. *Asymptotic expansions for SDE's with small multiplicative noise*, To appear in Stoch. Proc. Appl. (2014).

# On the Impact of Correlation on the Optimality of Product-type Designs in SUR Models

**Moudar Soumaya** *Moudar Soumaya Institute of Process Engineering, Otto-von-Guericke University, Germany*
**Rainer Schwabe** *Institute for Mathematical Stochastics, Otto-von-Guericke University, Germany*

**Abstract:** For multivariate observations with seemingly unrelated variables product-type designs often turn out to be optimal which are generated by their univariate optimal counterparts. This is, in particular, the case when all variables contain an intercept term. If these intercepts are missing, the product-type designs may lose their optimality when the correlation between the components becomes stronger.

# Use of a generalized multivariate gamma distribution based on copula functions in the average bioequivalence

**Roberto Molina de Souza** *University of São Paulo, Faculty of Medicine of Ribeirão Preto, Department of Social Medicine, Brazil*
*Federal Technological University of Paraná, Department of Mathematics, Brazil*
**Jorge Alberto Achcar** *University of São Paulo, Faculty of Medicine of Ribeirão Preto, Department of Social Medicine, 3900, Bandeirantes Avenue, Ribeirão Preto, SP, 14040-900, Brazil*
**Edson Zangiacomi Martinez** *University of São Paulo, Faculty of Medicine of Ribeirão Preto, Department of Social Medicine, 3900, Bandeirantes Avenue, Ribeirão Preto, SP, 14040-900, Brazil*
**Josmar Mazucheli** *State University of Maringá, Department of Statistics, 5790, Colombo Avenue, Maringá, PR, 87020-900, Brazil*

**Abstract:** Bioequivalence studies have been generally used to compare a test formulation with a reference, in order to validate the interchangeability between them. Some pharmacokinetic (PK) parameters are compared in this type of study, typically using a model which assumes independence among PK parameters, the same variance for the different formulations, logarithmic transformation for the data and normal distribution for the residuals. We propose an alternative model based on a generalized gamma distribution, which permits the presence of positive asymmetry for the data and possible differences in the variances for the different formulations which could have more flexibility in this case. For the multivariate structure, we use a Gaussian copula function to capture the possible dependence between the PK parameters. We use Bayesian inference methods to obtain the results of interest. We also introduce a real data example from where we observe a good fit of the proposed model for the dataset. From this study, we conclude that the proposed model could be a good alternative in some applications where the distribution of the bioequivalence data presents a positive asymmetric distribution.

# Taking account of covariance estimation uncertainty in spatial sampling design for prediction with trans-Gaussian random fields

**Gunter Spöck** *Department of Statistics, University of Klagenfurt, Austria*
**Jürgen Pilz** *Department of Statistics, University of Klagenfurt, Austria*

**Abstract:** Recently an article of us, Spöck and Pilz (2010), has been published. It was demonstrated there that the spatial sampling design problem for the Bayesian linear kriging predictor can be transformed to an experimental design problem for a linear regression model with stochastic regression coefficients and uncorrelated errors. The stochastic regression coefficients derive from the polar spectral approximation of the residual process. Thus, standard optimal convex experimental design theory could be used to calculate optimal spatial sampling designs. The design functionals considered in the mentioned work did not take into account the fact that the kriging predictor actually is a plug-in predictor, where the estimated covariance function is plugged into the best linear predictor. Because the design criterion did not consider the uncertainty of the covariance function the resulting optimal designs were close to space-filling designs. This work on the other hand assumes the covariance function to be estimated, too, i.e. by restricted maximum likelihood (REML), and considers a design criterion that fully takes account of the fact that the kriging predictor is a plug-in predictor. The designs resulting from a design criterion measuring the average length of estimated predictive intervals with coverage probability bias 0, Smith and Zhu (2004), now are no longer so regular and space-filling as before but also samples very close to each other are needed in the optimal designs in order to get the covariance function well estimated. We also dismiss the Gaussian assumption and assume the data to be transformed to Gaussianity by means of the Box-Cox transformation. The resulting prediction method is known as trans-Gaussian kriging. We apply the Smith-Zhu approach also to this kind of kriging and show that resulting optimal designs now are dependent also on the available data. As illustrative data set serve monthly rainfall measurements from Upper Austria.

## References

[1] Smith, R.L. and Zhu, Z., (2004), Asymptotic Theory for Kriging with Estimated Parameters and its Application to Network Design, Technical Report, University of North Carolina.

[2] Spöck, G. and Pilz, J., (2010), Spatial sampling design and covariance-robust minimax prediction based on convex design ideas, Stochastic Environmental Research and Risk Assessment, 24, 463-482.

# Learning with localized support vector machines

**Mona Eberts** *Institute for Stochastics and Applications, University of Stuttgart, Germany* **Ingo Steinwart** *Institute for Stochastics and Applications, University of Stuttgart, Germany*

**Abstract:** One of the limiting factors of using support vector machines (SVMs) in large scale applications are their super-linear computational requirements in terms of the number of training samples. To address this issue, several approaches that train SVMs on many small chunks of large data sets separately have been proposed in the literature. So far, however, almost all these approaches have only been empirically investigated. In addition, their motivation was always based on computational requirements.

In this work, we consider a localized SVM approach based upon a partition of the input space. For this local SVM, we derive a general oracle inequality. Then we apply this oracle inequality to least squares regression using Gaussian kernels and deduce local learning rates that are essentially minimax optimal under some standard smoothness assumptions on the regression function.

We further introduce a data-dependent parameter selection method for our local SVM approach and show that this method achieves the same learning rates as before. Finally, we present some larger scale experiments for our localized SVM showing that it achieves essentially the same test performance as a global SVM for a fraction of the computational requirements. In addition, it turns out that the computational requirements for the local SVMs are similar to those of a vanilla random chunk approach, while the achieved test errors are significantly better.

# Large sample approximations for inference and change-point analysis of high dimensional data

**Rainer v. Sachs** *ISBA, Université catholique de Louvain, Louvain-la-Neuve, Belge*
**Ansgar Steland** *Institute of Statistics, RWTH Aachen University, Aachen, Germany*

**Abstract:** High–dimensional time series data arise in diverse areas. For high–dimensional vector time series of dimension $d = d_n$ depending on the sample size $n$, the case that $d$ is large compared to $n$ or is even larger than $n$ is of particular interest. Due to the lack of consistency of the sample variance-covariance matrix with respect to commonly used matrix norms such as the Frobenius norm, various regularized modifications have been proposed and studied, e.g. banding and tapering, [1], or shrinkage estimation, see [6], [7] and [3]. But in many cases one is mainly interested in bilinear forms of the sample variance-covariance matrix representing the covariance of linear projection statistics.

Within a high-dimensional time series model that allows for full covariance matrices, we propose novel large sample approximations for bilinear forms of the sample variance-covariance matrix of a high–dimensional vector time series, in terms of strong approximations by Brownian motions, by extending martingale approximations obtained by [4]. Such approximations play a critical role to analyze the dependence structure in terms of the second moments and to analyze projections onto lower dimensional spaces as those generated by principal components. The results, strong approximations by Brownian motions, cover weakly as well as many long–range dependent linear processes and are valid for a large class of projection vectors that arise, naturally or by construction, in many statistical problems extensively studied for high–dimensional vector time series.

Among those key applications are the following: For sparse financial portfolio optimization, [2] proposed to construct regularized portfolio vectors. In order to conduct sparse principal component analysis, there are several recent proposals to construct $\ell_1$-bounded components such as the SCotLASS (simplified component technique-lasso) approch of [5], the penalized matrix decomposition problem (PMD) studied by [10] or the lassoed principal components (LPC) method of [9]. Our results are also directly applicable to the problem of shrinkage estimation ([6], [7], [3]). Lastly, the results allow us to propose a high-dimensional change-point analysis, in order to test for the presence of a change-point in the dependence structure.

## References

[1] Bickel, P.J. and Levina, E. (2008). Covariance regularization by thresholding. *Annals of Statistics*, 36(6): 2577–2604.

[2] Brodie, J., Daubechies, C., De Mol, C., Giannne, D. and Loris, I. (2009). Sparse and stable Markowitz portfolios. *Proceedings of the National Academy of Sciences of the U.S.A.* (PNAS), 106(30): 12267–12272.

[3] Boehm, H. and von Sachs, R. (2009). Shrinkage estimation in the frequency domain of multivariate time series. *Journal of Multivariate Analysis*, 100(5): 913–935.

[4] Kouritzin, M.A. (1995). Strong approximation for cross-covariances of linear variables with long-range dependence. *Stochastic Processes and Their Applications*, 60(2): 343-353.

[5] Jolliffe, L., Trendafilov, N. and Uddin, M. (2003). A modified principal component technique based on the lasso. *Journal of Computational and Graphical Statistics*, 12: 531–547.

[6] Ledoit, O. and Wolf, M. (2004). A well-conditioned estimator for large-dimensional covariance matrices. *Journal of Multivariate Analysis*, 88(2): 365–411.

[7] Sancetta, A. (2008). Sample covariance shrinkage for high-dimensional dependent data. *Journal of Multivariate Analysis*, 99(5): 949–967.

[8] Steland, A. and von Sachs, R. (2015). Large sample approximations for variance-covariance matrices of high-dimensional time series. *Bernoulli*, under revision.

[9] Tibshirani, R. (2011). Regression shrinkage and selection via the lasso: A retrospective. *Journal of the Royal Statistical Society, Series B*, 73(3): 273–282.

[10] Witten, D.M., Tibshirani, R. and Hastie, T. (2009). A penalized decomposition, with applications to sparse principal components and canonical correlation analysis. *Biostatistics* 10: 515–534.

# Kaplan-Meier estimator based on ranked set samples

**Mahdi Mahdizadeh** *Department of Statistics, Hakim Sabzevari University, Iran*
**Ewa Strzalkowska-Kominiak** *Department of Statistics, Universidad Carlos III de Madrid, Spain*

**Abstract:** When quantification of all sampling units is expensive but a set of units can be ranked, without formal measurement, ranked set sampling (RSS) is a cost-efficient alternative to simple random sampling (SRS). See, e.g. [1]. In our work, we propose a new Kaplan-Meier estimator for the distribution function based on RSS under random censoring and study its asymptotic properties. We present a simulation study to compare the performance of the proposed estimator and the standard Kaplan-Meier estimator based on SRS. It turns out that RSS design can yield a substantial improvement in efficiency over the SRS design. Additionally, we propose a new bootstrap approach in the setup of ranked set sampling under censoring. Similarly, as by Kaplan-Meier estimator under simple random sampling (see [2]), the bootstrap based confidence intervals for the parameter of interest are more accurate than the intervals based on the asymptotic normality. Finally, we apply our methods to a real data set from an environmental study.

### Introduction

Ranked set sampling starts with randomly drawing $k$ units from the underlying population. Those units are then ranked by judgment ranking, and the unit in the lowest position is chosen for actual measurement. Another set of size $k$ is drawn and ranked. The unit ranked second lowest is chosen and quantified. This procedure is continued until $k$th ranked unit is measured. Repeating this process for $m$ times (cycles), we have a sample of total size $n = mk$. In notation, $\{X_{[r]j} : r = 1, \ldots, k\,; j = 1, \ldots, m\}$ is the resulting sample where $X_{[r]j}$ is the $r$th order statistic from the $j$th cycle.

We consider the case when the sample units, $X_{[r]j}$, are not always fully observed and may be censored. We focus on the more common case of right-censoring but, as shown in the real data example, our proposed method can be easily adapted to the case of left-censored data.

### The proposed estimator

Let $\{X_{[r]j}\}$ be a ranked set sample of size $n = mk$ drawn from $F$ with corresponding censoring times $\{C_{[r]j}\}$. We observe $Y_{[r]j} = \min\{X_{[r]j}, C_{[r]j}\}$ and $\delta_{[r]j} = 1\{X_{[r]j} \leq C_{[r]j}\}$. Note that $C_{[r]j}$s form a simple random sample of size $n$ from $G$. According to a basic identity in RSS, we have

$$F(x) = \frac{1}{k}\sum_{r=1}^{k} F_{[r]}(x),$$

where $F_{[r]}$ is cumulative distribution function (cdf) of $r$th order statistics of a simple random sample of size $k$. Employing the above relation, we define

$$\hat{F}_{RSS}(t) = \frac{1}{k}\sum_{r=1}^{k} \hat{F}_{[r]}(t),$$

where $\hat{F}_{[r]}(t)$ is a standard Kaplan-Meier estimator based on $(Y_{[r]1}, \delta_{[r]1}), ..., (Y_{[r]m}, \delta_{[r]m})$. See [3] for details.

**Example**

We illustrate our methods by using a data set on MTBE contamination of groundwater from underground fuel tanks (suspected to leak) in Khorasan Razavi province of Iran. A total of 36 wells were divided into $m = 4$ sets of size 9 each. The RSS procedure with $k = 3$ was applied to each set, where the ranking was based on the distance to the fuel tank. MTBE concentration is measured by gas chromatography instrument which could not correctly detect very low values due to technical features.

# References


[1] Chen, Z., Bai, Z., and Sinha, B.K. (2004). *Ranked set sampling: Theory and Applications.* Springer: New York.

[2] Efron, B. (1981). *Censored data and the bootstrap.* JASA 76: 312-319.

[3] Strzalkowska-Kominiak, E. and Mahdizadeh, M. (2014) *On the Kaplan-Meier estimator based on ranked set samples.* Journal of Statistical Computation and Simulation 84: 2577-2591

# Change-point analysis tools by means of scaled Bregman distances

**Wolfgang Stummer** *Department of Mathematics, University of Erlangen-Nürnberg, Germany*

**Abstract:** Density-based statistical distances between two distributions serve as very useful contemporary tools for parameter estimation, goodness-of-fit testing, Bayesian decision procedures, as well as for other research fields such as information theory, image and speech processing, machine learning, and physics. Amongst others, some prominent distance classes are the so-called Csiszar divergences (including the Kullback-Leibler information divergence, the relative entropy, the Hellinger distance, the Pearson chi-squared divergence, the total variation distance, and many others), the density power divergences as well as the "classical" Bregman distances.

In Stummer & Vajda [3] (see also Stummer [2]) we introduced the concept of *scaled* Bregman divergences SBD, which generalizes all the abovementioned statistical distances at once, and which thus constitutes a quite general framework for dealing with a wide range of statistical analyses, in a well-structured way. For various different scalings (other than the mixing in Kißlinger & Stummer [1]), we study SBD between distributions from exponential families, respectively, data-derived empirical distributions. The corresponding results are used for the development of concrete situation-based 3D computer-graphical methods for change-point detection. This is accompanied by asymptotic results on the corresponding SBD-test-statistics behaviour where the sample sizes of the involved empirical distributions tend to infinity.

## References

[1] Kißlinger, A.-L. and Stummer, W. (2013). Some decision procedures based on scaled Bregman distance surfaces, *in: Geometric Science of Information*, F. Nielsen and F. Barbaresco (eds.), Lecture Notes in Computer Science 8085: 479-486.

[2] Stummer, W. (2007). Some Bregman distances between financial diffusion processes, *Proc. Appl. Math. Mech.* 7: 1050503 - 1050504.

[3] Stummer, W. and Vajda, I. (2012). On Bregman Distances and Divergences of Probability Measures, *IEEE Transactions on Information Theory* 58, No.3: 277-288.

# The Multivariate Kaplan-Meier Estimator

**Arusharka Sen** *Department of Mathematics and Statistics, Concordia University, Montreal, Canada*
**Winfried Stute** *Mathematical Institute, University of Giessen, Germany*

**Abstract:** Finding the multivariate extension of the famous Kaplan-Meier (KM) estimator is an important question which has attracted many researchers over the last thirty years. Since, for higher-dimensional data, the distribution function is no longer specified by the hazard function, traditional analysis focusing on the product limit approach is not feasible. Rather we propose a so-called mass-shifting method, by which we are able to uniquely solve an associated multivariate Volterra integral equation and obtain the multivariate extension of KM, both by solving an appropriate eigenvalue problem resp. computing the Neumann series of a Volterra operator. We study our new estimator for small and large sample sizes and derive its efficiency.

# On Some Distributed Disorder Detection

**Krzysztof Szajowski** *Institute of Mathematics and CS, Wrocław University of Tech., Poland*

**Abstract:** In the paper a multivariate detection of the transition probabilities changes at some sensitivity level in the multidimensional process is investigated. The random vector is observed. Each coordinate form the Markov process having different transition probabilities at the beginning segment and after some moment. It is assume that the moments of transition probability change are unknown. The aim of statisticians is to estimate it based on the observation of the process. The Bayesian approach is used with the risk function depending on measure of chance of a false alarm and some cost of overestimation. The detection of transition probabilities changes at some coordinates determine the moment of system disorder. The modeling of critical coordinates is based on the simple game.

It is investigation of the mathematical model of a multivariate surveillance system introduce in [6]. It is assumed that there is net $\mathfrak{N}$ of $p$ nodes. At each node the state is the signal at moment $n \in \mathbb{N}$ which is at least one coordinate of the vector $\overrightarrow{x}_n \in \mathbb{E} \subset \Re^m$. The distribution of the signal at each node has two forms and depends on *a pure* or *a dirty* environment of the node. The state of the system change dynamically. We consider the discrete time signal observed as $m \geq p$ dimensional process defined on the fixed probability space $(\Omega, \mathcal{F}, \mathbf{P})$. The observed at each node Markov processes are non homogeneous with two homogeneous segment having different transition probabilities (see [4] for details). The visual consequence of the transition distribution changes at moment $\theta_i$, $i \in \mathfrak{N}$ is a change of its character. To avoid false alarm the confirmation from other nodes is needed. The family of subsets (coalitions) of nodes are defined in such a way that the decision of all member of some coalition is equivalent with the claim of the net that the disorder appeared. It is not sure that the disorder has had place. The aim is to define the rules of nodes and a construction of the net decision based on individual nodes claims. Various approaches can be found in the recent research for description or modeling of such systems (see e.g. [7], [3]). The problem is quite similar to a pattern recognition with multiple algorithm when the fusions of individual algorithms results are unified to a final decision.Two different approaches are proposed. Both are based on the simple game defined on the nodes. The naive methods determine the detection of system disordering by fusion individual node strategies. In this construction the individual decision are based on the observation at each node separately.

The advanced solution will be based on a stopping game defined by a simple game on the observed signals. It gives a centralized, Bayesian version of the multivariate detection with a common fusion center. The individual decisions are determined based on the analysis of processes observed at all nodes and knowledge of nodes interaction (the simple game). The sensors' strategies are constructed as an equilibrium strategy in a non-cooperative stopping game with a logical function defined by a simple game (which aggregates their decision).

The general description of such multivariate stopping games has been formulated by Kurano, Yasuda and Nakagami in the case when the aggregation function is defined by the voting majority rule [2] and investigate in a generalized form by Yasuda et al. [8], Ferguson [1] and the author and Yasuda [5].

The model of detection the disorders at each sensor is presented. It allows to define the individual payoffs of the players (sensors). The final decision based on the state of the sensors

is given by the fusion center. The natural direction of further research will be formulated.

# References


[1] Ferguson, T.S.: Selection by committee. In: Nowak, A., Szajowski, K. (eds.) Advances in dynamic games, Ann. Internat. Soc. Dynam. Games, vol. 7, pp. 203–209. Birkhäuser Boston, Boston, MA (2005).

[2] Kurano, M., Yasuda, M., Nakagami, J.: Multi-variate stopping problem with a majority rule. J. Oper. Res. Soc. Jap. 23, 205–223 (1980)

[3] Raghavan, V., Veeravalli, V.V.: Quickest change detection of a Markov process across a sensor array. IEEE Trans. Inform. Theory 56(4), 1961–1981 (2010).

[4] Sarnowski, W., Szajowski, K.: Optimal detection of transition probability change in random sequence. Stochastics 83(4-6), 569–581 (2011)

[5] Szajowski, K., Yasuda, M.: Voting procedure on stopping games of Markov chain. In: Anthony H. Christer, S.O., Thomas, L.C. (eds.) UK-Japanese Research Workshop on Stochastic Modelling in Innovative Manufecuring, July 21-22, 1995. Lecture Notes in Economics and Mathematical Systems, vol. 445, pp. 68–80. Moller Centre, Churchill College, Univ. Cambridge, UK, Springer 1996, springer Lecture Notes in Economics and Mathematical Systems.

[6] Szajowski, K.: Multi-variate quickest detection of significant change process. In: Baras, J.S., Katz, J., Altman, E. (eds.) Decision and Game Theory for Security. Second international conference, GameSec 2011, College Park, MD, Maryland, USA, November 14–15, 2011. Lecture Notes in Computer Science, vol. 7037, pp. 56–66. Springer, Berlin (2011)

[7] Tartakovsky, A.G., Veeravalli, V.V.: Asymptotically optimal quickest change detection in distributed sensor systems. Sequential Anal. 27(4), 441–475 (2008).

[8] Yasuda, M., Nakagami, J., Kurano, M.: Multi-variate stopping problem with a monoton rule. J. Oper. Res. Soc. Jap. 25, 334–350 (1982).

# Nonparametric quantile estimation using importance sampling

**Reinhard Tent** *Department of Mathematics, Technische Universität Darmstadt, Germany*
**Michael Kohler** *Department of Mathematics, Technische Universität Darmstadt, Germany*
**Adam Krzyżak** *Department of Computer Science and Software Engineering, Concordia University, Canada*
**Harro Walk** *Department of Mathematics, Universität Stuttgart, Germany*

**Abstract:** Considering a $\mathbb{R}^d$-valued random variable with known density $f : \mathbb{R}^d \to \mathbb{R}$ and a black-box function $m : \mathbb{R}^d \to \mathbb{R}$ which is costly to compute the $\alpha$-quantile of $m(X)$ is to be estimated, for $\alpha \in (0, 1)$. Here a nonparametric quantile estimate using importance sampling is presented which is based on an estimate $m_n$ of $m$. The main idea of this method is to modify the density $f$ of $X$ such that a new density $h$ is obtained for who's associated random variable $Z$ the value of $m(Z)$ is more likely to be near $q_\alpha$.
Under some suitable assumptions on the smoothness of $m$ the rate of convergence of the so constructed new estimate is deduced.

# Estimation of the Ratio of the Geometric Process

**Alicja Jokiel-Rokita** *Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*
**Rafał Topolnicki** *Faculty of Fundamental Problems of Technology, Wroclaw University of Technology, Poland*

**Abstract:**

A stochastic process $\{X_n, n = 1, 2, \ldots\}$ is a geometric process (GP), if there exists a positive real number $a$, such that $\{Y_n = a^{n-1}X_n, n = 1, 2, \ldots\}$ forms a renewal process. It was introduced by Lam in [2]. The GP process, under the reparametrization $a = d^{-1}$ is called the quasi-renewal process (see for example [?]). The GP process can be used e.g. to model hardware maintenance process, software reliability growth process in testing or operation phase, hardware repair times, and to model hardware reliability growth in burn-in stage.

In the paper we propose a new estimator of the ratio parameter $a$ in the case when the cumulative distribution function $F$ of the random variables $Y_i$, $i = 1, 2, \ldots$, is completely unknown. We compare accuracy of the proposed estimator with estimators given in [3] and [1]. We also compare some nonparametric estimators of the distribution function $F$.

## References

[1] Chan, J. S. K., Yu, P. L. H., Lam, Y. and Ho, A. P. K. (2006). Modeling SARS data using threshold geometric process. *Statistics in Medicine*, 25:1826-1839.

[2] Lam Y. (1988). Geometric process and replacement problem. *Acta Mathematicae Applicatae Sinica*, 4:366-377.

[3] Lam Y. (1992). Nonparametric inference for geometric process. *Communications in Statistics - Theory and Methods*, 21:2083-2105.

[4] Wang, H. and Pham, H. (2006). *Reliability and Optimal Maintenance.* Springer, London.

# Panel Data Segmentation under Finite Time Horizon

**Leonid Torgovitski** *Mathematical Institute, University of Cologne, Germany* **Abstract:** We study

the nonparametric change point estimation for common changes in the means of panel data. The consistency of estimates is investigated when the number of panels tends to infinity but the sample size remains finite. Our focus is the weighted total variation denoising estimates (involving the group fused LASSO) and the popular classical weighted CUSUM (cumulative sums) estimates.

Due to the fixed sample size, the common weighting schemes do not guarantee consistency under (serial) dependencies and most typical weightings do not even provide consistency in the i.i.d. setting when the noise is too dominant.

Hence, on the one hand, we propose a consistent extension of existing weighting schemes. We discuss straightforward estimates of those weighting schemes and propose further modifications based on convex/concave regression. The performance will be demonstrated empirically (also for multiple changepoints) in a simulation study.

On the other hand, we derive sharp bounds on the change to noise ratio that ensures consistency in the i.i.d. setting for classical weightings.

We show that these results can be partly generalized to the estimation of changes in panels of (spatial) functional data and also for estimation in time series of functional data based on the Karhunen-Loève transformation.

# An Algorithm for Construction of Constrained D-Optimum Designs

**Dariusz Uciński** *Institute of Control and Computation Engineering, University of Zielona Góra, Poland*

**Abstract:** A computational algorithm is proposed for determinant maximization over the set of all convex combinations of a finite number of nonnegative definite matrices subject to additional box constraints on the weights of those combinations. The underlying idea is to apply a simplicial decomposition algorithm in which the restricted master problem reduces to an uncomplicated multiplicative weight optimization algorithm.

### Introduction

Optimum experimental design seeks to allocate measurement resources so that the best linear estimates of unknown parameters are optimal with respect to some clearly defined real-valued function of their covariance matrices which quantifies the 'goodness' of an experiment. A strength of this formulation is that the relevant design criterion can be maximized to provide an optimal allocation. Feasible allocations are identified with probability measures on the design region [4, 7].

In general, an iterative numerical procedure is needed to determine optimal measures. A standard sequential design algorithm embodies the idea of the feasible-direction method used in nonlinear programming [7]. An alternative simpler strategy is to cover the design region with a suitable network, $\mathcal{N}$, of points which should be rich enough to contain close approximations to the points likely to have positive mass in the optimal design, and to focus solely on optimizing the masses associated with elements in $\mathcal{N}$. This formulation is extremely convenient since we deal with maximization of a concave function over a canonical simplex, and this can be tackled, e.g., by the gradient projection or conditional gradient methods. For some criteria, however, even more specialized algorithms can be invented, which exploit specific problem structures. For the most popular D-optimal design criterion a very simple multiplicative computational procedure was devised and analysed in [5, 4, 2].

### The method

The multiplicative algorithm is limited to equality constraints on the design weights [6]. In practice, however, various inequality constraints must be sometimes considered which are due to cost limitations, required design measure space restrictions for achieving certain robustness properties, or restrictions on the experimental space. Although much work has been done as regards theory [1], the number of publications on the algorithmic aspects of constrained experimental design is still very limited.

The main aim here is to propose an extension of the multiplicative algorithm to maximization of the D-optimality criterion subject to additional box constraints on the design weights. The underlying idea is to apply simplicial decomposition which is a simple and direct method for dealing with large-scale convex optimization problems [3]. The decomposition iterates by alternately solving a linear programming subproblem within the set of all feasible points and a nonlinear master problem within the convex hull of a subset previously generated points. The former problem is solved here using an algorithm being almost as simple as a closed form

solution and the latter problem reduces to employing the original multiplicative algorithm mentioned above. As a result, an uncomplicated computational scheme is obtained which can be easily implemented without resorting to sophisticated numerical software.

# References


[1] Cook D and Fedorov V (1995) Constrained optimization of experimental design, *Stat*, 26:129–178

[2] Harman R and Trnovská (2009) Approximate D-optimal designs of experiments on the convex hull of a finite set of information matrices. *Math Slovaca* 59:693–704

[3] Patriksson M (2001) Simplicial decomposition algorithms. In: Floudas CA and Pardalos PM (eds) *Encyclopedia of Optimization*, Vol. 5, pp. 205–212, Kluwer, Dordrecht

[4] Pázman A (1986) *Foundations of Optimum Experimental Design*. D. Reidel, Dordrecht

[5] Torsney B (1981) Algorithms for a constrained optimisation problem with applications in statistics and optimum design, Unpublished Ph.D. Thesis, University of Glasgow, available at `http://theses.gla.ac.uk/1088/1/1981torsneyphd.pdf`

[6] Torsney B, Mandal S (2004) Multiplicative algorithms for constructing optimizing distributions: Further developments. In: Di Bucchianico A, Läuter H and Wynn HP (eds) *mODa 7, Proc. 7th Int. Workshop on Model-Oriented Data Analysis*, pp.163–171, Physica-Verlag, Heidelberg

[7] Uciński D (2005) *Optimal Measurement Methods for Distributed-Parameter System Identification*. CRC Press, Boca Raton

# The impact of wind power production on electricity prices

**Almut E. D. Veraart** *Department of Mathematics, Imperial College London, UK*

**Abstract:** This paper studies the impact of wind power production on electricity prices in the European Energy Exchange market. We find that wind power production decreases the prices overall, but also increases their volatility. We introduce a new stochastic modelling framework which can describe these features and obtain promising empirical results.

# Universal Confidence Sets in Multiobjective Optimization

**Silvia Vogel** *Institute of Mathematics, Ilmenau University of Technology, Germany*

**Abstract:** Often decision makers have to deal with an optimization problem with unknown quantities. Then they will estimate these quantities and solve the problem as it then appears - the 'approximate problem'. Thus there is a need to establish conditions which ensure that the solutions to the approximate problem come close to the solutions to the true problem in a suitable manner. Confidence sets can provide important quantitative information. We consider multiobjective decision problems and derive confidence sets for the sets of efficient points, weakly efficient points, and the corresponding solution sets. We investigate two approaches: one method makes use of some knowledge about the true problem, the other one can cope without this information. The results will be applied to the Markowitz model of portfolio optimization.

**Introduction**

We assume that a deterministic multiobjective optimization problem $\min\limits_{x\in\Gamma_0} f_0(x)$ with $\Gamma_0 \subset R^p$ and $f_0(x) \in R^k$ is approximated by a sequence of random problems $(P_n)_{n\in N}$. The random problems arise, if unknown parameters or probability distributions are replaced with estimates, based on samples of size $n$, or for numerical reasons, e.g. if Sample Average Approximation is used. Minimization is understood with respect to the usual partial ordering in $R^k$, i.e. we ask for the sets of minimal points in the image space, the so-called efficient points, and the corresponding decisions.

Confidence sets in parametric statistics are usually derived from a statistic with known distribution (or at least asymptotic distribution), which may be rearranged for the parameter. Here we use a different approach: we rely on sequences of random sets which cover the true deterministic set $M_0$ with a prescribed high probability, i.e. we assume that sequences $(M_{n,\kappa}^{sup})_{n\in N},\ \kappa > 0$, with the following property are available:
$\forall \kappa > 0 : \sup\limits_{n\in N} P\{\omega :\ M_0 \setminus M_{n,\kappa}^{sup}(\omega) \neq \emptyset\} \leq \mathcal{H}(\kappa)$
where $\lim\limits_{\kappa\to\infty} \mathcal{H}(\kappa) = 0$ and $(M_{n,\kappa}^{sup})_{n\in N}$ should shrink to $M_0$ if $n$ increases. Then, given a prescribed probability level $\varepsilon_0$, we can choose $\kappa_0$ such that $\mathcal{H}(\kappa_0) \leq \varepsilon_0$, and the sequence $(M_{n,\kappa_0}^{sup})_{n\in N}$ yields for each $n \in N$ a set which covers the true set $M_0$ with probability $1 - \varepsilon_0$.

Important examples of sequences $(M_{n,\kappa}^{sup})_{n\in N}$ are so-called outer approximations in probability, which can be regarded as quantified versions of (the outer part of) Kuratowski-Painlevè convergence in probability of random sets. They have the form $M_{n,\kappa}^{\sup} = U_{\beta_{n,\kappa}} M_n$, where $M_n$ is the set under consideration, e.g. the set of efficient points, for the problem $P_n$, $(\beta_{n,\kappa})_{n\in N}$ is a sequence of nonnegative numbers with $\lim\limits_{n\to\infty} \beta_{n,\kappa} = 0\ \forall \kappa > 0$, and $U_{\beta_{n,\kappa}} M_n = \{x \in R^p : d(x, M_n) < \beta_{n,\kappa}\}$. Furthermore, sequences $(M_{n,\kappa}^{sup})_{n\in N}$ can be obtained via relaxation, see below.

Obviously, one is interested in sequences $(M_{n,\kappa}^{sup})_{n\in N}$ which converge in some sense to the true set $M_0$. Unfortunately, the sets of efficient points of the problems $P_n$, in general, do not tend to be contained in the set of efficient points of the true problem. Usually they approximate a superset, the set of weakly efficient points. Therefore we will also investigate the sets of weakly efficient points and present conditions which ensure that weakly efficient points are also efficient.

**Outer Approximations and Relaxation**

Let $E_0 = \{y \in f_0(\Gamma_0) : (y - R^k_+) \cap f_0(\Gamma_0) = \{y\}\}$ the set of efficient points of the true problem and $S^E_0$ the solution set. $E_n$ and $S^E_n$ denote the corresponding random sets for $P_n$. Among others we shall derive a convergence rate $\beta_{n,\kappa}$ and a tail behavior function $\mathcal{H}$ such that
$\forall \kappa > 0 : \sup_{n \in N} P\{\omega : E_0 \setminus U_{\beta_{n,\kappa}} E_n(\omega) \neq \emptyset\} \leq \mathcal{H}(\kappa)$
holds. Furthermore we aim at a corresponding result for the solution sets. Crucial assumptions are uniform concentration-of-measure properties of the objective functions and constraint functions. Moreover, in order to determine the convergence rates exactly, we need some knowledge about the true problem. We will discuss available sufficient conditions with special emphasis on results which can be applied in the Markowitz model of portfolio optimization.

If the needed information about the true problem is not available, one can use superset approximations, which are based on relaxation. The relaxation approach takes into account 'probable' deviations from the true model, in the objective functions and the constraint sets. We investigate the following sets $S^W_{R,n}$, which yield a superset approximation for $S^E_0$:
$S^W_{R,n}(\omega) := \{x \in U_{\beta^{(1)}_{n,\kappa}} \Gamma_n(\omega) : (f_n(x,\omega) - \mathrm{int}(R^k + 2\beta^{(2)}_{n,\kappa}\mathbf{1})) \cap F^{sub}_{n,\kappa}(\omega) = \emptyset\}$.
$(\beta^{(1)}_{n,\kappa})_{n\in N}$ and $(\beta^{(1)}_{n,\kappa})_{n\in N}$ denote the convergence rates for the constraint set and the objective functions, respectively, and $(F^{sub}_{n,\kappa})_{n\in N}$ is a suitable 'subset-approximation in probability' for $f_0(\Gamma_0)$.

# References


[1] Vogel, S. (2014). Random Approximations in Multiobjective Optimization. Preprint, TU Ilmenau.

# Monitoring Euro Area Real Exchange Rates

**Philipp Aschersleben** *Faculty of Statistics, Technical University Dortmund, Germany*
**Martin Wagner** *Faculty of Statistics, Technical University Dortmund, Germany*
**Dominik Wied** *Faculty of Statistics, Technical University Dortmund, Germany*

**Abstract:** We apply the stationarity and cointegration monitoring procedure ofWagner and Wied (2014) to monthly real exchange rate indices, visâĂŞ ‘ aâĂŞvis Germany, of the first round Euro area member states. For all countries except Portugal structural breaks are detected prior to the onset of the Euro area crisis triggered in turn by the global financial crisis. The results indicate that a more detailed investigation of RER behavior in the Euro area may be useful for understanding the unfolding of the deep crisis currently plaguing many countries in the Euro area.

# Nonparametric quantile estimation by importance sampling

**Harro Walk**
*Fachbereich Mathematik, Universität Stuttgart, Germany*

**Abstract:** The talk concerns joint work with Michael Kohler (TU Darmstadt), Adam Krzyżak (Concordia University Montreal) and Reinhard Tent (TU Darmstadt), see [4] and [5]. A simulation model with real-valued outcome $Y = m(X)$ is considered, where the d-dimensional random vector $X$ has a known density and the function $m$ is costly to compute and satisfies some smoothness condition. A nonparametric importance sampling quantile estimate of $Y$ is defined, which has a stochastic convergence rate of order $1/\mathrm{n}$ up to a slowly increasing, e.g., logarithmic factor. A similar result is obtained for a recursive Robbins-Monro type variant.

There is considered a simulation model of a complex technical system described by $Y = m(X)$, where $X$ is a $d$-dimensional random vector with known density $f$ and $m : \mathbb{R}^d \to \mathbb{R}$ is a black-box function with the possibility of expensive evaluation at arbitrarily chosen design points. Let $G$ be the cumulative distribution function (cdf) of $Y$. For fixed $\alpha \in (0,1)$ we are interested in estimating the $\alpha$-quantile $q_\alpha := \inf\{y \in \mathbb{R} : G(y) \geq \alpha\}$ using at most $n$ (or $3n$) evaluations of the function $m$. Assume that $Y$ has a bounded continuous density $g$ with $g(q_\alpha) > 0$.

The classic approach uses an i.i.d. sample of $X$, the corresponding empirical cdf of $G$ and estimation of $q_\alpha$ as an order statistic. A recursive estimation of Robbins-Monro type was proposed in [6]. Both approaches yield a stochastic convergence rate of order $1/\sqrt{n}$.

To obtain a better estimation of $q_\alpha$, we apply importance sampling, using a mild smoothness assumption on the function m, which allows replacement of $m$ by a surrogate function with cheap evaluation at arbitrary points. Both proposed approaches are completely nonparametric and yield a rate of convergence, in contrast to [1] and [2], respectively.

In the first approach we use an initial estimate of the quantile based on the order statistics of samples of $m(X)$ in order to determine an interval $[a_n, b_n]$ containing the quantile. Then we construct a spline approximation $m_n$ (surrogate) of $m$ via interpolation according to [3] and restrict $f$ to the inverse image $m_n^{-1}([a_n, b_n])$ of $[a_n, b_n]$ to construct a new random variable $Z$ with a corresponding instrumental density, thus we sample only from an area where the values are especially important for the computation of the quantile. Our final estimate of the quantile is then defined as an order statistic of $m(Z)$, where the level of the order statistic takes into account that we sample only from a part of the original density f. Under the assumption that $m$ is $(p, C)$-smooth, e.g., $p$-times continuously differentiable, for some $p > d/2$ and $E(\exp(\|X\|/2)) < \infty$, this estimate achieves the stochastic convergence rate of order $\gamma_n/n$ with arbitrary $\gamma_n \uparrow \infty$ in context of $[a_n, b_n]$. The finite sample size behavior of the estimate is illustrated for a simple load-bearing system.

The second approach employs a recursion $(U_n)$ of Robbins-Monro type in order to save time of sorting and space of storing. In each step one evaluation $m(Z_n)$ is used, where $Z_n$ has a random instrumental density concentrated on the inverse image $m_n^{-1}((-\infty, U_n])$ and $m_n$ is a spline approximation of $m$ with increasing design set. In case that $m$ is $(p, C)$-smooth with $p = d$ and $E(\exp(\|X\|)) < \infty$, $(U_n)$ is strongly consistent and has a stochastic convergence rate of order $(\log n)^{3+p/2}/n$.

## References


[1] Dubourg, V., Sudret, B., Deheeger, F. (2013). Metamodel-based importance sampling for structural reliability analysis, *Probabilistic Engineering Mechanics* 33: 47-57.

[2] Egloff, D., Leippold, M. (2010). Quantile estimation with adaptive importance sampling, *Annals of Statistics* 38: 1244-1278.

[3] Kohler, M. (2013). Optimal global rates of convergence for noiseless regression estimation problems with adaptively chosen design. Submitted for publication.

[4] Kohler, M., Krzyżak, A., Tent, R., Walk, H. (2014). Nonparametric quantile estimation using importance sampling. Submitted for publication.

[5] Kohler, M., Krzyżak, A., Walk, H. (2014). Nonparametric recursive quantile estimation, *Statistics and Probability Letters* 93: 102-107.

[6] Tierney, L. (1983). A space-efficient recursive procedure for estimating a quantile of an unknown distribution, *SIAM Journal of Scientific and Statistical Computing* 4: 706-711.

# The Marginal Distribution of Compound Poisson INAR(1) Processes

**Pedro Puig** *Department of Mathematics, Universitat Autònoma de Barcelona, Spain.*
**Christian H. Weiß** *Department of Mathematics and Statistics, Helmut Schmidt University, Hamburg, Germany.*

**Abstract:** A compound Poisson distribution is a natural choice for the innovations of an INAR(1) model. If the support of the compounding distribution is finite (Hermite-type distributions), the observations' marginal distribution belongs to the same family and it can be computed exactly. In the infinite case, however, which includes the popular choice of negative binomial innovations, this is not so simple. We propose two types of Hermite approximations for this case and investigate their quality in a numerical study.

**The Compound Poisson INAR(1) Model**

The INAR(1) model is a counterpart to the Gaussian AR(1) model but for counts, which is based on the probabilistic operation of binomial thinning. Let the innovations $(\epsilon_t)_{\mathbb{Z}}$ be an i.i.d. process with range $\mathbb{N}_0$. Let $\alpha \in (0;1)$. A process $(X_t)_{\mathbb{Z}}$, which follows the recursion

$$X_t \;=\; \alpha \circ X_{t-1} \;+\; \epsilon_t, \tag{1}$$

is said to be an *INAR(1) process* if all thinning operations are performed independently of each other and of $(\epsilon_t)_{\mathbb{Z}}$, and if the thinning operations at each time $t$ as well as $\epsilon_t$ are independent of $(X_s)_s$ The INAR(1) process is a homogeneous Markov chain, which has a unique stationary solution under weak conditions. The stationary marginal distribution satisfies

$$\mathrm{pgf}_X(z) = \mathrm{pgf}_X(1-\alpha+\alpha z)\cdot \mathrm{pgf}_\epsilon(z). \tag{2}$$

For the factorial cumulants and their generating function, it follows

$$\mathrm{fcgf}_X(z) \;=\; \mathrm{fcgf}_X(\alpha z) \;+\; \mathrm{fcgf}_\epsilon(z), \qquad \kappa_{(n),\,X} \;=\; \tfrac{\kappa_{(n),\,\epsilon}}{1-\alpha^n}. \tag{3}$$

There are many options of how to choose the innovations' distribution. The most natural approach is to assume the innovations to be CP-distributed, leading to the *compound Poisson INAR(1) process*: a count data model being parametrized by its $\nu$ first factorial cumulants $\kappa_{(1)},\ldots,\kappa_{(\nu)}$ is closed under addition and under binomial thinning *iff* it has a $\mathrm{CP}_\nu$-distribution. In view of the INAR(1) recursion (1), this implies that observations and innovations stem from the same $\nu$-th order family *iff* these are $\mathrm{CP}_\nu$-distributed.

The pmf of $X_t$ can always be computed numerically exactly if $\nu < \infty$:

1. Given the pgf of the innovations' $\mathrm{CP}_\nu$-distribution, compute the pgf of the observations' $\mathrm{CP}_\nu$-distribution; extract the parameters $\eta$ and $g_1, \ldots, g_\nu$.

   (a) If $\lambda$ and $h_1, \ldots, h_\nu$ readily available, compute $\eta$ and $g_1, \ldots, g_\nu$ from

   $$g_1 + \ldots + g_\nu = 1, \qquad \tfrac{\lambda}{\eta} \;-\; (1-\alpha)\cdot g_1 \;- \ldots -\; (1-\alpha)^\nu \cdot g_\nu \;=\; 0,$$
   $$h_k \cdot \tfrac{\lambda}{\eta} \;-\; (1-\alpha^k)\cdot g_k \;+\; \alpha^k \textstyle\sum_{i=k+1}^{\nu} \binom{i}{k} (1-\alpha)^{i-k} \cdot g_i \;=\; 0 \quad \text{for } k = \nu, \ldots, 2.$$

   (b) If innovations' $\mathrm{CP}_\nu$-distribution specified by $\kappa_{(1),\,\epsilon}, \ldots, \kappa_{(\nu),\,\epsilon}$, then first compute $\kappa_{(1),\,X}, \ldots, \kappa_{(\nu),\,X}$ via (3), then expand

   $$\eta\big(G(z)-1\big) \;:=\; \textstyle\sum_{r=1}^{\nu} \frac{\kappa_{(r),\,X}}{r!} \cdot (z-1)^r.$$

2. Apply the following recursive scheme for the computation of $P(X=k)$:

   $$P(X=0) \;=\; e^{-\eta}, \qquad P(X=k) \;=\; \tfrac{\eta}{k} \cdot \textstyle\sum_{j=1}^{\min\{k,\nu\}} j\, g_j \cdot P(X=k-j) \quad \text{for } k \geq 1.$$

**Approximating the Marginal Distribution**

We propose and investigate two approximations for the observations' pmf, which replace the original infinite compounding structure by a finite one and then continue with the above scheme. We refer to these approximations as *Hermite approximations*; the 1st order approximations are just Poisson approximations.

To evaluate the performance of the two types of Hermite approximations, we consider the NB-INAR(1) model with $\mathrm{NB}(n,\pi)$-distributed innovations. For different levels of the mean $\mu_\epsilon = n\,(1-\pi)/\pi$, of the dispersion ratio $\sigma_\epsilon^2/\mu_\epsilon = 1/\pi$ and of the autocorrelation parameter $\alpha$, we compute the marginal distribution approximately by the above Hermite approximations, and we compare the result with the numerically exact Markov chain approach.

# References


[1] Puig, P., Valero, J. (2007) Characterization of count data distributions involving additivity and binomial subsampling. *Bernoulli* **13**(2):544–555.

[2] Schweer, S., Weiß, C.H. (2014). Compound Poisson INAR(1) processes: stochastic properties and testing for overdispersion. *Comp. Stat. Data Anal.* **77**:267–284.

[3] Weiß, C.H., Puig, P. (2015), The Marginal Distribution of Compound Poisson INAR(1) Processes, in Steland et al. (eds.): *Stochastic Models, Statistics and Their Applications*, Springer Proceedings in Mathematics & Statistics, Vol. 122, Springer-Verlag.

# The analysis of stochastic signal from LHD mining machine

**Agnieszka Wyłomańska** *Wrocław University of Technology, Department of Mathematics, Poland*
**Radosław Zimroz** *Diagnostics and Vibro-Acoustics Science Laboratory, Wrocław University of Technology and KGHM CUPRUM Ltd CBR, Wrocław, Poland*

**Abstract:** In this paper a novel procedure for LHD (Load-Haul-Dump) machine temperature signal analysis is proposed. In this procedure the signal segmentation and its decomposition into trend and residuals is made. Moreover in the next step the novel technique for further decomposition of residuals is proposed and stochastic analysis procedure is applied. The stochastic analysis is based on the ARMA (autoregressive moving average) models with Gaussian and strictly stable distribution. Different nature of extracted sub-signals offers specific opportunity to use them for condition monitoring as well as process monitoring purposes. Appropriate processing techniques give a chance to observe specific character in the acquired data. In this paper we present basic theory related to the applied methodology as well as practical example obtained by application of proposed techniques.

# Model Selection for Bayesian Multi-Step Ahead Predictions

**Fumiyasu Komaki** *Department of Mathematical Informatics, The University of Tokyo, Japan, Riken Brain Science Institute, Japan*
**Keisuke Yano** *Department of Mathematical Informatics, The University of Tokyo, Japan, Riken Brain Science Institute, Japan*

**Abstract:** We propose an information criterion for multi-step ahead predictions. The proposed information criterion is also used for extrapolations. Throughout the numerical experiments, we show the effectiveness of the proposed information criterion.

**Summary**

We consider multi-step ahead predictions: Let $x^{(N)} = (x_1, \cdots, x_N)$ be observations having the distribution $p(x^{(N)})$ and let $y^{(M)} = (y_1, \cdots, y_M)$ be target variables having the distribution $q(y^{(M)})$. We assume that the sample size $M$ is given as the constant multiplication of the sample size $N$. We predict the distribution of the target variables based on the observations. Here the distributions $p(x^{(N)})$ and $q(y^{(M)})$ may be different but we assume that $x_1, \cdots, x_N, y_1, \cdots, y_M$ are independent.

For the prediction, we consider parametric models of the distributions of the observations and the target variables: for $m \in \{1, \cdots, m_{\rm full}\}$, the $m$-th model $\mathcal{M}_m$ is given as $\{p_m(x^{(N)}|\theta_m)q_m(y^{(M)}|\theta_m) : \theta_m \in \Theta_m\}$. For simplicity, we denote $\theta_{m_{\rm full}}$ by $\omega$, $p_{m_{\rm full}}(x^{(N)}|\omega)$ by $p(x^{(N)}|\omega)$, $q_{m_{\rm full}}(y^{(M)}|\omega)$ by $q(y^{(M)}|\omega)$ and $\Theta_{m_{\rm full}}$ by $\Theta$. After the model selection, we construct the predictive distribution in the selected model.

For example, consider the curve fitting: We obtain the values of the unknown curve at points $\{z_i\}_{i=1}^N$ and predict the distribution of the values at points $\{z_i\}_{i=N+1}^M$. We use regression models with the basis set $\{\phi_a\}_a^{d_{\rm full}}$: for $m \in \{1, \cdots, d_{\rm full}\}$, for $i \in \{1, \cdots, N\}$, and for $j \in \{1, \cdots, M\}$, the $i$-th observation and the $j$-th target variable in the $m$-th model are given as

$$x_i = \sum_{a=1}^{m} \phi_a(z_i)\theta_{m,a} + \epsilon_i$$

and

$$y_j = \sum_{a=1}^{m} \phi_a(z_{N+j})\theta_{m,a} + \epsilon_{N+j}.$$

Here $\theta_m = (\theta_{m,1}, \cdots, \theta_{m,m})$ are the unknown vector. Two random vectors $\epsilon = (\epsilon_1, \cdots, \epsilon_N)^\top$ and $\tilde{\epsilon} = (\epsilon_{N+1}, \cdots, \epsilon_{N+M})^\top$ are independent and distributed according to Gaussian distributions with zero mean and covariance matrices $\sigma^2 I_{N\times N}$ and $\sigma^2 I_{M\times M}$, respectively.

By using the asymptotics as the sample sizes $N$ and $M = cN$ go to infinity, we construct an information criterion for multi-step ahead predictions based on the Bayesian predictive distribution in the sub-model $\mathcal{M}_m$ with respect to prior $\pi$

$$q_{m,\pi}(y^{(M)}|x^{(N)}) = \frac{\int q_m(y^{(M)}|\theta_m)p(x^{(N)}|\theta_m)\pi(\theta_m)\mathrm{d}\theta_m}{\int p_m(x^{(N)}|\theta_m)\pi(\theta_m)\mathrm{d}\theta_m}.$$

The proposed information criterion is a natural extension of the predictive likelihood ([1]) and PIC ([2]). Several numerical experiments including the curve extrapolation show the effectiveness of the proposed information criterion.

## References

[1] Akaike, H. (1980). On the use of the predictive likelihood of a gaussian model, *Annals of the Institute of Statistical Mathematics*, Vol., 32, pp. 311–324

[2] Kiatagawa, G. (1997). Information criteria for the predictive evaluation of bayesian models, *Communications in Statistics - Theory and Methods*, Vol., pp. 2223–2246

# Changepoint inference for Erdős-Rényi random graphs

**Moulinath Banerjee** *Department of Statistics, University of Michigan, USA*
**George Michailidis** *Department of Statistics, University of Michigan, USA*
**Elena Yudovina** *Department of Mathematics, University of Minnesota, USA*

**Abstract:** The problem of estimating the location of a jump discontinuity (*changepoint*) has been extensively studied in the statistics literature. There are two versions of the problem. The *on-line* version is concerned with the quickest detection of a changepoint in the parameters of a dynamic stochastic system, and is closely related to classical problems in sequential analysis. In the *off-line* version, data are available for $n$ covariate-response pairs, and one is interested in estimating the location of the changepoint as accurately as possible. Both versions of the problem have dealt primarily with low- (usually one-) dimensional problems.

We consider the off-line version in a high-dimensional network setting. Data are indexed by the edges of a graph; in the simplest case, binary data indicate whether the edge is present. We consider edges which evolve independently, so that at each point in time the network looks like an Erdős-Rényi random graph. This is a fundamental problem in changepoint analysis on networks, and already presents technical challenges: the biggest problem is that, as graph size grows, we are forced to deal with a higher-dimensional nuisance parameter space. The main focus of our investigation is on the limiting regimes that appear for the maximum likelihood estimator (MLE), as a function of the signal-to-noise ratio and the number of edges in the network. We obtain insights into the scaling regimes available in high-dimensional data, and compute the limiting distributions of the maximum likelihood estimates of both the changepoint and the remaining model parameters. We also develop an adaptive inference framework for estimating the distribution of the MLE; interestingly, in the high-dimensional setting there is a regime where the MLE is consistent but we do not know how to estimate its distribution from data.

# Modelling and Forecasting Electricity Spot Prices Using Lasso Methods

**Sven Husmann** *European University Viadrina Frankfurt(Oder), Germany*
**Rick Steinert** *European University Viadrina Frankfurt(Oder), Germany*
**Florian Ziel** *European University Viadrina Frankfurt(Oder), Germany*

**Abstract:** We present a multivariate time series model for electricty spot prices and discuss a lasso based estimation algorithm and its forecasting performance.

**Summary**

In this talk we present a new model for electricity prices. The considered model is a multivariate time-varying AR process $(\boldsymbol{Y}_t)_{t\in\mathbb{Z}}$ with

$$\boldsymbol{Y}_t = \boldsymbol{\Phi}_0(t) + \sum_k \boldsymbol{\Phi}_k(t)\boldsymbol{Y}_{t-k} + \boldsymbol{\varepsilon}_t$$

and condional heteroscedastic errors $\boldsymbol{\varepsilon}_t$. The proposed parametrisation of the model and is very close to a periodic AR-TARCH process.

We consider the hourly day-ahead electricity prices for Germany and Austria traded at the European Power Exchange, but also take into account other relevant time series, like of the electricity load, electricity prices of other related markets and renewable energy feed-in. The model is designed in that way that it is able to capture periodic structure, such as the daily, weekly, and annual seasonal behaviour. Furthermore effects due to public holidays and the daylight saving time are covered by the model approach as well.

We use an efficient iteratively reweighted lasso approach for the parameter estimation to enjoy model selection properties of the lasso estimator. This procedure takes into account the conditional heteroscedasticity behaviour and improves the estimates and forecast in comparison to common homoscedastic aproaches. Moreover we discuss the asymptotic behaviour of the considered estimator. Additionally we provide evidence for leverage effects within the data and test for the impact of wind and solar power on the electricity price. Finally we compare the forecasting performance with other recent models from literature.

The proposed lasso based estimation method provides a wide range of applications in other areas of high-dimensional time series modelling.

## References

[1] Ziel F., Steinert R., Husmann S., (2015). Efficient Modeling and Forecasting of Electricity Spot Prices, *Energy Economics*, 47:98–111

[2] J. Wagener, H. Dette, (2012). Bridge estimators and the adaptive Lasso under heteroscedasticity, *Mathematical Methods of Statistics*, 21, No. 2, 109–126

# Participants

**Alberto Achcar, Jorge**
University of São Paulo, Brazil, achcar@fmrp.usp.br
**Alaba, Oluwayemisi Oyeronke**
University of Ibadan, Nigeria and University of South Africa, alabaoo@unisa.ac.za
**Alasseur, Clemence**
EDF R&D, France, clemence.alasseur@edf.fr
**Al-Awadhi, Fahimah A.**
Kuwait University, Kuwait, mapfahaa@hotmail.com
**Ambach, Daniel**
European University Viadrina, Frankfurt (Oder), Germany, ambach@europa-uni.de
**Aspelmeier, Timo**
Georg-August University of Göttingen, Germany timo.aspelmeier@mathematik.uni-goettingen.de
**Balcerek, Michał**
Wrocław University of Technology, Poland, michal.balcerek@pwr.edu.pl
**Baran, Sándor**
University of Debrecen, Hungary, baran.sandor@inf.unideb.hu
**Biedermann, Stefanie**
University of Southampton, UK, s.biedermann@soton.ac.uk
**Boczkowski, Krzysztof**
Wrocław University of Technology, Poland, Krzysztof.Boczkowski@pwr.edu.pl
**Bogdan, Małgorzata**
Wrocław University of Technology, Poland, Malgorzata.Bogdan@pwr.edu.pl
**Bott,Ann-Kathrin**
Technische Universität Darmstadt, Germany, abott@mathematik.tu-darmstadt.de
**Bucchia, Beatrice**
University of Cologne, Germany, bbucchia@math.uni-koeln.de
**Burkschat, Marco**
RWTH Aachen University, Germany, marco.burkschat@rwth-aachen.de
**Chen, Hong**
University of Hohenheim, Germany, hong.chen@uni-hohenheim.de
**Chevallier, Julien**
Univ. Paris 8 and IPAG Business School, France, julien.chevallier04@univ-paris8.fr
**Coad, Steve**
School of Mathematical Sciences, Queen Mary, University of London, U.K., d.s.coad@qmul.ac.uk
**Dahlen, Eric Kai**
Norwegian University of Science and Technology, Norway, kai.e.dahlen@himolde.no
**Darkhovsky, Boris**
Norwegian University of Science and Technology, Norway, darbor2004@mail.ru
**De Brabanter, Kris**
Iowa State University, USA, kbrabant@iastate.edu
**Dickhaus, Thorsten**
WIAS, Berlin, Germany, Thorsten.Dickhaus@wias-berlin.de
**Döring, Maik**
TU Dortmund University, Germany, maik.doering@uni-hohenheim.de
**Eckardt, Matthias**

Humboldt Universität zu Berlin, Germany, eckardtm@cms.hu-berlin.de
**Eichner, Gerrit**
Justus-Liebig-University Giessen, Germany, gerrit.eichner@math.uni-giessen.de
**Faizullah, Faiz**
National University of Sciences and Technology, Pakistan, faiz_math@yahoo.com
**Falbo, Paolo**
University of Brescia, Italy, paolo.falbo@unibs.it
**Ferenstein, Elżbieta Z.**
Warsaw University of Technology, Poland, efer@mini.pw.edu.pl
**Ferger, Dietmar**
Technische Universität Dresden, Germany, dietmar.ferger@tu-dresden.de
**Féron, Olivier**
EDF R&D and FiME, Clamart Cedex, France, olivier-2.feron@edf.fr
**Grothe, Olivier**
University of Cologne, Germany, grothe@statistik.uni-koeln.de
**Györfi, László**
Budapest University of Technology and Economics, Hungary, gyorfi@cs.bme.hu
**Harman, Radoslav**
Comenius University, Bratislava, Slovakia, harman@fmph.uniba.sk
**Heuser, Christoph**
University of Cologne, Germany, cheuser@math.uni-koeln.de
**Hicks, Jessica**
Iowa State University, USA, jahicks@iastate.edu
**Hoegel, Josef**
University of Ulm, Germany, josef.hoegel@uni-ulm.de
**Holling, Heinz**
University of Münster, Germany, holling@uni-muenster.de
**Hotz, Thomas**
Technische Universität Ilmenau, Germany, thomas.hotz@tu-ilmenau.de
**Hušková, Marie**
Charles University, Prague, Czech Republic, huskova@karlin.mff.cuni.cz
**Jabłońska-Sabuka, Matylda**
Lappeenranta University of Technology, Finland, matylda.jablonska-sabuka@lut.fi
**Jaworski, Piotr**
University of Warsaw, Poland, P.Jaworski@mimuw.edu.pl
**Jibasen, Danjuma**
Modibbo Adama University of Technology, Yola, Nigeria, djibasen1@yahoo.co.uk
**Jokiel-Rokita, Alicja**
Wrocław University of Technology, Poland, alicja.jokiel-rokita@pwr.edu.pl
**Kahle, Waltraud**
Otto-von-Guericke-University Magdeburg, Germany, waltraud.kahle@ovgu.de
**Kanamura, Takashi**
Kyoto University, Japan, tkanamura@gmail.com
**Katris, Christos**
University of Patras, Greece, chriskatris@upatras.gr
**Klement, Erich Peter**
Johannes Kepler University, Linz and Softwarepark Hagenberg, Austria, ep.klement@jku.at
**Knight, Keith**
University of Toronto, Canada, keith@utstat.toronto.edu
**Knoth, Sven**
Helmut Schmidt Univ., Hamburg, Germany, knoth@hsu-hh.de

**Koronacki, Jacek**
Polish Academy of Sciences, Poland, jacek.koronacki@ipipan.waw.pl
**Kössler, Wolfgang**
Humboldt-Universität zu Berlin, Germany, koessler@informatik.hu-berlin.de
**Krzywda, Marcin**
Jagiellonnian University in Krakow, Poland, marcin@krzywda.net
**Krzyżak, Adam**
Concordia University, Monteral, Canada, krzyzak@cs.concordia.ca
**Kunert, Joachim**
TU Dortmund University, Germany, joachim.kunert@udo.edu
**Lahmer, Tom**
Bauhaus University Weimar, Germany, tom.lahmer@uni-weimar.de
**Lawniczak, Anna T.**
University of Guelph, Ontario, Canada, alawnicz@uoguelph.ca
**Lazar, Daniel**
Wrocław University of Technology, Poland, daniel.lazar@pwr.edu.pl
**Lazariv, Taras**
European University Viadrina, Germany, lazariv@europa-uni.de
**Lee, Sangkyun**
TU Dortmund University, Germany, sangkyun.lee@cs.tu-dortmund.de
**Ledwina, Teresa**
Polish Academy of Sciences, Poland, ledwina@impan.pan.wroc.pl
**Leśkow, Jacek**
Cracow Technical University, Poland, jleskow@pk.edu.pl
**Libal, Urszula**
Wrocław University of Technology, Poland, urszula.libal@pwr.edu.pl
**Liebscher, Eckhard**
University of Applied Sciences Merseburg, Germany, eckhard.liebscher@hs-merseburg.de
**Lucheroni, Carlo**
University of Camerino, Italy, carlo.lucheroni@unicam.it
**Maciejewski, Henryk**
Wrocław University of Technology, Poland, Henryk.Maciejewski@pwr.edu.pl
**Maciejowska, Katarzyna**
Wrocław University of Technology, Poland, Katarzyna.Maciejowska@pwr.edu.pl
**Magiera, Ryszard**
Wrocław University of Technology, Poland, Ryszard.Magiera@pwr.edu.pl
**Meister, Alexander**
University of Rostock, Germany, alexander.meister@uni-rostock.de
**Mesiar, Radko**
Slovak Univ. of Technology, Slovakia & IRAFM, Czech Republic, mesiar@math.sk
**Mielniczuk, Jan**
Polish Academy of Sciences and Warsaw University of Technology, Poland, miel@ipipan.waw.pl
**Moffat, Imoh U.**
University of Uyo, Nigeria, moffitto2011@gmail.com
**Möller, Tobias**
Helmut Schmidt University, Germany, moellert@hsu-hh.de
**Morais, Manuel Cabral**
Universidade de Lisboa, Portugal, maj@math.ist.utl.pt
**Muche, Lutz**
Technische Universität Dresden, Germany, lutz.muche@tu-dresden.de
**Müller, Florian**

Technische Universität Darmstadt, Germany, fmueller@mathematik.tu-darmstadt.de
**Mzyk, Grzegorz**
Wrocław University of Technology, Poland, Grzegorz.Mzyk@pwr.edu.pl
**Nowotarski, Jakub**
Wrocław University of Technology, Poland, Jakub.Nowotarski@pwr.edu.pl
**Otto, Philipp**
European University Viadrina, Germany, potto@europa-uni.de
**Paraschiv, Florentina**
University of St. Gallen, Switzerland, florentina.paraschiv@unisg.ch
**Patan, Maciej**
University of Zielona Góra, Poland, m.patan@issi.uz.zgora.pl
**Pawlak, Mirosław**
University of Manitoba, Canada, Miroslaw.Pawlak@umanitoba.ca
**Pelizzari, Cristian**
University of Brescia, Italy, cristian.pelizzari@unibs.it
**Perrone, Elisa**
Johannes Kepler University Linz, Austria, elisa.perrone@jku.at
**Pflug, Georg**
University of Vienna, Austria, georg.pflug@univie.ac.at
**Pinson, Pierre**
Technical University of Denmark, ppin@dtu.dk
**Piryatinska, Alexandra**
San Francisco State University, CA, USA, alpiryat@sfsu.edu
**Polański, Andrzej**
Silesian University of Technology, Gliwice, Poland, andrzej.polanski@polsl.pl
**Polunchenko, Aleksey S.**
State University of New York at Binghamton, USA, aleksey@binghamton.edu
**Prause, Annabel**
RWTH Aachen University, Germany, prause@stochastik.rwth-aachen.de
**Prášková, Zuzanna**
Charles University in Prague, Czech Republic, praskova@karlin.mff.cuni.cz
**Proksch, Katharina**
University of Siegen, Germany, katharina.proksch@rub.de
**Rabyk, Liubov**
European University Viadrina, Frankfurt (Oder), Germany, rabyk@europa-uni.de
**Rafajłowicz, Ewaryst**
Wrocław University of Technology, Poland, Ewaryst.Rafajlowicz@pwr.edu.pl
**Riccomagno, Eva**
Universitá degli Studi di Genova, Italy, riccomagno@dima.unige.it
**Rychlik, Tomasz**
Polish Academy of Sciences, Poland, trychlik@impan.pl
**Saggini, Eleonora**
University of Genova, Italy, saggini@dima.unige.it
**Sagnol, Guillaume**
Zuse Institut Berlin, Germany, sagnol@zib.de
**Sapio, Alessandro**
Parthenope University of Naples, Italy, alessandro.sapio@uniparthenope.it
**Schellhase, Christian**
Bielefeld University, Germany, cschellhase@wiwi.uni-bielefeld.de
**Schürle, Michael**
University of St. Gallen, Switzerland, michael.schuerle@unisg.ch

**Schwabe, Reiner**
Otto-von-Guericke-Universität Magdeburg, Germany, rainer.schwabe@ovgu.de
**Schweer, Sebastian**
University of Heidelberg, Germany, schweer@uni-heidelberg.de
**Sikolya, Kinga**
University of Debrecen, Hungary, sikolya.kinga@inf.unideb.hu
**Skarupski, Marek**
Wrocław University of Technology, Poland, Marek.Skarupski@pwr.edu.pl
**Skubalska-Rafajłowicz, Ewa**
Wrocław University of Technology, Poland, ewa.rafajlowicz@pwr.wroc.pl
**Śliwiński, Przemysław**
Wrocław University of Technology, Poland, przemyslaw.sliwinski@pwr.wroc.pl
**Smii, Boubaker**
King Fahd University of Petroleum and Minerals, Saudi Arabia, boubaker@kfupm.edu.sa
**Soumaya, Moudar**
Otto-von-Guericke University, Germany, moudar.soumaya@ovgu.de
**Souza, Robeto Molina de**
University of São Paulo, Brazil, rmolinasouza@utfpr.edu.br
**Spöck, Gunter**
University of Klagenfurt, Austria, gunter.spoeck@aau.at
**Steinwart, Ingo**
University of Stuttgart, Germany, ingo.steinwart@mathematik.uni-stuttgart.de
**Steland, Ansgar**
RWTH Aachen University, Germany, steland@stochastik.rwth-aachen.de
**Strzalkowska-Kominiak, Ewa**
Universidad Carlos III de Madrid, Spain, ewa.kominiak@gmail.com
**Stummer, Wolfgang**
University of Erlangen-Nürnberg, Germany, stummer@math.fau.de
**Stute, Winfried**
University of Giessen, Germany, Winfried.Stute@math.uni-giessen.de
**Szajowski, Krzysztof**
Wrocław University of Technology, Poland, Krzysztof.Szajowski@pwr.wroc.pl
**Tent, Reinhard**
Technische Universität Darmstadt, Germany, tent@mathematik.tu-darmstadt.de
**Topolnicki, Rafał**
Wrocław University of Technology, Poland, Rafal.Topolnicki@pwr.wroc.pl
**Torgovitski, Leonid**
University of Cologne, Germany, ltorgovi@math.uni-koeln.de
**Uciński, Dariusz**
University of Zielona Góra, Poland, d.ucinski@issi.uz.zgora.pl
**Veraart, Almut**
Imperial College London, UK, a.veraart@imperial.ac.uk
**Vogel, Silvia**
Ilmenau University of Technology, Germany, Silvia.Vogel@tu-ilmenau.de
**Wagner, Martin**
Technical University Dortmund, Germany, mwagner@statistik.tu-dortmund.de
**Walk, Harro**
Universität Stuttgart, Germany, walk@mathematik.uni-stuttgart.de
**Weiß, Christian**
Helmut Schmidt University, Hamburg, Germany, weissc@hsu-hh.de
**Weron, Rafał**

Wrocław University of Technology, Poland, Rafal.Weron@pwr.edu.pl

**Wyłomańska, Agnieszka**

Wrocław University of Technology, Poland, agnieszka.wylomanska@pwr.edu.pl

**Yano, Keisuke**

Univ. of Tokyo, Riken Brain Science Institute, Japan, Keisuke_Yano@mist.i.u-tokyo.ac.jp

**Yudovina, Elena**

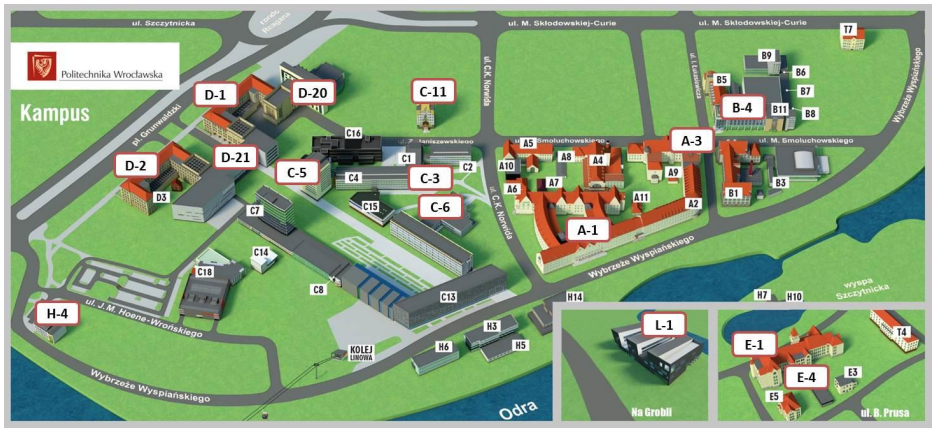
University of Minnesota, USA, eyudovin@umn.edu

**Ziel, Florian**

European University Viadrina, Frankfurt (Oder), Germany, ziel@europa-uni.de

# Index

# Campus map

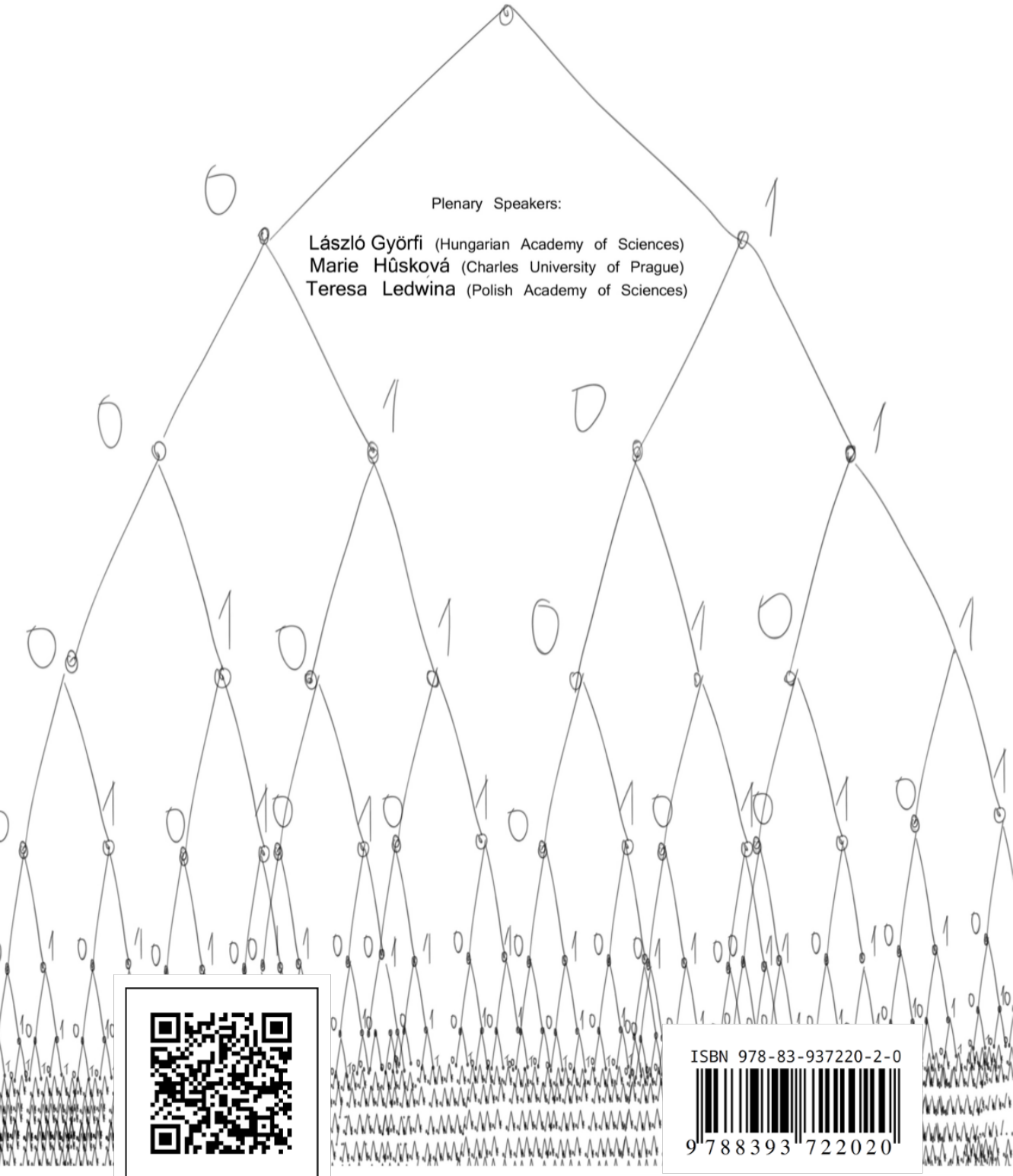



Traditional Library **A-1**
Electronic Library **D-21**

OCW1 Center's Branch at the Faculty of Architecture: **E-1, E-4**
OCW2 Center's Branch at the Faculty of Civil Engineering: **D-1**
OCW3 Center's Branch at the Faculty of Chemistry: **A-3**
OCW4 Center's Branch at the Faculty of Electronics: **C-3, C-5, C-6**
OCW5 Center's Branch at the Faculty of Electrical Engineering: **D-20**
OCW6 Center's Branch at the Faculty of Geoengineering, Mining and Geology: **L-1**
OCW7 Center's Branch at the Faculty of Environmental Engineering: **D-2**
OCW8 Center's Branch at the Faculty of Computer Science and Management: **B-4**
OCW9 Center's Branch at the Faculty of Mechanical and Power Engineering: **C-6**
OCW10 Center's Branch at the Faculty of Mechanical Engineering: **B-4**
OCW11 Center's Branch at the Faculty of Fundamental Problems of Technology: **A-1, C11**
OCS1 Center's Branch at the Department of Foreign Languages: **H-4**

Printed by:
esus
Agencja Reklamowo-Wydawnicza
Tomasz Przybylak
ul. Franciszka Ratajczaka 26/8
61-815 Poznań
http://www.esus.pl

# GERMAN - POLISH 12TH WORKSHOP ON STOCHASTIC MODELS, STATISTICS AND THEIR APPLICATIONS



Plenary Speakers:

László Györfi (Hungarian Academy of Sciences)
Marie Hûsková (Charles University of Prague)
Teresa Ledwina (Polish Academy of Sciences)

ISBN 978-83-937220-2-0

Wrocław University of Technology

February 16-20, 2015

www.smsa2015.rwth-aachen.de