

Copyright

© ECMS2017

Printed: ISBN: 978-0-9932440-4-9

**European Council for Modelling
and Simulation**

CD: ISBN: 978-0-9932440-5-6

Cover pictures

**front side: © Kravka |
Dreamstime.com
back side: © Stefano Ferrario |
pixabay.com**

Printed by

**Digitaldruck Pirrot GmbH
66125 Sbr.-Dudweiler,
Germany**

PROCEEDINGS

31st European Conference on Modelling and Simulation ECMS 2017

May 23rd – May 26th, 2017
Budapest, Hungary

Edited by:

Zita Zoltay Paprika

Péter Horák

Kata Váradi

Péter Tamás Zwierczyk

Ágnes Vidovics-Dancs

János Péter Rádics

Organized by:

ECMS - European Council for Modelling and Simulation

Hosted by:

Corvinus University of Budapest, Corvinus Business School

Budapest University of Technology and Economics

Sponsored by:

Budapest University of Technology and Economics

Central-European Training Center for Brokers / Közép-európai
Brókerképző Alapítvány

Corvinus University of Budapest, Corvinus Business School

KELER CCP Ltd.

MVM Group
CLAAS Hungária Kft.
FÉMALK Zrt.

International Co-Societies:

IEEE - Institute of Electrical and Electronics Engineers
ASIM - German Speaking Simulation Society
EUROSIM - Federation of European Simulation Societies
PTSK - Polish Society of Computer Simulation
LSS - Latvian Simulation Society

ECMS 2017 ORGANIZATION

Conference Chair

Zita Zoltay Paprika

Corvinus University of Budapest
Corvinus Business School
Hungary

Conference Co-Chairs

Kata Váradi

Corvinus University of Budapest
Corvinus Business School
Hungary

Péter Tamás Zwierczyk

Budapest University of Technology
and Economics
Hungary

Programme Chair

Péter Horák

Budapest University of Technology
and Economics
Hungary

Programme Co-Chairs

Ágnes Vidovics-Dancs

Corvinus University of Budapest
Corvinus Business School
Hungary

János Péter Rádics

Budapest University of Technology
and Economics
Hungary

President of European Council for Modelling and Simulation

Khalid Al-Begain

University of South Wales, United Kingdom

Vice-President of European Council for Modelling and Simulation

Lars Nolle

Jade University of Applied Science, Wilhelmshaven, Germany

Managing Editor

Martina-Maria Seidel

St. Ingbert, Germany

EUROPEAN COUNCIL BOARD 2017

<p><i>Khalid Al-Begain</i></p> <p>University of South Wales, United Kingdom</p>	<p>President of European Council for Modelling and Simulation and Past President of European Council for Modelling and Simulation (2006-2010)</p>
<p><i>Lars Nolle</i></p> <p>Jade University of Applied Science, Wilhelmshaven, Germany</p>	<p>Vice-President of European Council for Modelling and Simulation elected in 2016</p>
<p><i>Evtim Peytchev</i></p> <p>Nottingham Trent University United Kingdom</p>	<p>Past President of European Council for Modelling and Simulation (2012-2014) Treasurer (2015-today)</p>
<p><i>Andrzej Bargiela</i></p> <p>United Kingdom</p>	<p>Past President of European Council for Modelling and Simulation (2002-2004, 2004-2006, 2010-2012)</p>
<p><i>Eugène Kerckhoffs</i></p> <p>The Netherlands</p>	<p>Founder, Past President and Historian of ECMS</p>
<p><i>Kata Váradi</i></p> <p>Corvinus University of Budapest, Corvinus Business School Hungary</p>	<p>Conference Co-Chair of ECMS 2017</p>
<p><i>Peter T. Zwierczyk</i></p> <p>Budapest University of Technology and Economics Hungary</p>	<p>Programme Co-Chair of ECMS 2017</p>
<p><i>Frank Herrmann</i></p> <p>Ostbayerische Technische Hochschule Germany</p>	<p>Conference Chair of ECMS 2016</p>
<p><i>Michael Manitz</i></p> <p>Universität Duisburg-Essen Germany</p>	<p>Programme Chair of ECMS 2016</p>

INTERNATIONAL PROGRAMME COMMITTEE

Agent-Based Simulation

Track Chair: **Michael Möhring**
University of Koblenz-Landau, Germany

Co-Chair: **Ulf Lotzmann**
University of Koblenz-Landau, Germany

Simulation in Industry, Business, Transport and Services

Track Chair: **Alessandra Orsoni**
University of Kingston, United Kingdom

Co-Chair: **Edward J. Williams**
University of Michigan-Dearborn, USA

Simulation of Intelligent Systems

Track Chair: **Zuzana Kominková Oplatková**
Tomas Bata University of Zlín, Czech Republic

Co-Chair: **Roman Senkerik**
Tomas Bata University of Zlín, Czech Republic

Finance and Economics and Social Science

Track Chair: **Kata Váradi**
Corvinus University of Budapest, Corvinus Business School, Hungary

Co-Chairs:
Barbara Dömötör
Corvinus University of Budapest, Corvinus Business School, Hungary

Ágnes Vidovics-Dancs
Corvinus University of Budapest, Corvinus Business School, Hungary

Modelling, Simulation and Control of Technological Processes

Track Chair: **Jiří Vojtěšek**

Tomas Bata University in Zlín, Czech Republic

Co-Chairs:

Petr Dostál

Tomas Bata University in Zlín, Czech Republic

František Gazdoš

Tomas Bata University in Zlín, Czech Republic

Simulation and Optimization

Track Chair: **Frank Herrmann**

OTH Regensburg, Germany

Co-Chairs:

Thorsten Claus

Technical University Dresden, Germany

Michael Manitz

University of Duisburg-Essen, Germany

High Performance Modelling and Simulation

Track Chair: **Mauro Iacono**

Seconda Università degli Studi di Napoli, Italy

Co-Chairs:

Daniel Grzonka

Cracow University of Technology, Poland

Agnieszka Jakobik

Cracow University of Technology, Poland

Rostislav V. Razumchik

Institute of Informatics Problems FRC CSC RAS,
Russia

Honorary Track Chair:

Joanna Kolodziej

Cracow University of Technology, Poland

IPC Members in Alphabetical Order

Pavel Abaev, Peoples' Friendship University of Russia, Russia

Frederic Amblard, Université Toulouse 1 Capitole, France

Piotr Arabas, Warsaw University of Technology and NASK, Poland

Monika Bakosova, Slovak University of Technology in Bratislava, Slovakia

Hans-Peter Barbey, University of Applied Sciences in Bielefeld, Germany

Enrico Barbierato, Politecnico di Milano, Italy

Jan Bielanski, AGH University of Science and Technology, Poland

Vladimir Bobal, Tomas Bata University in Zlin, Czech Republic

Riccardo Boero, Los Alamos National Laboratory, USA

Aleksander Byrski, AGH University of Science and Technology, Poland

Petr Chalupa, Tomas Bata University in Zlin, Czech Republic

Emile Chappin, Delft University of Technology, The Netherlands

Adriana Chis, National College of Ireland Dublin, Ireland

Marina Chukalina, Russian Academy of Science, Russia

Franco Cicirelli, University of Calabria, Italy

Catherine Cleophas, RWTH Aachen, Germany

Gregoire Danoy, University of Luxembourg, Luxembourg

Ciprian Dobre, University Politehnica of Bucharest, Romania

František Dušek, University of Pardubice, Czech Republic

Nóra Ágota Felföldi-Szűcs, Corvinus University of Budapest, Hungary

Massimo Ficco, Seconda Università degli Studi di Napoli, Italy

Robert Forstner, SimPlan AG in Regensburg, Germany

Christopher Frantz, Otago Polytechnic, New Zealand

Amineh Ghorbani, Delft University of Technology, The Netherlands

Horacio Gonzalez-Velez, National College of Ireland, Ireland

Claudius Gräbner, (ICAE) Johannes Kepler University Linz, Austria

Marco Gribaudo, Politecnico di Milano, Italy

Alexander Grusho, Institute of Informatics Problems FRC CSC RAS, Russia

Magdalena Handerek, AGH University of Science and Technology, Poland

Stefan Hannig, ZF Friedrichshafen AG Passau, Germany
Benjamin Hildebrandt, University Duisburg-Essen, Germany
Daniel Honc, University of Pardubice, Czech Republic
Mark Hoogendorn, VU University of Amsterdam, The Netherlands
Thomas Hußlein, OptWare GmbH in Regensburg, Germany
Zsuzsa Huszár, National University of Singapore, Singapore
Teruaki Ito, The University of Tokushima, Japan
Michal Janosek, University of Ostrava, Czech Republic
Jácint Juhász, Babes-Bolyai University, Romania
Bogumil Kamiński, Warsaw School of Economics, Poland
Bart Kamphorst, VU University of Amsterdam, The Netherlands
Michał Konopczak, Warsaw School of Economics, Poland
Petia Koprinkova, Bulgarian Academy of Sciences, Bulgaria
Victor Korolev, Moscow State University, Russia
Ina Kortemeier, University Duisburg-Essen, Germany
Igor Kotenko, SPIIRAS, Russia
Martin Kotyrba, University of Ostrava, Czech Republic
Achyutha Krishnamoorthy, Cochin University of Science and Technology, India
Julia Kruk, Belarusian National Technical University, Belarus
Mateusz Krzysztoń, Warsaw University of Technology and NASK, Poland
Marek Kubalcik, Tomas Bata University in Zlin, Czech Republic
Frederick Lange, Maschinenfabrik Reinhausen Regensburg, Germany
Andrea Marin, Università Ca' Foscari di Venezia, Italy
Michal Marks, Research and Academic Computer Network (NASK), Poland
Stefano Marrone, Seconda Università degli Studi di Napoli, Italy
Agnieszka Mars, Jagiellonian University Cracow, Poland
Radek Matusu, Tomas Bata University in Zlin, Czech Republic
Nicolas Meseth, University of Applied Sciences in Osnabrueck, Germany
Christian Müller, University of Applied Sciences in Wildau, Germany
Maximilian Munninger, University of Applied Sciences in Regensburg, Germany
Tamas Nagy, Corvinus University of Budapest, Hungary

Valeriy Naumov, Service Innovation Research Institute, Finland
Catalin Negru, University Politehnica of Bucharest, Romania
Libero Nigro, University of Calabria, Italy
Dmitry P. Nikolaev, Russian Academy of Science, Russia
Igor Nikolic, Delft University of Technology, The Netherlands
Lars Nolle, Jade University of Applied Science Wilhelmshafen, Germany
Jakub Novak, Tomas Bata University in Zlin, Czech Republic
Beatrix Oravecz, Corvinus University of Budapest, Hungary
Francesco Palmieri, Università degli Studi di Salerno, Italy
Falk Stefan Pappert, Universität der Bundeswehr München, Germany
Libor Pekar, Tomas Bata University in Zlin, Czech Republic
Marc-Philip Piehl, University Duisburg-Essen, Germany
Michal Pluhacek, Tomas Bata University in Zlin, Czech Republic
Zoltan Pollak, Corvinus University of Budapest, Hungary
Florin Pop, University Politehnica of Bucharest, Romania
Simone Righi, Hungarian Academy of Sciences, Hungary
Boris Rohal-Ilkiv, Slovak University of Technology in Bratislava, Slovakia
Michael Römer, Martin-Luther-Universität Halle-Wittenberg, Germany
Juliette Rouchier, GREQAM-CNRS, France
Konstantin Samouylov, Peoples' Friendship University, Russia
Leonid Sevastyanov, Peoples' Friendship University, Russia
Oleg Shestakov, Moscow State University, Russia
Sergey Ya. Shorgin, Institute of Informatics Problems FRC CSC RAS, Russia
Markus Siegle, Universität der Bundeswehr München, Germany
Stelios Sotiriadis, University of Toronto, Canada
Grażyna Suchacka, Opole University, Poland
Katarzyna Sum, Warsaw School of Economics, Poland
Grzegorz Szafrński, Institute of Finance, Lodz University, Poland
János Száz, Corvinus University of Budapest, Hungary
Magdalena Szmajduch, Cracow University of Technology, Poland
Piotr Szuster, Cracow University of Technology, Poland

Pawel Szyrkiewicz, Polish Academy of Science Warsaw, Poland
Armando Tacchella, Università degli Studi di Genova, Italy
Kristóf Tamás, Corvinus University of Budapest, Hungary
Enrico Teich, Technical University of Dresden, Germany
Marco Trost, Technical University of Dresden, Germany
Christopher Tubb, University of South Wales, United Kingdom
Tobias Uhlig, Universität der Bundeswehr München, Germany
Nikolai Ushakov, Norwegian University of Science and Technology, Norway
Ward van Breda, VU University of Amsterdam, The Netherlands
Enrico Vicario, Università degli Studi di Firenze, Italy
Andrea Vinci, CNR – National Research Council of Italy, Italy
Narayanan Viswanath, Government Engineering College Thrissur, India
Jaroslav Vitku, GoodAI, Czech Republic
Thorsten Vitzthum, University of Applied Sciences in Regensburg, Germany
Eva Volna, University of Ostrava, Czech Republic
Andrzej Wilczyński, Cracow University of Technology, Poland
Victor Zakharov, Institute of Informatics Problems FRC CSC RAS, Russia
Alexander Zeifman, Vologda State University, Russia
Bihary Zsolt, Corvinus University of Budapest, Hungary

PREFACE

It is a pleasure to welcome the more than 100 researchers at the 31st European Conference on Modelling and Simulation (ECMS) conference from May 23rd till May 26th 2017, and have their research collected in this proceedings.

The 31st ECMS conference will be hosted by Corvinus University of Budapest and Budapest University of Technology and Economics. Organizing ECMS 2017 is a great opportunity for these two long-established Hungarian universities to give rise to a fruitful cooperation – bringing the two geographically very close institutions even closer. Modelling and simulation are exciting and useful methodologies to study various problems in several research fields.

Besides the disciplines closely related to the two organizing universities (business, economics, finance, engineering, kinematics, mechanisms, mechanical simulations), we are eager to get acquainted with all the fields related to the conference. The main goal of the conference is to share your research questions and expertise with the ECMS community as well. It is always a nice experience to bring inspired researchers together. This conference is a forum to communicate and share new ideas and methods that will foster the development across all aspects of computational methods and their applications in modelling and simulation of different fields of applied science.

We hope you will find your field of interest in our conference tracks which cover exciting topics about intelligent systems, virtual prototyping, operating simulation, applied modelling, simulation and optimization, controlling of technological processes and the modelling and simulation of cases in finance, economics and social sciences.

The high prestige of the ECMS 2017 program is enhanced by our two keynote speakers, one from the field of economics, and the other from the field of engineering. István P. Székely – director of the European Commission, Economic and Financial Affairs, and honorary professor of Corvinus University of Budapest – will talk about the economic modelling and economic policy surveillance in Europe. Jin Ooi – professor of particulate solid mechanics at the University of Edinburgh – will give a lecture on discrete element modelling of granular materials.

The conference will also give you the opportunity to visit Budapest, one of the most exciting cities in Europe. In addition to a decent scientific program, we sincerely hope that you will take a chance to enjoy the culture of Budapest.

We are looking forward to welcoming you in Budapest!

Zita Zoltay Paprika, Péter Horák

Budapest, May 2017

TABLE OF CONTENTS

Plenary Talks - Abstracts

Challenges To Policy-Oriented Modelling And Model-Based Policy Formulation During The Crises: A User Perspective

Istvan P. Szekely5

Discrete Element Modelling Of Cohesionless, Cohesive And Bonded Granular Materials - From Model Conceptualisations To Industrial Scale Applications

Jin Y. Ooi7

Agent-Based Simulation

Statistical Model Checking Of Multi-Agent Systems

Libero Nigro, Paolo F. Sciammarella11

Driving Behaviour Clustering For Realistic Traffic Micro-Simulators

Alessandro Petraro, Federico Caselli, Michela Milano, Marco Lippi18

Finance and Economics and Social Science

Simulation Models Of Two Duopoly Games

Ingolf Stahl27

Determination Of Factors Influencing The Decision On Purchasing Organic Food

Walailak Atthirawong34

Lifetime Probability Of Default Modeling For Hungarian Corporate Debt Instruments

Tamas Kristof, Miklos Virag41

The Use Of Econometric Models In The Study Of Demographic Policy Measures (Based On The Example Of Fertility Stimulation In Russia)

Oksana Shubat, Anna Bagirova47

The Use Of Cluster Analysis To Assess The Demographic Potential Of Russian Regions

Oksana Shubat, Anna Bagirova, Irina Shmarova53

Blind Vs. Embedded Indirect Reciprocity And The Evolution Of Cooperation	
<i>Simone Righi, Karoly Takacs</i>	60
Modelling The Development Of Strategic Management	
<i>Nikolett Deutsch, Tamas Meszaros, Lajos Szabo</i>	67
Intermediary Activities On Decentralized Financial Markets	
<i>Daniel Havran, Balazs Arpad Szucs</i>	74
Indexed Bonds With Mean-Reverting Risk Factors	
<i>Attila A. Vig, Agnes Vidovics-Dancs</i>	81
Stress Test Modelling Of PD Risk Parameter Under Advanced IRB	
<i>Zoltan Pollak, David Popper</i>	87
Combination Of Time-Frequency Representations For Background Noise Suppression	
<i>Eva Klejmová, Jitka Pomenková, Jiri Blumenstein</i>	93
A Margin Calculation Method For Illiquid Products	
<i>Marcell Belj, Csilla Szanyi, Kata Varadi</i>	100
Modelling Civil Society's Transformational Dynamism And Its Potential Effects	
<i>Jozsef Veress</i>	106
Determinants Of FX-Risk Management Evidence Of Hungary	
<i>Barbara Doemoetoer, Erzsebet Kovacs</i>	113
Model Of The State And EU Involvement In The Venture Capital Market	
<i>Erika Jaki, Endre Mihaly Molnar</i>	120
Factors Associated With Thai Exporter's Interest In Using New Dawei Deep Seaport	
<i>Kanogkan Leerojanaprapa, Kittiwat Sirikasemsuk, Komn Bhundarak</i>	127
Valuation Of The Prepayment Option In The Banking Book	
<i>Petra Kalfmann, Janos Szaz, Agnes Vidovics-Dancs</i>	135
Experiments On Risk Perception And Investment Decisions Of Economic Actors	
<i>Nora Felfoldi-Szucs, Peter Juhasz</i>	141

Volatility Surface Calibration In Illiquid Market Environment	
<i>Laszlo Nagy, Mihaly Ormos</i>	148
Modelling Of Provision Under New International Financial And Reporting Standard (IFRS 9)	
<i>Csaba Kadar</i>	153
Enhancing Model Interchangeability For Powerflow Studies: An Example Of A New Hungarian Network Model In Powerfactory And eASiMOV	
<i>Balint Hartmann, Hueseyin K. Cakmak, Uwe G. Kuehnappel, Veit Hagenmeyer</i>	158
 Simulation in Industry, Business, Transport and Services	
No More Deadlocks – Applying The Time Window Routing Method To Shuttle Systems	
<i>Thomas Lienert, Johannes Fottner</i>	169
The Worker Allocation Planning Of A Medical Device Distribution Center Using Simulation Modelling	
<i>Kittikhun Iamsamai, Thananya Wasusri</i>	176
Simulation Of A Queueing Model Useful In Crowdsourcing	
<i>Srinivas R. Chakravarthy, Serife Ozkar</i>	183
3D Simulation Modeling Of Apron Operation In A Container Terminal	
<i>Jingjing Yu, Guolei Tang, Da Li, Baoying Mu</i>	190
Container Terminals Capacity Evaluation Considering Port Service Level Based On Simulation	
<i>Ningning Li, Jingjing Yu, Guolei Tang, Da Li, Yong Zhang</i>	197
Hybrid Flow Shop Scheduling Of Automotive Parts	
<i>Tuanjai Somboonwiwat, Chatkaew Ratcharak, Tuangyot Supeekit</i>	204
Integrated Modelling Of Complex Processes On Basis Of BPMN	
<i>Semyon A. Potryasaev</i>	209

**Modelling And Simulation Of Public Transport Safety
And Scheduling Algorithm**

Anna Beinarovica, Mikhail Gorobetz, Anatoly Levchenkov.....215

**A Design Pattern For Modelling And Simulation In Hospital Pharmacy
Management**

Wirachchaya Chanpuypetch, Duangpun Kritchanhai.....222

Discrete Event Simulation – Production Model In SIMUL8

Jakub Fousek, Martina Kuncova, Jan Fabry.....229

Context-Aware Multi-Objective Vehicle Routing

Janis Grabis, Vineta Minkevica.....235

**A Simulation Optimization Tool For The Metal Accessory Suppliers
In The Fashion Industry: A Case Study**

Virginia Fani, Romeo Bandinelli, Rinaldo Rinaldi.....240

**An Optimization Of Spray Coating Process
To Minimize Coating Material Consumption**

Nitchakan Somboonwiwat, Suksan Prombanpong247

Simulation of Intelligent Systems

**On The Effect Of Neighborhood Schemes And Cell Shape On The Behaviour
Of Cellular Automata
Applied To The Simulation Of Submarine Groundwater Discharge**

Christoph Tholen, Lars Nolle, Oliver Zielinski255

**Application Of Genetic Optimization Algorithms To Lumped Circuit Modelling
Of Coupled Planar Coils**

Jens Werner, Lars Nolle, Jennifer Schuett.....262

Automatic Beam Hardening Correction For CT Reconstruction

*Marina Chukalina, Anastasia Ingacheva, Alexey Buzmakov, Igor Polyakov,
Andrey Gladkov, Ivan Yakimchuk, Dmitry P. Nikolaev.....270*

An Intelligent Winch Prototyping Tool

*Robin T. Bye, Ottar L. Osen, Webjoern Rekdalsbakken,
Birger Skogeng Pedersen, Ibrahim A. Hameed276*

Russian License Plate Segmentation Based On Dynamic Time Warping	
<i>Mikhail A. Povolotskiy, Elena G. Kuznetsova, Timur M. Khanipov.....</i>	<i>285</i>
Evolutionary Winch Design Using An Online Winch Prototyping Tool	
<i>Ibrahim A. Hameed, Robin T. Bye, Birger Skogeng Pedersen, Ottar L. Osen</i>	<i>292</i>
SHADE Mutation Strategy Analysis Via Dynamic Simulation In Complex Network	
<i>Adam Viktorin, Roman Senkerik, Michal Pluhacek, Tomas Kadavy</i>	<i>299</i>
Uncovering Communication Density In PSO Using Complex Network	
<i>Michal Pluhacek, Roman Senkerik, Adam Viktorin, Tomas Kadavy</i>	<i>306</i>
Firework Algorithm Dynamics Simulated And Analyzed With The Aid Of Complex Network	
<i>Tomas Kadavy, Michal Pluhacek, Adam Viktorin, Roman Senkerik</i>	<i>313</i>
Simulation Of Chaotic Dynamics For Chaos Based Optimization – An Extended Study	
<i>Roman Senkerik, Michal Pluhacek, Adam Viktorin, Zuzana Kominkova Oplatkova, Tomas Kadavy</i>	<i>319</i>
Different Approaches For Constant Estimation In Analytic Programming	
<i>Zuzana Kominkova Oplatkova, Adam Viktorin, Roman Senkerik, Tomas Urbanek.....</i>	<i>326</i>

Modelling, Simulation and Control of Technological Processes

Modeling Of Continuous Ethanol Fermentation In Ideal Mixing Column Bioreactor

*Ivan Petelkov, Rositsa Denkova, Vesela Shopska, Georgi Kostov,
Zapryana Denkova, Bogdan Goranov, Vasil Iliev*335

Predictive Control Of Two-Input Two-Output System With Non-Minimum Phase

Marek Kubalcik, Vladimir Bobal, Tomas Barot.....342

Verification Of Robust Properties Of Digital Control Closed-Loop Systems

Vladimir Bobal, Lubos Spacek, Peter Hornak.....348

Modeling Of Corn Ears By Discrete Element Method (DEM)

Adam Kovacs, Gyoergy Kerenyi.....355

Optimal Control With Disturbance Estimation

Frantisek Dusek, Daniel Honc, Rahul Sharma K.362

Modelling And Model Predictive Control Of Magnetic Levitation Laboratory Plant

Petr Chalupa, Jakub Novak, Martin Maly.....367

Predictive Control Of A Series Of Multiple Liquid Tanks Substituted By A Single Dynamics With Time-Delay

Stanislav Talas, Vladimir Bobal, Adam Krhovjak, Lukas Rusar374

Compensation Of Valve Deadzone Using Mixed Integer Predictive Control

Jakub Novak, Petr Chalupa379

State-Space Predictive Control Of Inverted Pendulum Model

Lukas Rusar, Adam Krhovjak, Stanislav Talas, Vladimir Bobal384

1DOF Gain Scheduled PH Control Of CSTR

Adam Krhovjak, Stanislav Talas, Lukas Rusar391

Design Of A Simple Bandpass Filter Of A Third Octave Equalizer

Martin Pospisilik.....397

LQ Digital Control Of Ball & Plate System	
<i>Lubos Spacek, Vladimir Bobal, Jiri Vojtesek</i>	403
An Embedded System Implementation Of A Predictive Algorithm For A Bioprocess	
<i>Florin Stinga, Marius Marian, Valentin Kese, Lucian Barbulescu, Emil Petre</i>	409
Wireless Radiation Monitoring System	
<i>Camelia Avram, Silviu Folea, Dan Radu, Adina Astilean</i>	416
SIMTONIA – A Framework Of SIMulation TOols For Nuclear Industrial Applications	
<i>Jozsef Pales, Aron Vecsi, Gabor Hazi</i>	423
Nuclear Industrial Applications Of SIMTONIA	
<i>Jozsef Pales, Aron Vecsi, Gabor Hazi</i>	429
CAE/VR Integration – A Path To Follow? A Validation Based On Industrial Use	
<i>Holger Graf, Andre Stork</i>	436
Simulation Study Of 1DOF Hybrid Adaptive Control Applied On Isothermal Continuous Stirred-Tank Reactor	
<i>Jiri Vojtesek, Lubos Spacek, Petr Dostal</i>	446
Teaching Process Modelling And Simulation At Tomas Bata University In Zlin Using MATLAB And Simulink	
<i>Frantisek Gazdos</i>	453
Biometric Identification Of Persons	
<i>Milan Adamek, Petr Neumann, Dora Lapkova, Martin Pospisilik, Miroslav Matysek</i>	460

Simulation and Optimization

Application Of Two Phase Multi-Objective Optimization To Design Of Biosensors Utilizing Cyclic Substrate Conversion

Linus Litvinas, Romas Baronas, Antanas Zilinskas469

Evidence Of The Relevance Of Master Production Scheduling For Hierarchical Production Planning

Thorsten Vitzthum, Frank Herrmann.....475

Influence Of Random Orders On The Bullwhip Effect

Hans-Peter Barbey482

A Discrete Element Model For Agricultural Decision Support

Adam Kovacs, Janos Peter Radics, Gyoergy Kerenyi488

Integrated Optimization Of Transportation And Supply Concepts In The Automotive Industry

Corinna Maas, Andreas Tisch, Carsten Intra, Johannes Fottner495

Modeling And Simulation Of Cooperation And Learning In Cyber Security Defense Teams

Pasquale Legato, Rina Mary Mazza502

Numerical Discrete Element Simulation Of Soil Direct Shear Test

Krisztian Kotrocz, Gyoergy Kerenyi510

Modelling Preference Ties And Equal Treatment Policy

Kolos Cs. Agoston, Peter Biro516

Calibration Of Railway Ballast DEM Model

Akos Orosz, Janos Peter Radics, Kornel Tamas523

Backbone Strategy For Unconstrained Continuous Optimization

Michael Feldmeier, Thomas Husslein529

Generation Algorithms Of Fast Generalized Hough Transform

Egor I. Ershov, Evgeny A. Shvets, Timur M. Khanipov, Dmitry P. Nikolaev534

High Performance Modelling and Simulation

Modelling and Simulation of Data Intensive Systems - Special Session -

Computer Intensive Vs. Heuristic Methods In Automated Design Of Elevator Systems

Leopoldo Annunziata, Marco Menapace, Armando Tacchella.....543

Extension Of Bank Application Scoring Model With Big Data Analysis

Laszlo Madar550

Improving Message Delivery In Vehicular Ad-Hoc Networks

Nnamdi Anyameluhor, Evtim Peytchev, Javad Akhlaghinia.....555

Supporting Pension Pre-Calculation With Dynamic Microsimulation Technologies

David Burka, Laszlo Mohacsi, Jozsef Csicsman, Benjamin Soos.....562

Data Fusion In Cloud Computing: Big Data Approach

Piotr Szuster, Jose M. Molina, Jesus Garcia-Herrero, Joanna Kolodziej.....569

Profiling And Rating Prediction From Multi-Criteria Crowd-Sourced Hotel Ratings

*Fatima Leal, Horacio Gonzalez–Velez, Benedita Malheiro,
Juan Carlos Burguillo.....576*

Security Supportive Energy Aware Scheduling And Scaling For Cloud Environments

Agnieszka Jakobik, Daniel Grzonka, Joanna Kolodziej583

A Low-cost Distributed IoT-based Augmented Reality Interactive Simulator For Team Training

*Pietro Piazzolla, Marco Gribaudo, Simone Colombo, Davide Manca,
Mauro Iacono.....591*

Performance Evaluation Of Massively Distributed Microservices Based Applications

Marco Gribaudo, Mauro Iacono, Daniele Manini.....598

Modeling A Session-Based Bots' Arrival Process At A Web Server

Grazyna Suchacka, Daria Wotzka605

Probability and Statistical Methods for Modelling and Simulation of High Performance Information Systems - Special Session -

Modelling Of The Underwater Targets Tracking With The Aid Of Pseudomeasurements Kalman Filter

Alexander B. Miller, Boris M. Miller615

Approaches To Stochastic Modeling Of Wind Turbines

*Migran N. Gevorkyan, Anastasiya V. Demidova, Ivan S. Zaryadov,
Robert A. Sobolewski, Anna V. Korolkova, Dmitry S. Kulyabov,
Leonid A. Sevastianov*622

Bounds For Markovian Queues With Possible Catastrophes

*Alexander Zeifman, Anna Korotysheva, Yacov Satin, Ksenia Kiseleva,
Victor Korolev, Sergey Shorgin*628

Two-Sided Truncations For The M_t/M_t/S Queueing Model

*Yacov Satin, Anna Korotysheva, Galina Shilova, Alexander Sipin,
Elena Fokicheva, Ksenia Kiseleva, Alexander Zeifman,
Victor Korolev, Sergey Shorgin*635

Generalized Gamma Distributions As Mixed Exponential Laws And Related Limit Theorems

*Victor Korolev, Andrey Gorshenin, Alexander Korchagin,
Alexander Zeifman*642

System Performance Of A Variable-Capacity Batch-Service Queue With Geometric Service Times And Customer-Based Correlation

Jens Baetens, Bart Steyaert, Dieter Claeys, Herwig Bruneel649

Modelling For Ensuring Information Security Of The Distributed Information Systems

Alexander A. Grusho, Elena E. Timonina, Sergey Shorgin656

On Asymptotic Approximations To The Distributions Of Statistics Constructed From Samples With Random Sizes

Vladimir Bening, Victor Korolev, Alexander Zeifman661

Using Inter-Arrival Times For Scheduling In Non-Observable Queues

Mikhail Konovalov, Rostislav Razumchik667

Infinite-Server Queueing Tandem With MMPP Arrivals And Random Capacity Of Customers	
<i>Alexander Moiseev, Svetlana Moiseeva, Ekaterina Lisovskaya</i>	673
Analysis Of Unreliable Multi-Server Queueing System With Breakdowns Spread And Quarantine	
<i>Alexander Dudin, Sergei Dudin, Olga Dudina, Konstantin Samouylov</i>	680
Asymptotic Analysis Of Markovian Retrial Queue With Two-Way Communication Under Low Rate Of Retrials Condition	
<i>Anatoly Nazarov, Svetlana Paul, Irina Gudkova</i>	687
Modelling Of Vertical Handover From Untrusted WLAN Network To LTE	
<i>Alexander Grebeshkov, Elvira Zaripova, Alexander Roslyakov, Konstantin Samouylov</i>	694
Modeling And Simulation Of Reliability Function Of A Homogeneous Hot Double Redundant Repairable System	
<i>Vladimir Rykov, Dmitry Kozyrev, Elvira Zaripova</i>	701
Modelling And Response Time Analysis For Web Browsing Under Interruptions In LTE Network	
<i>Evgeny Mokrov, Eduard Sopin, Ekaterina Markova, Dmitry Poluektov, Irina Gudkova, Pavel Masek, Jiri Hosek</i>	706
On An Exact Solution Of The Rate Matrix Of Quasi-Birth-Death Process With Small Number Of Phases	
<i>Rama Murthy Garimella, Alexander Rumyantsev</i>	713
SIR Distribution In D2D Environment With Non-Stationary Mobility Of Users	
<i>Sergey Fedorov, Yurii Orlov, Andrey Samuylov, Dmitri Moltchanov, Yuliya Gaidamaka, Konstantin Samouylov, Sergey Shorgin.....</i>	720
Time-Dependent SIR Modeling For D2D Communications In Indoor Deployments	
<i>Yurii Orlov, Dmitry Zenyuk, Andrey Samuylov, Dmitri Moltchanov, Sergey Andreev, Oxana Romashkova, Yuliya Gaidamaka, Konstantin Samouylov</i>	726
Author Index	733

APPROACHES TO STOCHASTIC MODELING OF WIND TURBINES

Migran N. Gevorkyan,
Anastasiya V. Demidova
Department of Applied Probability and Informatics,
RUDN University
(Peoples' Friendship University of Russia),
6 Miklukho-Maklaya str., Moscow, 117198, Russia
Email: gevorkyan_mn@rudn.university,
demidova_av@rudn.university

Robert A. Sobolewski
Department of Power Engineering,
Fotonics and Lighting Technology,
Bialystok University of Technology,
45D Wiejska str., 15-351 Bialystok, Poland
Email: r.sobolewski@pb.edu.pl
Dmitry S. Kulyabov
Department of Applied Probability and Informatics,
RUDN University
(Peoples' Friendship University of Russia),
6 Miklukho-Maklaya str., Moscow, 117198, Russia
and Laboratory of Information Technologies
Joint Institute for Nuclear Research
6 Joliot-Curie, Dubna,
Moscow region, 141980, Russia
Email: kulyabov_ds@rudn.university

Ivan S. Zaryadov
Department of Applied Probability and Informatics,
RUDN University
(Peoples' Friendship University of Russia),
6 Miklukho-Maklaya str., Moscow, 117198, Russia
and Institute of Informatics Problems,
FRC CSC RAS, IPI FRC CSC RAS,
44-2 Vavilova str., Moscow, 119333, Russia
Email: zaryadov_is@rudn.university
Anna V. Korolkova
Department of Applied Probability and Informatics,
RUDN University
(Peoples' Friendship University of Russia),
6 Miklukho-Maklaya str., Moscow, 117198, Russia
Email: korolkova_av@rudn.university
Leonid A. Sevastianov
Department of Applied Probability and Informatics,
RUDN University
(Peoples' Friendship University of Russia),
6 Miklukho-Maklaya str., Moscow, 117198, Russia
and Bogoliubov Laboratory of Theoretical Physics
Joint Institute for Nuclear Research
6 Joliot-Curie, Dubna,
Moscow region, 141980, Russia
Email: sevastianov_la@rudn.university

KEYWORDS

Weibull distribution, approximation, lognormal distribution, gamma distribution, beta distribution, wind speed, statistics

ABSTRACT

Background. This paper study statistical data gathered from wind turbines located on the territory of the Republic of Poland. The research is aimed to construct the stochastic model that predicts the change of wind speed with time. **Purpose.** The purpose of this work is to find the optimal distribution for the approximation of available statistical data on wind speed. **Methods.** We consider four distributions of a random variable: Log-Normal, Weibull, Gamma and Beta. In order to evaluate the parameters of distributions we use method of maximum likelihood. To assess the the results of approximation we use a quantile-quantile plot. **Results.** All the considered distributions properly approximate the available data. The Weibull distribution shows the best results for the extreme values of the wind speed. **Conclusions.** The results of the analysis are consistent

with the common practice of using the Weibull distribution for wind speed modeling. In the future we plan to compare the results obtained with a much larger data set as well as to build a stochastic model of the evolution of the wind speed depending on time.

INTRODUCTION

This work is devoted to the problem of stochastic modeling of speed of wind, which is used to generate electrical power in wind plants located on the territory of the Republic of Poland. As a first step several distributions for accuracy of the wind speed approximation will be examined. For this purpose Log-normal, Weibull, Gamma and Beta are chosen. All these distributions have shape-location-scale parametrisation. For statistical data processing the authors used Python 3 with `numpy`, `scipy.stats` (see Jones et al. (2001)) and `matplotlib` (see Droettboom et al. (2017)) libraries and also `Jupyter` (see *Project Jupyter home* (2017))—an interactive shell. We used books (see Norman L. Johnson (1994, 1995); Nelson (1982)) as reference materials for distributions properties. Articles

(see Frchet (1927); Weibull (1951)) are the primary sources in which the Weibull distribution is presented for the first time. Articles (see Lun and Lam (2000); Seguro and Lambert (2000); Bowden et al. (1983); Yeh and Wang (2008); Islam et al. (2011); Garcia et al. (1998)) describe the use of the Weibull distribution in the modeling of wind turbines and wind speed.

THE DESCRIPTION OF THE STATISTICAL DATA STRUCTURE

The set of statistical data is stored in the file `csv` consisting of the following columns:

- 1) T — time of fixation of wind speed and direction by sensors installed on the wind power turbine (hh:mm format);
- 2) X_1 — output power of wind turbine [kW] (the negative values mean the power is consumed rather than generated);
- 3) X_2 — wind speed [m/s] (measured by anemometer installed at the top of wind turbine nacelle);
- 4) X_3 — wind direction [deg] (measured by anemometer installed at the top of wind turbine nacelle; measured clockwise, the value 0 to the N);
- 5) X_4 — wind speed 10 m [m/s] obtained at 10 m above the ground m;
- 6) X_5 — wind direction 10 m [deg] (obtained at 10 m above the ground; measured clockwise, the value from 0 to the N);
- 7) X_6 — wind speed 50 m [m/s] (obtained at 50 m above the ground);
- 8) X_7 — wind direction 50 m [deg] (obtained at 50 m above the ground; measured clockwise, the value from 0 to the N).

The indicators of wind speed and direction were read out from the sensors every 10 minutes for about 9 months. In total, the table contains 39606 entries.

To make an initial choice of distributions that may be suitable for wind speed approximation, the histograms of wind speed are drawn. Visual assessment of these histograms suggest that the adequate choice will be a “heavy-tailed” distribution. But for the wind direction approximation these distributions are not suitable, as can be seen from the figure 1.

To read out the data we used the function `genfromtxt` from `numpy` (see Jones et al. (2001)) lib:

```
ws1, ws2, ws3 =
    np.genfromtxt('data.csv',
        delimiter=';', skip_header=True,
        usecols=(2, 4, 6), unpack=True)
```

where `'data.csv'` is data file, `delimiter=';'` is columns separator, `skip_header = True` specifies ignoring of the first line as the names of the columns, `usecols=(2, 4, 6)` makes function to use only 2, 4, 6 columns (numbering begins with zero) and `unpack=True` — contents of each column should be

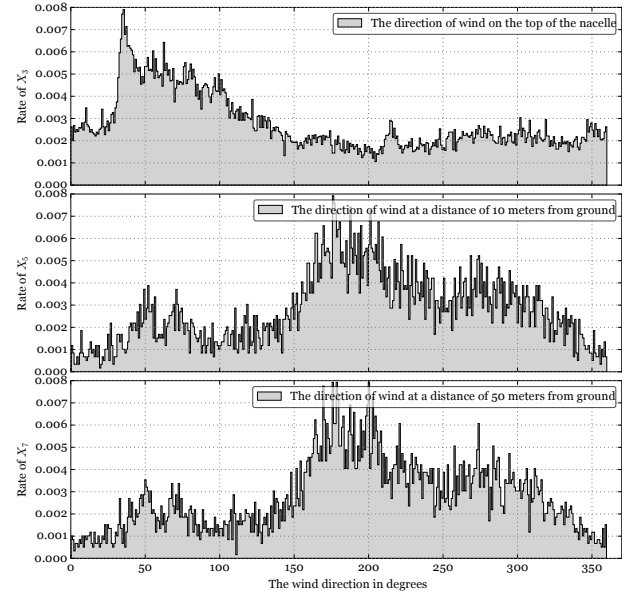


Fig. 1. Histogram of wind direction at three levels of height

written in separate arrays `ws1`, `ws2` and `ws3` for further analysis of the data separately.

PROBABILITY DISTRIBUTIONS

Each of distributions is parameterized by three parameters: α — shape factor, l — location factor and s — scale factor. In the case of the beta distribution the second scale factor is added, denoted by β -letter. All distributions parameters are positive real numbers: $\alpha, \beta, s, l \in \mathbb{R}$, $\alpha, \beta, s > 0$, $l \geq 0$.

The probability density function (PDF) of a Log-Normal random variable X is:

$$f_{LN}(x; \alpha, l, s) = \begin{cases} \frac{1}{(x-l)\alpha\sqrt{2\pi}} \cdot \exp\left(-\frac{1}{2}\left(\frac{\ln(x-l)-\ln s}{\alpha}\right)^2\right), & x \geq l, \\ 0, & x < l. \end{cases}$$

The probability density function of a Weibull (see Frchet (1927); Weibull (1951)) random variable X is:

$$f_W(x; \alpha, l, s) = \begin{cases} \frac{\alpha}{s} \left(\frac{x-l}{s}\right)^{\alpha-1} \exp\left[-\left(\frac{x-l}{s}\right)^\alpha\right], & x \geq l, \\ 0, & x < l. \end{cases}$$

The probability density function of a Gamma random variable X is:

$$f_\Gamma(x; \alpha, l, s) = \begin{cases} \frac{(x-l)^{\alpha-1} \exp\left(-\frac{(x-l)}{s}\right)}{s^\alpha \Gamma(\alpha)}, & x \geq l, \\ 0, & x < l. \end{cases}$$

where $\Gamma(\alpha)$ is gamma-function.

The probability density function of a Beta random variable X is:

$$f_B(x; \alpha, \beta, l, s) = \begin{cases} \frac{\Gamma(\alpha + \beta)}{s\Gamma(\alpha)\Gamma(\beta)} \left(\frac{x-l}{s}\right)^{\alpha-1} \left(1 - \frac{x-l}{s}\right)^{\beta-1}, & x \geq l, \\ 0, & x < l. \end{cases}$$

If in PDF formulas of Log-Normal, Weibull and Gamma distributions let $l = 0$, and for Beta distribution let $s = 1$, we get the formulas of distributions most frequently used in Norman L. Johnson (1994); Nelson (1982).

DETERMINATION OF DISTRIBUTIONS PARAMETERS

In `scipy.stats` (see Jones et al. (2001)) following objects are defined: `lognorm`, `weibull_min`, `gamma` and `beta`. These objects implement distributions we work with. Every one of these objects has PDF function `pdf(x, a, [b,] loc, scale)` and CDF (cumulative distribution) function `cdf(x, a, [b,] loc, scale)`, where x — function argument, a, b — shape parameters α , (and β for Beta-distribution), `loc` and `scale` are location and scale parameters.

For parameters estimation of our distributions the library `scipy.stats` provides the function `fit(data)`, which calculates the parameters of distributions by maximum likelihood method and the empirical data. We used this function to calculate parameters of the considered distributions. Then we used `pdf` and `cdf` functions to compute values of the probability density function and cumulative distribution function.

There is the example of the code for the case of Log-Normal distribution:

```
s, loc, scale =
    scipy.stats.lognorm.fit(ws1)
xs = np.linspace(np.min(ws1),
    np.max(ws1), 1000)
logN_PDF =
    scipy.stats.lognorm.pdf(xs, s,
        loc, scale)
logN_CDF =
    scipy.stats.lognorm.cdf(xs, s,
        loc, scale)
```

The results are presented graphically on figures 2–9.

The figures were plotted for theoretical distributions, the parameters of which have been determined on the basis of the entire dataset. From the analysis of the quantile-quantile plots (Q-Q plots) we can conclude that the Weibull distribution is best suited for approximation of available data (although only slightly), outmatching them only in the approximation of extreme values of a random variable.

We also performed computations with the considered distributions parameterized by only two parameters

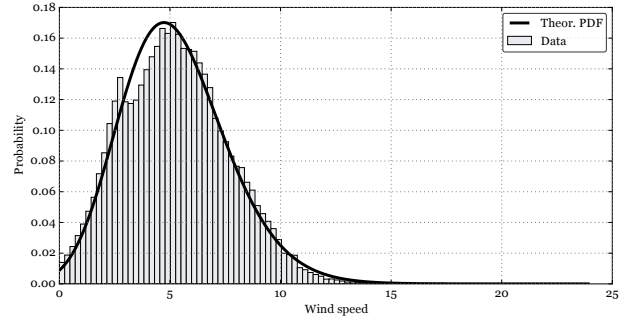


Fig. 2. PDF of **Log-Normal** distribution compared with data histogram

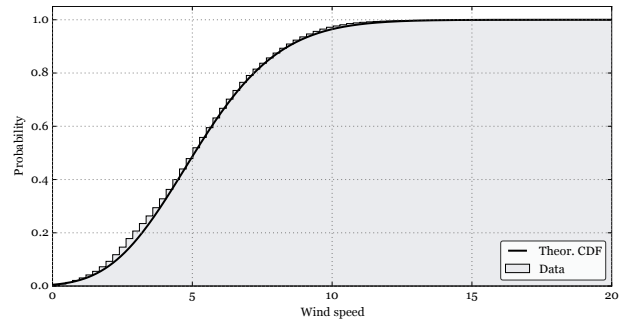


Fig. 3. CDF of **Log-Normal** distribution compared with empirical distribution function

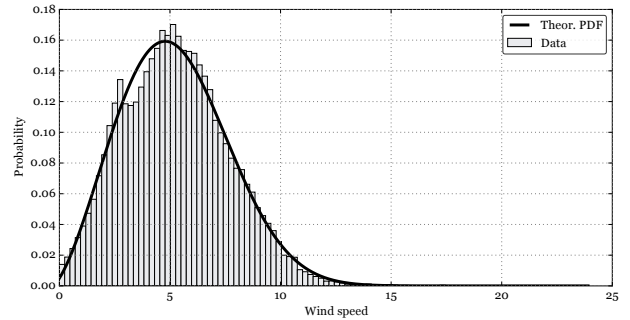


Fig. 4. PDF of **Weibull** distribution compared with data histogram

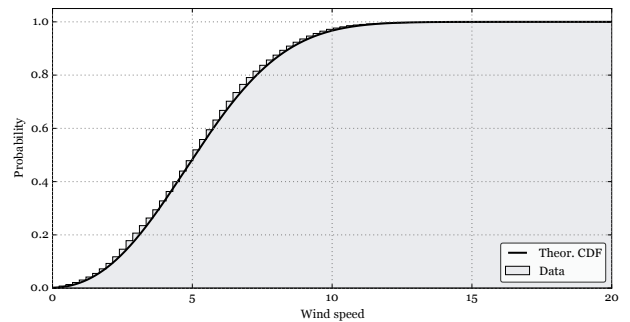


Fig. 5. CDF of **Weibull** distribution compared with empirical distribution function

(let $l = 0$, and for Beta distribution an addition let $s = 1$). After plotting the results of calculations we found out that the two-parameter Weibull distribution has superiority over other two-parameters distributions (Log-Normal, Gamma and Beta), which is not true for

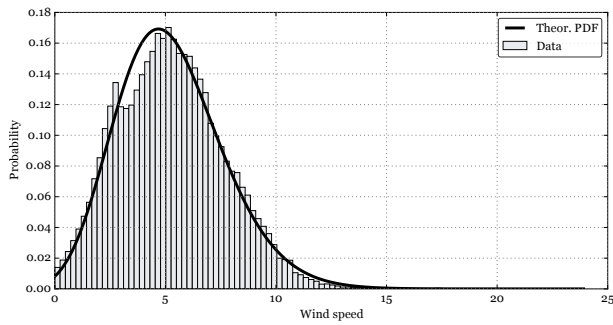


Fig. 6. PDF of **Gamma** distribution compared with data histogram

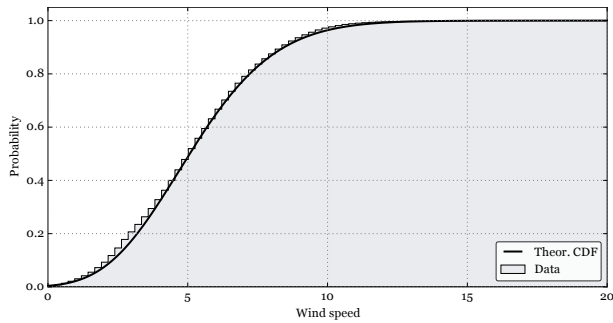


Fig. 7. CDF of **Gamma** distribution compared with empirical distribution function

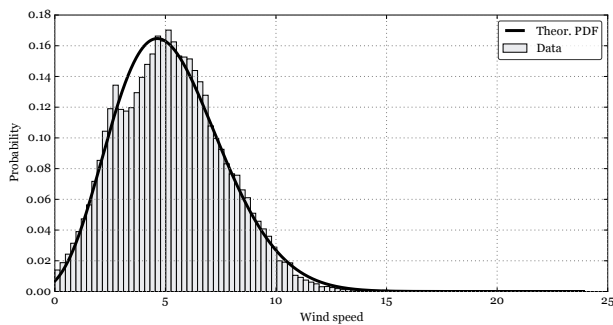


Fig. 8. PDF of **Beta** distribution compared with data histograms

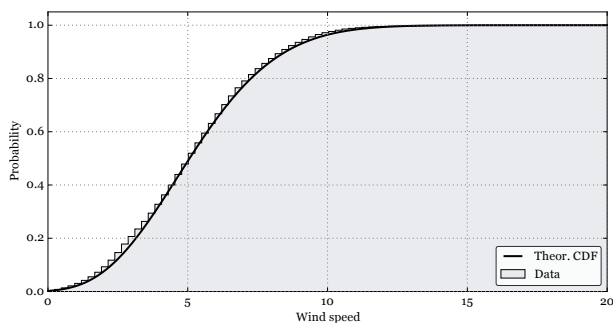


Fig. 9. CDF of **Beta** distribution compared with empirical distribution function

three-parameter case (Fig. 10–13).

CONCLUSIONS

The results of statistical data processing correspond to the results presented in the literature, where Weibull distribution is the most often used distribution for the

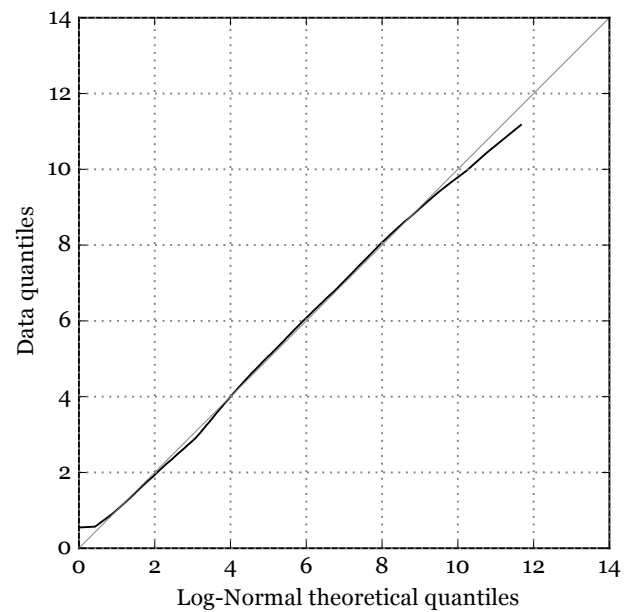


Fig. 10. Q-Q plot for LogNormal distribution

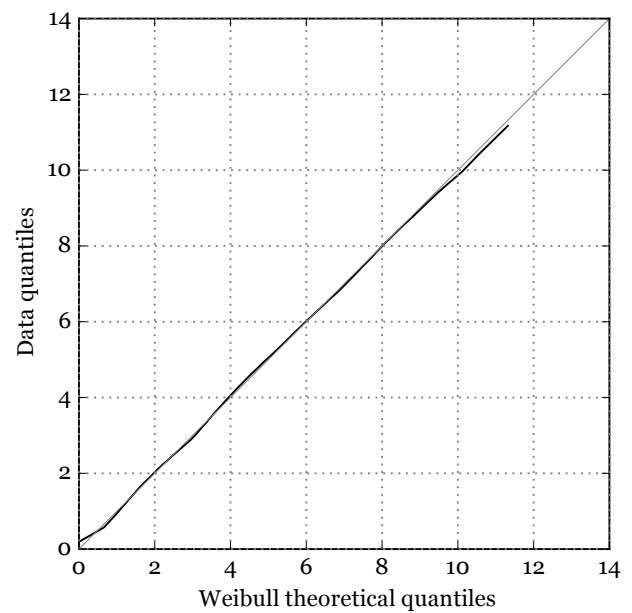


Fig. 11. Q-Q plot for Weibull distribution

wind speed approximation (see Lun and Lam (2000); Seguro and Lambert (2000); Bowden et al. (1983); Yeh and Wang (2008); Islam et al. (2011); Garcia et al. (1998)).

Our future work will be aimed at the construction of stochastic models that can approximate the wind speed depending on time (see Miano and Milano (2015)). On the other hand, we expect to verify the results of this work by using more dilated and large data array.

ACKNOWLEDGMENT

The work is partially supported by RFBR grants No's 15-07-08795 and 16-07-00556. Also the publication was supported by the Ministry of Education

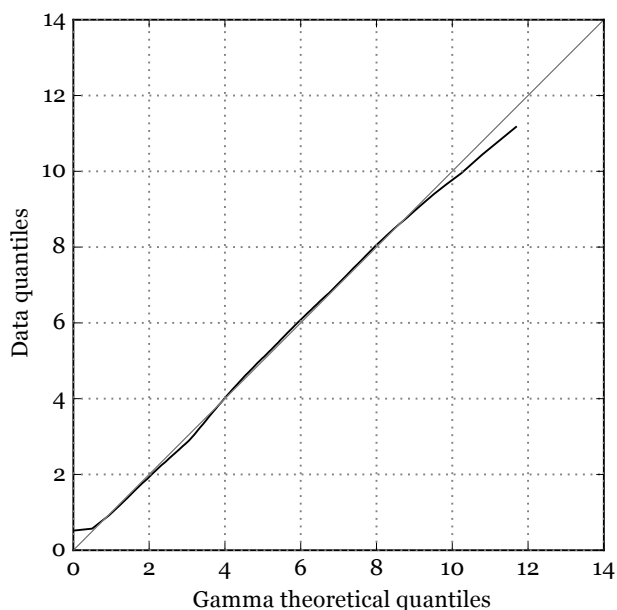


Fig. 12. Q-Q plot for Gamma distribution

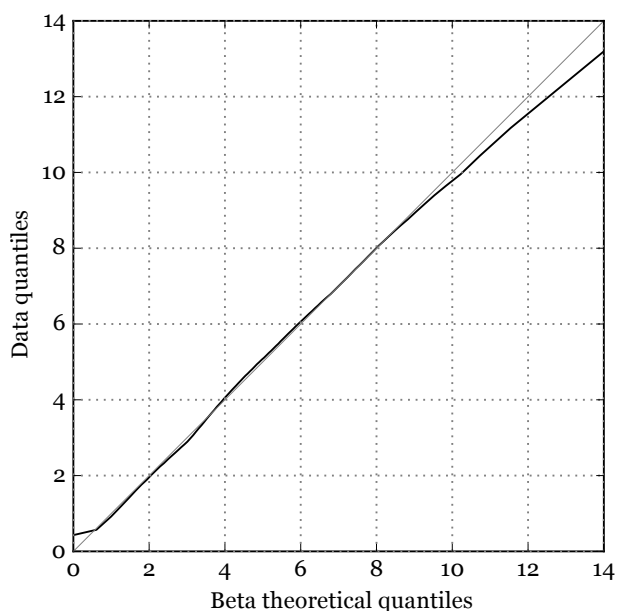


Fig. 13. Q-Q plot for Beta distribution

and Science of the Russian Federation (the Agreement No 02.a03.21.0008). The computations were carried out on the Felix computational cluster (RUDN University, Moscow, Russia) and on the HybriLIT heterogeneous cluster (Multifunctional center for data storage, processing, and analysis at the Joint Institute for Nuclear Research, Dubna, Russia).

REFERENCES

Bowden, G. J., Barker, P. R., Shestopal, V. O. and Twidell, J. W. (1983), The weibull distribution function and wind power statistics, *Wind Engineering* 7, 85–98. Provided by the SAO/NASA Astrophysics Data System.

- Droettboom, M., Caswell, T. A., Hunter, J., Firing, E., Nielsen, J. H., Root, B., Elson, P., Dale, D., Lee, J.-J., Varoquaux, N., Seppnen, J. K., McDougall, D., May, R., Straw, A., de Andrade, E. S., Lee, A., Yu, T. S., Ma, E., Gohlke, C., Silvester, S., Moad, C., Hobson, P., Schulz, J., Wrtz, P., Ariza, F., Cimarron, Hisch, T., Kniazev, N., Vincent, A. F. and Thomas, I. (2017), matplotlib/matplotlib: v2.0.0. <https://doi.org/10.5281/zenodo.248351>
- Frchet, M. R. (1927), Sur la loi de probabilit de l'cart maximum, *Annales de la Socit Polonaise de Mathematique* pp. 93–116.
- Garcia, A., Torres, J., Prieto, E. and de Francisco, A. (1998), Fitting wind speed distributions: a case study, *Solar Energy* 62(2), 139–144.
- Islam, M., Saidur, R. and Rahim, N. (2011), Assessment of wind energy potentiality at kudat and labuan, malaysia using weibull distribution function, *Energy* 36(2), 985–992.
- Jones, E., Oliphant, T., Peterson, P. et al. (2001), SciPy: Open source scientific tools for Python. [Online; accessed 19.01.2017]. <http://www.scipy.org/>
- Lun, I. Y. and Lam, J. C. (2000), A study of weibull parameters using long-term wind observations, *Renewable Energy* 20(2), 145–153.
- Miano, R. Z. and Milano, F. (2015), Construction of sde-based wind speed models with exponential autocorrelation.
- Nelson, W. B. (1982), *Applied Life Data Analysis* (Wiley Series in Probability and Statistics).
- Norman L. Johnson, Samuel Kotz, N. B. (1994), *Continuous Univariate Distributions*, Vol. 1 of Wiley Series in Probability and Statistics, Wiley-Interscience.
- Norman L. Johnson, Samuel Kotz, N. B. (1995), *Continuous Univariate Distributions*, Vol. 2, Vol. 2 of Wiley Series in Probability and Statistics, Wiley-Interscience.
- Project Jupyter home (2017). [Online; accessed 19.01.2017]. <https://jupyter.org>
- Seguro, J. and Lambert, T. (2000), Modern estimation of the parameters of the weibull wind speed distribution for wind energy analysis, *Journal of Wind Engineering and Industrial Aerodynamics* 85(1), 75–84.
- Weibull, W. (1951), A statistical distribution function of wide applicability, *Journal of Applied Mechanics* pp. 293–297.
- Yeh, T. H. and Wang, L. (2008), A study on generator capacity for wind turbines under various tower heights and rated wind speeds using weibull distribution, *IEEE Transactions on Energy Conversion* 23(2), 592–602.

AUTHOR BIOGRAPHIES

MIGRAN N. GEVORKYAN received his Ph.D. in Mathematics in 2013. Since then, he has worked as associate professor in RUDN University (Peoples' Friendship University of Russia). His current research activity

focuses on mathematical modeling. His email address is gevorkyan_mn@rudn.university.

ANASTASIYA V. DEMIDOVA received her Ph.D. in Mathematics in 2014. Since then, she has worked as associate professor in RUDN University (Peoples' Friendship University of Russia). Her email address is demidova_av@rudn.university.

IVAN S. ZARYADOV received his Ph.D. in Mathematics in 2010. Since then, he has worked as associate professor in RUDN University (Peoples' Friendship University of Russia). His current research activity focuses on probability theory. His email address is zaryadov_is@rudn.university.

ROBERT A. SOBOLEWSKI He has worked in Department of Power Engineering, Photonics and Lighting Technology in Bialystok University of Technology. His email address is r.sobolewski@pb.edu.pl.

ANNA V. KOROLKOVA received her Ph.D. in Mathematics in 2010. Since then, she has worked as associate professor in RUDN University (Peoples' Friendship University of Russia). Her current research activity focuses on mathematical modeling. Her email address is korolkova_av@rudn.university.

DMITRY S. KULYABOV received his Ph.D. in Physics in 2000. Since then, he has worked as associate professor in RUDN University (Peoples' Friendship University of Russia). His current research activity focuses on mathematical modeling. His email address is kulyabov_ds@rudn.university.

LEONID A. SEVASTIANOV received his D.Sc. in Phys.-Math. in 1999. Since then, he has worked as full professor in RUDN University (Peoples' Friendship University of Russia). His current research activity focuses on mathematical modeling. His email address is sevastianov_la@rudn.university.