

Wojciech Zamojski  
Jacek Mazurkiewicz  
Jarosław Sugier  
Tomasz Walkowiak  
Janusz Kacprzyk *Editors*

# Advances in Dependability Engineering of Complex Systems

Proceedings of the Twelfth  
International Conference on  
Dependability and Complex Systems  
DepCoS-RELCOMEX, July 2–6, 2017,  
Brunów, Poland

# **Advances in Intelligent Systems and Computing**

Volume 582

## **Series editor**

Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland  
e-mail: [kacprzyk@ibspan.waw.pl](mailto:kacprzyk@ibspan.waw.pl)

### *About this Series*

The series “Advances in Intelligent Systems and Computing” contains publications on theory, applications, and design methods of Intelligent Systems and Intelligent Computing. Virtually all disciplines such as engineering, natural sciences, computer and information science, ICT, economics, business, e-commerce, environment, healthcare, life science are covered. The list of topics spans all the areas of modern intelligent systems and computing.

The publications within “Advances in Intelligent Systems and Computing” are primarily textbooks and proceedings of important conferences, symposia and congresses. They cover significant recent developments in the field, both of a foundational and applicable character. An important characteristic feature of the series is the short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

### *Advisory Board*

#### Chairman

Nikhil R. Pal, Indian Statistical Institute, Kolkata, India  
e-mail: [nikhil@isical.ac.in](mailto:nikhil@isical.ac.in)

#### Members

Rafael Bello Perez, Universidad Central “Marta Abreu” de Las Villas, Santa Clara, Cuba  
e-mail: [rbellop@uclv.edu.cu](mailto:rbellop@uclv.edu.cu)

Emilio S. Corchado, University of Salamanca, Salamanca, Spain  
e-mail: [escorchado@usal.es](mailto:escorchado@usal.es)

Hani Hagras, University of Essex, Colchester, UK  
e-mail: [hani@essex.ac.uk](mailto:hani@essex.ac.uk)

László T. Kóczy, Széchenyi István University, Győr, Hungary  
e-mail: [koczy@sze.hu](mailto:koczy@sze.hu)

Vladik Kreinovich, University of Texas at El Paso, El Paso, USA  
e-mail: [vladik@utep.edu](mailto:vladik@utep.edu)

Chin-Teng Lin, National Chiao Tung University, Hsinchu, Taiwan  
e-mail: [ctlin@mail.nctu.edu.tw](mailto:ctlin@mail.nctu.edu.tw)

Jie Lu, University of Technology, Sydney, Australia  
e-mail: [Jie.Lu@uts.edu.au](mailto:Jie.Lu@uts.edu.au)

Patricia Melin, Tijuana Institute of Technology, Tijuana, Mexico  
e-mail: [epmelin@hafsamx.org](mailto:epmelin@hafsamx.org)

Nadia Nedjah, State University of Rio de Janeiro, Rio de Janeiro, Brazil  
e-mail: [nadia@eng.uerj.br](mailto:nadia@eng.uerj.br)

Ngoc Thanh Nguyen, Wroclaw University of Technology, Wroclaw, Poland  
e-mail: [Ngoc-Thanh.Nguyen@pwr.edu.pl](mailto:Ngoc-Thanh.Nguyen@pwr.edu.pl)

Jun Wang, The Chinese University of Hong Kong, Shatin, Hong Kong  
e-mail: [jwang@mae.cuhk.edu.hk](mailto:jwang@mae.cuhk.edu.hk)

More information about this series at <http://www.springer.com/series/11156>

Wojciech Zamojski · Jacek Mazurkiewicz  
Jarosław Sugier · Tomasz Walkowiak  
Janusz Kacprzyk  
Editors

# Advances in Dependability Engineering of Complex Systems

Proceedings of the Twelfth International  
Conference on Dependability and Complex  
Systems DepCoS-RELCOMEX,  
July 2–6, 2017, Brunów, Poland

### *Editors*

Wojciech Zamojski  
Department of Computer Engineering  
Wrocław University of Science  
and Technology  
Wrocław  
Poland

Tomasz Walkowiak  
Department of Computer Engineering  
Wrocław University of Science  
and Technology  
Wrocław  
Poland

Jacek Mazurkiewicz  
Department of Computer Engineering  
Wrocław University of Science  
and Technology  
Wrocław  
Poland

Janusz Kacprzyk  
Systems Research Institute  
Polish Academy of Sciences  
Warsaw  
Poland

Jarosław Sugier  
Department of Computer Engineering  
Wrocław University of Science  
and Technology  
Wrocław  
Poland

ISSN 2194-5357

ISSN 2194-5365 (electronic)

Advances in Intelligent Systems and Computing

ISBN 978-3-319-59414-9

ISBN 978-3-319-59415-6 (eBook)

DOI 10.1007/978-3-319-59415-6

Library of Congress Control Number: 2017940846

© Springer International Publishing AG 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature

The registered company is Springer International Publishing AG

The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Preface

This volume presents proceedings of the Twelfth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX which took place in the Brunów Palace in Poland from 2nd to 6th July 2017.

The volume appears in the series “Advances in Intelligent Systems and Computing” (AISC) published by Springer Nature, one of the largest and most prestigious scientific publishers, in the series which is one of the fastest growing book series in their programme. The AISC is meant to include various high-quality and timely publications, primarily conference proceedings of relevant conference, congresses and symposia but also monographs, on the theory, applications and implementations of broadly perceived modern intelligent systems and intelligent computing, in their modern understanding, i.e. including tools and techniques of artificial intelligence (AI), computational intelligence (CI)—which includes neural networks, fuzzy systems, evolutionary computing, as well as hybrid approaches that synergistically combine these areas—but also topics such as multiagent systems, social intelligence, ambient intelligence, Web intelligence, computational neuroscience, artificial life, virtual worlds and societies, cognitive science and systems, perception and vision, DNA and immune-based systems, self-organizing and adaptive systems, e-learning and teaching, human-centred and human-centric computing, autonomous robotics, knowledge-based paradigms, learning paradigms, machine ethics, intelligent data analysis, various issues related to “big data”, security and trust management, to just mention a few. These areas are at the forefront of science and technology, and have been found useful and powerful in a wide variety of disciplines such as engineering, natural sciences, computer, computation and information sciences, ICT, economics, business, e-commerce, environment, health care, life science and social sciences. The AISC book series is submitted for indexing in ISI Conference Proceedings Citation Index (now run by Clarivate), EI Compendex, DBLP, SCOPUS, Google Scholar and SpringerLink, and many other indexing services around the world.

DepCoS-RELCOMEX is an annual conference series organized since 2006 at the Faculty of Electronics, Wrocław University of Science and Technology, formerly by Institute of Computer Engineering, Control and Robotics (CECR) and

now by Department of Computer Engineering. Its idea came from the heritage of the other two cycles of events: RELCOMEX (1977–89) and Microcomputer School (1985–95) which were organized by the Institute of Engineering Cybernetics (the previous name of CECR) under the leadership of Prof. Wojciech Zamojski, still the DepCoS chairman, so this year we can celebrate the 40th anniversary of its origins. In this volume of “Advances in Intelligent Systems and Computing”, we would like to present results of studies on selected problems of complex systems and their dependability. Effects of the previous DepCoS events were published (in chronological order) by IEEE Computer Society (2006–09), by Wrocław University of Technology Publishing House (2010–12) and presently by Springer in “Advances in Intelligent Systems and Computing” volumes no. 97 (2011), 170 (2012), 224 (2013), 286 (2014), 365 (2015) and 479 (2016).

Dependability is the contemporary answer to new challenges in reliability evaluation of complex systems. Dependability approach in theory and engineering of complex systems (not only computer systems and networks) is based on multidisciplinary attitude to system theory, technology and maintenance of the systems working in real (and very often unfriendly) environments. Dependability concentrates on efficient realization of tasks, services and jobs by a system considered as a unity of technical, information and human assets, in contrast to “classical” reliability which is more restrained to analysis of technical resources (components and structures built from them). Such a transformation has shaped natural evolution in topical range of subsequent DepCoS conferences which can be seen over the recent years. This edition additionally hosted the 7th CrISS-DESSERT Workshop devoted particularly to the challenges and solutions in analysis and assurance of critical infrastructure and computer (software and programmable logic-based) system safety and cybersecurity.

The Programme Committee of the 12th International DepCoS-RELCOMEX Conference, its organizers and the editors of these proceedings would like to gratefully acknowledge participation of all reviewers who helped to refine contents of this volume and evaluated conference submissions. Our thanks go to, in alphabetic order, Andrzej Białas, Ilona Bluemke, Eugene Brezhniev, Dariusz Caban, Frank Coolen, Manuel Gil Perez, Zbigniew Huzar, Igor Kabashkin, Vyacheslav Kharchenko, Leszek Kotulski, Alexey Lastovetsky, Jan Magott, István Majzik, Jacek Mazurkiewicz, Marek Młyńczak, Yiannis Papadopoulos, Oksana Pomorova, Krzysztof Sacha, Rafał Scherer, Mirosław Siergiejczyk, Janusz Sosnowski, Jarosław Sugier, Victor Toporkov, Tomasz Walkowiak, Irina Yatskiv, Wojciech Zamojski and Włodzimierz Zuberek.

Thanking all the authors who have chosen DepCoS as the publication platform for their research, we would like to express our hope that their papers will help in further developments in design and analysis of engineering aspects of complex systems, being a valuable source material for scientists, researchers, practitioners and students who work in these areas.

The Editors

# **Twelfth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX**

organized by  
Department of Computer Engineering,  
Wrocław University of Science and Technology  
Brunów Palace, Poland, 2–6 July 2017

## **Programme Committee**

Wojciech Zamojski (Chairman)	Wrocław University of Science and Technology, Poland
Ali Al-Dahoud	Al-Zaytoonah University, Amman, Jordan
George Anders	University of Toronto, Canada
Włodzimierz M. Barański	Wrocław University of Science and Technology, Poland
Andrzej Białas	Institute of Innovative Technologies EMAG, Katowice, Poland
Ilona Bluemke	Warsaw University of Technology, Poland
Eugene Brezhniev	National Aerospace University “KhAI”, Kharkiv, Ukraine
Dariusz Caban	Wrocław University of Science and Technology, Poland
Krzysztof Cios	Virginia Commonwealth University, Richmond, USA
Frank Coolen	Durham University, UK
Mieczysław Drabowski	Cracow University of Technology, Poland
Francesco Flammini	University of Naples “Federico II”, Napoli, Italy
Manuel Gill Perez	University of Murcia, Spain



Zbigniew Huzar	Wrocław University of Science and Technology, Poland
Igor Kabashkin	Transport and Telecommunication Institute, Riga, Latvia
Janusz Kacprzyk	Polish Academy of Sciences, Warsaw, Poland
Vyacheslav S. Kharchenko	National Aerospace University “KhAI”, Kharkiv, Ukraine
Mieczysław M. Kokar	Northeastern University, Boston, USA
Krzysztof Kołowrocki	Gdynia Maritime University, Poland
Leszek Kotulski	AGH University of Science and Technology, Krakow, Poland
Henryk Krawczyk	Gdansk University of Technology, Poland
Alexey Lastovetsky	University College Dublin, Ireland
Marek Litwin	ITS Polska, Warsaw, Poland
Jan Magott	Wrocław University of Science and Technology, Poland
Istvan Majzik	Budapest University of Technology and Economics, Hungary
Jacek Mazurkiewicz	Wrocław University of Science and Technology, Poland
Marek Młyńczak	Wrocław University of Science and Technology, Poland
Yiannis Papadopoulos	Hull University, UK
Oksana Pomorova	Khmeltsky National University, Ukraine
Ewaryst Rafajłowicz	Wrocław University of Science and Technology, Poland
Krzysztof Sacha	Warsaw University of Technology, Poland
Rafał Scherer	Częstochowa University of Technology, Poland
Mirosław Siergiejczyk	Warsaw University of Technology, Poland
Czesław Smutnicki	Wrocław University of Science and Technology, Poland
Janusz Sosnowski	Warsaw University of Technology, Poland
Jarosław Sugier	Wrocław University of Science and Technology, Poland
Victor Toporkov	Moscow Power Engineering Institute (Technical University), Russia
Tomasz Walkowiak	Wrocław University of Science and Technology, Poland
Max Walter	Siemens, Germany
Bernd E. Wolfinger	University of Hamburg, Germany
Leonid G. Voskressensky	Peoples' Friendship University, Moscow, Russia

Min Xie	City University of Hong Kong, Hong Kong SAR, China
Irina Yatskiv	Transport and Telecommunication Institute, Riga, Latvia
Włodzimierz Zuberek	Memorial University, St.John's, Canada

## **Organizing Committee**

### **Honorary Chairman**

Wojciech Zamojski

### **Members**

Włodzimierz M. Barański  
Jacek Mazurkiewicz  
Jarosław Sugier  
Tomasz Walkowiak

## **Seventh CrISS-DESSERT Workshop**

Critical Infrastructure Security and Safety (CrISS) -  
Dependable Systems, Services & Technologies (DESSERT)

The CrISS-DESSERT Workshop evolved from the conference *Dependable Systems, Services & Technologies* DESSERT 2006–2016 ([www.dessertcon.com](http://www.dessertcon.com)). The 6th CrISS-DESSERT took place in Chernivtsi, Ukraine, 21–22 May 2016. In 2017, the 7th CrISS-DESSERT Workshop was held in the frameworks of the 12th Conference on Dependability and Complex Systems DepCoS-RELCOMEX.

The mission of the Workshop was to discuss challenges and solutions related to analysis and assurance of critical infrastructure and computer (software and programmable logic-based) system safety and cybersecurity. In particular, its focus was chosen in order to address:

- interplay and interdependencies of system of systems (telecommunication, smart grid, intelligent transportation system, etc.) and the current problems in providing its safety, security, reliability, quality of services, etc.;
- roles played by IT (SW, HW, FPGA)-based systems as the mandatory part of each infrastructure, thus turning distinct infrastructures into a complex cyber-physical system (system of systems) with emergent and cooperative behaviour, uncertainties, etc.;
- resource-effective IT-based approaches to safe and sustainable development.

The CrISS Workshop examined modelling, development, integration, verification, diagnostics and maintenance of computer and communications systems and infrastructures for safety-, mission- and business-critical applications.

### **Main Topics**

The main topics on the workshop agenda included the following:

- Formal methods for critical IT infrastructures and systems development and verification
- Vulnerability analysis and intrusion-tolerant systems
- Evolving infrastructures and self-systems

- Dependability and resilience of Web-, cloud- and IoT-based IT infrastructures
- Safety of human-machine interfaces and systems including cooperative HMI&S
- Functional/system safety perspective of intelligent transport systems (ITS)
- Information & data modelling in ITS context
- IT infrastructures for pre- and post-accident monitoring of critical objects
- Safety- and assurance-case methodologies, techniques and tools
- Smart grid safety, reliability and security
- Power saving in IT infrastructures, data centres and computing clusters

## **Workshop Panel Discussion**

Infrastructure and industrial systems safety and security: challenges, monitoring and assurance case-based solutions.

## **Workshop Chair**

Vyacheslav Kharchenko	National Aerospace University KhAI, Centre for Safety Infrastructure Oriented Research and Analysis, Ukraine
-----------------------	--

## **Co-chairs**

Todor Tagarev	Institute of Information and Communication Technologies, Bulgaria (TBC)
Nikos Bardis	Hellenic Military Academy, Greece

## **Industry Partner**

RPC Radiy, Ukraine

# Contents

<b>Detection of Network Attacks Using Hybrid ARIMA-GARCH Model</b> .....	1
Tomasz Andrysiak, Łukasz Saganowski, Mirosław Maszewski, and Adam Marchewka	
<b>Towards Mixed-Mode Risk Management – A Concept</b> .....	13
Andrzej Bialas and Barbara Flisiuk	
<b>Software Support of the Common Criteria Vulnerability Assessment</b> .....	26
Andrzej Bialas	
<b>On the Performance of Some C# Constructions</b> .....	39
Ilona Bluemke, Piotr Gawkowski, Waldemar Grabski, and Konrad Grochowski	
<b>Deep Stacking Convex Neuro-Fuzzy System and Its On-line Learning</b> .....	49
Yevgeniy Bodyanskiy, Olena Vynokurova, Iryna Pliss, Dmytro Peleshko, and Yuriy Rashkevych	
<b>Fault Tolerant ASIC/ULA-Based Computing Systems Testing via FPGA Prototyping with Fault Injection</b> .....	60
Oleg Brekhov and Alexander Klimenko	
<b>Critical Energy Infrastructure Safety Assurance Strategies Considering Emergent Interaction Risk</b> .....	67
Eugene Brezhnev, Vyacheslav Kharchenko, Viacheslav Manulik, and Konstantin Leontiev	
<b>Modelling an Optimal Capital Structure of the Telecommunication Company</b> .....	79
Alexandr Y. Bystryakov, Tatiana K. Blokhina, Elena V. Savenkova, Oksana A. Karpenko, and Elena V. Ponomarenko	

<b>Specification of Constraints in a System-of-Systems Configuration . . . .</b>	<b>89</b>
Dariusz Caban and Tomasz Walkowiak	
<b>A Methodological Framework for Model-Based Self-management of Services and Components in Dependable Cyber-Physical Systems . . . .</b>	<b>97</b>
DeJiu Chen and Zhonghai Lu	
<b>Maintenance of Wind Turbine Scheduling Based on Output Power Data and Wind Forecast. . . . .</b>	<b>106</b>
Guglielmo D'Amico, Filippo Petroni, and Robert Adam Sobolewski	
<b>Deadlock Detection in Distributed Systems Using the IMDS Formalism and Petri Nets. . . . .</b>	<b>118</b>
Wiktor B. Daszczuk and Wlodek M. Zuberek	
<b>Scheduling Tasks in Embedded Systems Based on NoC Architecture Using Simulated Annealing . . . . .</b>	<b>131</b>
Dariusz Dorota	
<b>Adaptation of Ant Colony Algorithm for CAD of Complex Systems with Higher Degree of Dependability. . . . .</b>	<b>141</b>
Mieczyslaw Drabowski	
<b>Context-Aware Anomaly Detection in Embedded Systems . . . . .</b>	<b>151</b>
Fatemeh Ehsani-Besheli and Hamid R. Zarandi	
<b>Comparative Analysis of Calculations in Cryptographic Protocols Using a Combination of Different Bases of Finite Fields . . . . .</b>	<b>166</b>
Sergey Gashkov and Alexander Frolov	
<b>Dynamic Redundancy in Communication Network of Air Traffic Management System. . . . .</b>	<b>178</b>
Igor Kabashkin	
<b>Availability Models and Maintenance Strategies for Smart Building Automation Systems Considering Attacks on Component Vulnerabilities . . . . .</b>	<b>186</b>
Vyacheslav Kharchenko, Yuriy Ponochovnyi, Al-Sudani Mustafa Qahtan Abdulmunem, and Anton Andrashov	
<b>Concept of Multi-criteria Evaluation of the Airport Security Control Process. . . . .</b>	<b>196</b>
Artur Kierzkowski and Tomasz Kisiel	
<b>Extending Continuous Integration with Post-mortem Debug Automation of Unhandled Exceptions Occurred in Kernel or User Mode Applications . . . . .</b>	<b>205</b>
Henryk Krawczyk and Dawid Zima	

<b>The Methodology of Studying of Active Traffic Management Module Self-oscillation Regime</b> . . . . .	215
Dmitry S. Kulyabov, Anna V. Korolkova, Tatyana R. Velieva, Ekaterina G. Eferina, and Leonid A. Sevastianov	
<b>Effectiveness Examination of a Multi-channel CSMA/CA Detector</b> . . . .	225
Dariusz Laskowski, Marcin Pólkowski, Piotr Łubkowski, and Leszek Nowosielski	
<b>IaaS vs. Traditional Hosting for Web Applications - Cost Effectiveness Analysis for a Local Market</b> . . . . .	233
Paweł Lorenc and Marek Woda	
<b>High Quality Stabilization of an Inverted Pendulum Using the Controller Based on Trigonometric Function</b> . . . . .	244
Michał Lower	
<b>The Application of RFID Technology in Supporting the Process of Reliable Identification of Objects in Video Surveillance Systems</b> . . . . .	254
Piotr Lubkowski, Dariusz Laskowski, and Marcin Polkowski	
<b>Aspect-Oriented Management of Service Requests for Assurance of High Performance and Dependability</b> . . . . .	264
Paweł Lubomski, Paweł Pszczoliński, and Henryk Krawczyk	
<b>Process of Mobile Application Development from the Security Perspective</b> . . . . .	277
Aneta Majchrzycka and Aneta Poniszewska-Maranda	
<b>Managing and Enhancing Performance Benchmarks</b> . . . . .	287
Jakub Maleszewski and Janusz Sosnowski	
<b>Reliability Optimization for Controller Placement in Software-Defined Networks</b> . . . . .	298
Jerzy Martyna	
<b>Agent Approach to Network Systems Experimental Analysis in Case of Critical Situations</b> . . . . .	308
Jacek Mazurkiewicz	
<b>Reliability Assessment of Driving Systems of City Buses</b> . . . . .	320
Marek Młyńczak, Murat Muzdybayev, Alfiya Muzdybayeva, and Dinara Myrzabekova	
<b>Testing the Significance of Parameters of Models Estimating Execution Time of Parallel Program Loops According to the Open MPI Standard</b> . . . . .	331
Łukasz Nozdrzykowski and Magdalena Nozdrzykowska	

<b>On Application of Regime-Switching Models for Short-Term Traffic Flow Forecasting</b> . . . . .	340
Dmitry Pavlyuk	
<b>Critical Information Infrastructure Protection Model and Methodology, Based on National and NATO Study</b> . . . . .	350
Lachezar Petrov, Nikolai Stoianov, and Todor Tagarev	
<b>The Method of Creating Players in the Marketing Strategy</b> . . . . .	358
Henryk Piech, Aleksandra Ptak, and Michal Saczek	
<b>Principles of Mobile Walking Robot Control in Scope of Technical Monitoring Tasks</b> . . . . .	368
Oleksandr Radomskyi	
<b>Computer Systems – Simple, Complicated or Complex</b> . . . . .	383
Dominik Strzałka	
<b>Improving FPGA Implementations of BLAKE and BLAKE2 Algorithms with Memory Resources</b> . . . . .	394
Jarosław Sugier	
<b>Assurance Case Patterns On-line Catalogue</b> . . . . .	407
Monika Szczygielska and Aleksander Jarzębowicz	
<b>Information System as a Cause of Cargo Handling Process Disruption in Intermodal Terminal</b> . . . . .	418
Justyna Świeboda and Mateusz Zajac	
<b>Anticipation Scheduling in Grid Virtual Organizations</b> . . . . .	428
Victor Toporkov, Dmitry Yemelyanov, Vadim Loginov, and Petr Potekhin	
<b>Stability Enhancement Against Fluctuations in Complex Networks by Optimal Bandwidth Allocation</b> . . . . .	439
K.Y. Henry Tsang and K.Y. Michael Wong	
<b>The Scope of the Collected Data for a Holistic Risk Assessment Performance in the Road Freight Transport Companies</b> . . . . .	450
Agnieszka Tubis and Sylwia Werbińska-Wojciechowska	
<b>Language Processing Modelling Notation – Orchestration of NLP Microservices</b> . . . . .	464
Tomasz Walkowiak	
<b>Type Variety Principle and the Algorithm of Strategic Planning of Diversified Portfolio of Electricity Generation Sources</b> . . . . .	474
Volodymyr Zaslavskyi and Maya Pasichna	
<b>Author Index</b> . . . . .	487



# Availability Models and Maintenance Strategies for Smart Building Automation Systems Considering Attacks on Component Vulnerabilities

Vyacheslav Kharchenko<sup>1,2</sup>, Yuriy Ponochovnyi<sup>3(✉)</sup>,  
Al-Sudani Mustafa Qahtan Abdulmunem<sup>1</sup>, and Anton Andrashov<sup>2</sup>

<sup>1</sup> National Aerospace University KhAI, Kharkiv, Ukraine  
V.Kharchenko@csn.khai.edu, mostafahkahtan1@gmail.com

<sup>2</sup> Research and Production Company Radiy, Kropyvnytskyi, Ukraine  
a.andrashov@radiy.com

<sup>3</sup> Poltava National Technical University, Poltava, Ukraine  
pnchl@rambler.ru

**Abstract.** The paper deals with developing and researching Markov's models and assessing of the availability of Instrumentation and control systems which are a part of smart building automation system (BAS). It was determined that the causes of failures and unavailability of the BAS component architecture can be hardware (physical), software (design) faults, and successful attacks on vulnerabilities (interaction faults), first of all. BAS failures are related to reliability issue, attacks on vulnerabilities is related to security issue. These two reason groups are considered as elements of two disjoint sets. The paper presents the detailed analysis of the BAS architecture consisting of control (FPGA-based), communication (ZigBee) and data levels considering their faults and vulnerabilities. Besides, maintenance procedures (without, common and separate maintenance for reliability and security) are described.

**Keywords:** Software faults and vulnerabilities · Availability · Maintenance strategy · Markov models · Smart buildings · Building automation system

## 1 Introduction

The development of virtualization technology and the creation of cloud computing environments are responsible for the appearance of new variants of the architecture of IT systems, which must be considered when assessing and ensuring the quality of modern computer systems and services, which include a system of “smart home”. This dynamic character of the processes of information interaction significantly complicates the possibility of rapid assessment of the reliability and availability of software and infrastructure resources available to remote access [1].

According to the international and national standards in [2, 3], we can assess the level of risk for a building automation system and give the requirements that must be met to achieve the desired goal of safety and availability.

The primary goals of the work in [4] are security issues for system design and the integration of security subsystems, which significantly tightens security requirements to the protocol of a network control system, and weaknesses in the system design according to hardware and software components.

In [5] it deals with development and research of Markov models of smart building automation systems (BAS), it has been taken into account that BAS failures can be caused by intra (reliability) and external (security) reasons including software faults and attacks on vulnerabilities. The sets of faults and vulnerabilities are considered as separated and disjoint ones, Markov models of BAS architecture with occurred software faults and attacked vulnerabilities considering three maintenance strategies are systemized and researched. These strategies are based on recovery without maintenance, maintenance with common and separate activities on reliability (faults) and vulnerabilities (security). Recommendations concerning choice of strategies and parameters of maintenance are suggested.

We develop number of strategies using a Markov model. These strategies deal with the system availability; it describes the possibility to recover the system from the down state (the state when there is a need to use these strategies) to the up state (the level of availability according to the customer requirements). The architecture of these strategies depends on the kind of maintenance (common or separate). The result of these strategies give different ways for recovering the system taking into account the customer requirements as the maximum value of availability during the minimum time.

In Sect. 2 we presented the analysis of system design and presented the classification of BAS. In Subsect. 2.1 the architecture of BAS and the main components in system design are analyzed. The faults and vulnerabilities of the main BAS components (FPGA, ZigBee, and database) are described in Subsect. 2.2. Subsection 2.3 analyzes the model and tree to draw the structure of the steps of the analysis using the Markov model and give the wide picture of system analysis. Subsection 2.4 presents the review of the development of Markov model strategy and how it can be applied to this work, and describe the parameter of the strategy. In Sect. 3 the analysis of system using Markov model for separated maintenance strategy is performed via marked graphs for the model of separated maintenance [5]. Section 4 is dedicated to research of Markov models depending to use the different strategies.

## 2 Approach and Modeling Technique

Analysis of the system is performed to determine its dependability taking into account reliability and security issues; in this work we have developed a number of strategies, which are used to analyze complex and big systems. According to [6, 7] BAS design have been divided into three levels, system availability will depend on these levels. The analysis the components for each level in [8] is performed. In Fig. 1, the classification of BAS describes the parameter of system design, which is divided between the reliability issues and security issues.



# Author Index

## A

Abdulmunem, Al-Sudani Mustafa Qahtan, 186  
Andrashov, Anton, 186  
Andrysiak, Tomasz, 1

## B

Bialas, Andrzej, 13, 26  
Blokhina, Tatiana K., 79  
Bluemke, Ilona, 39  
Bodyanskiy, Yevgeniy, 49  
Brekhov, Oleg, 60  
Brezhnev, Eugene, 67  
Bystryakov, Alexandr Y., 79

## C

Caban, Dariusz, 89  
Chen, DeJiu, 97

## D

D'Amico, Guglielmo, 106  
Daszczuk, Wiktor B., 118  
Dorota, Dariusz, 131  
Drabowski, Mieczysław, 141

## E

Eferina, Ekaterina G., 215  
Ehsani-Besheli, Fatemeh, 151

## F

Flisiuk, Barbara, 13  
Frolov, Alexander, 166

## G

Gashkov, Sergey, 166  
Gawkowski, Piotr, 39  
Grabski, Waldemar, 39  
Grochowski, Konrad, 39

## H

Henry Tsang, K.Y., 439

## J

Jarzębowicz, Aleksander, 407

## K

Kabashkin, Igor, 178  
Karpenko, Oksana A., 79  
Kharchenko, Vyacheslav, 67, 186  
Kierzkowski, Artur, 196  
Kisiel, Tomasz, 196  
Klimenko, Alexander, 60  
Korolkova, Anna V., 215  
Krawczyk, Henryk, 205, 264  
Kulyabov, Dmitry S., 215

## L

Laskowski, Dariusz, 225, 254  
Leontiev, Konstantin, 67  
Loginov, Vadim, 428  
Lorenc, Paweł, 233  
Lower, Michał, 244  
Lu, Zhonghai, 97  
Łubkowski, Piotr, 225, 254  
Lubomski, Paweł, 264

## M

Majchrzycka, Aneta, 277  
Maleszewski, Jakub, 287  
Manulik, Viacheslav, 67  
Marchewka, Adam, 1  
Martyna, Jerzy, 298  
Maszewski, Mirosław, 1  
Mazurkiewicz, Jacek, 308  
Michael Wong, K.Y., 439  
Młyńczak, Marek, 320

Muzdybayev, Murat, [320](#)  
Muzdybayeva, Alfiya, [320](#)  
Myrzabekova, Dinara, [320](#)

## N

Nowosielski, Leszek, [225](#)  
Nozdrzykowska, Magdalena, [331](#)  
Nozdrzykowski, Łukasz, [331](#)

## P

Pasichna, Maya, [474](#)  
Pavlyuk, Dmitry, [340](#)  
Peleshko, Dmytro, [49](#)  
Petroni, Filippo, [106](#)  
Petrov, Lachezar, [350](#)  
Piech, Henryk, [358](#)  
Pliss, Iryna, [49](#)  
Polkowski, Marcin, [225](#), [254](#)  
Poniszewska-Maranda, Aneta, [277](#)  
Ponochovnyi, Yuriy, [186](#)  
Ponomarenko, Elena V., [79](#)  
Potekhin, Petr, [428](#)  
Pszczoliński, Paweł, [264](#)  
Ptak, Aleksandra, [358](#)

## R

Radomskyi, Oleksandr, [368](#)  
Rashkevych, Yuriy, [49](#)

## S

Saczek, Michal, [358](#)  
Saganowski, Łukasz, [1](#)  
Savenkova, Elena V., [79](#)

Sevastianov, Leonid A., [215](#)  
Sobolewski, Robert Adam, [106](#)  
Sosnowski, Janusz, [287](#)  
Stoianov, Nikolai, [350](#)  
Strzałka, Dominik, [383](#)  
Sugier, Jarosław, [394](#)  
Świeboda, Justyna, [418](#)  
Szczygielska, Monika, [407](#)

## T

Tagarev, Todor, [350](#)  
Toporkov, Victor, [428](#)  
Tubis, Agnieszka, [450](#)

## V

Velieva, Tatyana R., [215](#)  
Vynokurova, Olena, [49](#)

## W

Walkowiak, Tomasz, [89](#), [464](#)  
Werbińska-Wojciechowska, Sylwia, [450](#)  
Woda, Marek, [233](#)

## Y

Yemelyanov, Dmitry, [428](#)

## Z

Zajac, Mateusz, [418](#)  
Zarandi, Hamid R., [151](#)  
Zaslavskyi, Volodymyr, [474](#)  
Zima, Dawid, [205](#)  
Zuberek, Wlodek M., [118](#)