



# mipro 2020



ISSN 1847-3946

organizer

μpro

43<sup>rd</sup>

## international convention

September 28 - October 2, 2020, Opatija, Croatia

*Lampadem tradere*



mipro - innovative promotional partnership

mipro proceedings

My profession.  
My organization.  
My IEEE.



Discover the benefits  
of IEEE membership.

Join a community of more than 365,000 innovators in over 150 countries. IEEE is the world's largest technical society, providing members with access to the latest technical information and research, global networking and career opportunities, and exclusive discounts on education and insurance products.

Join today  
[www.ieee.org/join](http://www.ieee.org/join)



# **MIPRO 2020**

## **43<sup>rd</sup> International Convention**

September 28, 2020 – October 2, 2020  
Opatija, Croatia

### **Proceedings**

Conferences:

**Microelectronics, Electronics and Electronic Technology /MEET**

**Data Science and Biomedical Engineering /DS-BE**

**Telecommunications & Information /CTI**

**Computers in Education /CE**

**Computers in Technical Systems /CTS**

**Intelligent Systems /CIS**

**Robotics Technologies and Applications/RTA**

**Information Systems Security /ISS**

**Business Intelligence Systems /miproBIS**

**Digital Economy and Digital Society /DE-DS**

**Information and Communication Technology Law /ICTLAW**

**Engineering Education /EE**

**Software and Systems Engineering /SSE**

**MIPRO Junior - Student Papers /SP**

**Smart, Sustainable And Resilient Cities And Infrastructure /SSRCI**

**Optoelectronics and Photonics /OPHO**

**Dew Computing /DEWCOM**

Edited by:  
**Karolj Skala**

## International Program Committee

- Karolj Skala, General Chair (Croatia)  
Lejla Abazi-Bexheti (North Macedonia)  
Enis Afgan (United States),  
Miimu Airaksinen (Finland),  
Saša Aksentijević (Croatia),  
Slaviša Aleksić (Germany),  
Slavko Amon (Slovenia),  
Krešo Antonović (Croatia),  
Michael E. Auer (Austria),  
Viktor Avbelj (Slovenia),  
Dubravko Babić (Croatia),  
Snježana Babić (Croatia),  
Tadej Bajd (Slovenia),  
Ante Bakić (Croatia),  
Marko Banek (Croatia),  
Mirta Baranović (Croatia),  
Bartosz Bebel (Poland),  
Nina Begičević Redep (Croatia),  
Ladjel Bellatreche (France),  
Adrian Boukalov (Belgium),  
Ricardo Branco (Portugal),  
Ljiljana Brkić (Croatia),  
Marian Bubak (Poland),  
Andrea Budin (Croatia),  
Željko Butković (Croatia),  
Patrizio Campisi (Italy),  
Željka Car (Croatia),  
Jesús Carretero Pérez (Spain),  
Bojan Cukic (United States),  
Alfredo Cuzzocrea (Italy),  
Duško Čakara (Croatia),  
Stipo Čelar (Croatia),  
Marina Čičin-Sain (Croatia),  
Dragan Čišić (Croatia),  
Davor Davidović (Croatia),  
Vlado Delić (Serbia),  
Radoslav Delina (Slovakia),  
Matjaž Depolli (Slovenia),  
Saša Dešić (Croatia),  
Dražen Dragičević (Croatia),  
Todd Eavis (Canada),  
Maurizio Ferrari (Italy),  
Tiziana Ferrari (Netherlands),  
Nikola Filip Fijan (Croatia),  
Renato Filjar (Croatia),  
Tihana Galinac Grbac (Croatia),  
Enrico Gallinucci (Italy),  
Dragan Gamberger (Croatia),  
Paolo Garza (Italy),  
Tom Gavazzi (Croatia),  
Gordan Gledec (Croatia),  
Matteo Golfarelli (Italy),  
Stjepan Golubić (Croatia),  
Vera Gradišnik (Croatia),  
Simeon Grazio (Croatia),  
Andrej Grgurić (Croatia),  
Stjepan Groš (Croatia),  
Nina Gumzej (Croatia),  
Marjan Gusev (North Macedonia),  
Jaak Henno (Estonia),  
Bojan Hlača (Croatia),  
Željko Hocenski (Croatia),  
Tatjana Holjevac (Croatia),  
Vlasta Hudek (Croatia),  
Darko Huljenić (Croatia),  
Robert Inkret (Croatia),  
Ivo Ipšić (Croatia),  
Mile Ivanda (Croatia),  
Marina Ivašić-Kos (Croatia),  
Hannu Jaakkola (Finland),  
Tomislav Jaguš (Croatia),  
Darko Jardas (Croatia),  
Vojko Jazbinšek (Slovenia),  
Leonardo Jelenković (Croatia),  
Bojan Jerbić (Croatia),  
Dragan Jevtić (Croatia),  
Alen Jugović (Croatia),  
Admela Jukan (Germany),  
Oliver Jukić (Croatia),  
Irena Jurdana (Croatia),  
Ozren Jureković (Croatia),  
Marko Jurić (Croatia),  
Đani Juričić (Slovenia),  
Nikola Kadoić (Croatia),  
Jurij Matija Kališnik (Slovenia),  
Ivan Kaštelan (Serbia),  
Zlatko Katalenić (Slovenia),  
Ana Katalinić Mucalo (Croatia),  
Tihomir Katulić (Croatia),  
Pekka Kess (Finland),  
Tonimir Kišasondi (Croatia),  
Zalika Klemenc-Ketiš (Slovenia),  
Mario Konecki (Croatia),  
Marko Koričić (Croatia),

Gregor Kosec (Slovenia),  
Igor Kotenko (Russia),  
Božidar Kovačić (Croatia),  
Miklós Kozlovsky (Hungary),  
Danica Kragić Jensfelt (Sweden),  
Goran Krajačić (Croatia),  
Dieter Kranzlmüller (Germany),  
Marjan Krašna (Slovenia),  
Srećko Krile (Croatia),  
Lene Krøl Andersen (Denmark),  
Benjamin Kušen (Croatia),  
Marko Lacković (Croatia),  
Erich Leitgeb (Austria),  
Jadran Lenarčič (Slovenia),  
Tomislav Lipić (Croatia),  
Hrvoje Lisičar (Croatia),  
Dražen Lučić (Croatia),  
Duško Lukač (Germany),  
Igor Ljubi (Croatia),  
Zongmin Ma (China),  
Goran Marković (Croatia),  
Leslie Martinich (United States),  
Ludek Matyska (Czech Republic),  
Mladen Mauher (Croatia),  
Igor Mekterović (Croatia),  
Željka Mihajlović (Croatia),  
Branko Mikac (Croatia),  
Anđelko Milardović (Croatia),  
Hrvoje Mlinarić (Croatia),  
Thor Moen (Norway),  
Lueny Morell (Puerto Rico),  
Gorana Mudronja (Croatia),  
Necta Nain (India),  
Jadranko F. Novak (Croatia),  
Dario Ogrizović (Croatia),  
Predrag Pale (Croatia),  
Dana Paľová (Slovakia),  
Nikola Pavešić (Slovenia),  
Mile Pavlič (Croatia),  
Branimir Pejčinović (United States),  
Ana Perić Hadžić (Croatia),  
Dana Petcu (Romania),  
Juraj Petrović (Croatia),  
Duc Truong Pham (UK),  
Damir Pintar (Croatia),  
Vincenzo Piuri (Italy),  
Tonka Poplas Susič (Slovenia),  
Andreja Pucihar (Slovenia),  
Aleksandra Rashkovska (Slovenia),  
Robert Repnik (Slovenia),  
Libuša Révészová (Slovakia),  
Slobodan Ribarić (Croatia),  
Vittorio Rosato (Italy),  
Dubravko Sabolić (Croatia),  
Ioan Sacala (Romania),  
Davor Salamon (Croatia),  
Jörg Schulze (Germany),  
Bruno Siciliano (Italy),  
Sandro Skansi (Croatia),  
Zoran Skočir (Croatia),  
Ivanka Sluganović (Croatia),  
Mladen Sokele (Croatia),  
Ana Sović Kržić (Croatia),  
Mario Spremić (Croatia),  
Vlado Struk (Croatia),  
Uroš Janez Stanič (Slovenia),  
Vjerran Strahonja (Croatia),  
Tomislav Suligoi (Croatia),  
Aleksandar Szabo (Croatia),  
Dina Šimunić (Croatia),  
Frano Škopljanač-Mačina (Croatia),  
Dejan Škvorc (Croatia),  
Zorislav Šojat (Croatia),  
Andreja Špernjak (Slovenia),  
Vitomir Štruc (Slovenia),  
Velimir Švedek (Croatia),  
Darko Švelec (Croatia),  
Viktor Švigelj (Slovenia),  
Zheng-Hua Tan (Denmark),  
Nikola Tanković (Croatia),  
Antonio Teixeira (Portugal),  
Edvard Tijan (Croatia),  
Paul Timmers (UK),  
A Min Tjoa (Austria),  
Ivan Tomašić (Sweden),  
Roman Trobec (Slovenia),  
Tibor Vámos (Hungary),  
Mladen Varga (Croatia),  
Lucija Vejmelka (Croatia),  
Matjaž Veselko (Slovenia),  
Linda Vicković (Croatia),  
Marijana Vidas-Bubanja (Serbia),  
Davor Vinko (Croatia),  
Goran Vojković (Croatia),  
Mihaela Vranić (Croatia),  
Miroslav Vrankić (Croatia),  
Boris Vrdoljak (Croatia),  
Slavomir Vukmirović (Croatia),  
Yingwei Wang (Canada),  
Mario Weber (Croatia),  
Roman Wyrzykowski (Poland)

**organized by**  
MIPRO Croatian Society

**technical cosponsorship**

IEEE Region 8  
IEEE Croatia Section  
IEEE Croatia Section Computer Chapter  
IEEE Croatia Section Electron Devices/Solid-State Circuits Joint Chapter  
IEEE Croatia Section Education Chapter  
IEEE Croatia Section Communications Chapter  
EAI European Alliance of Innovation

**under the auspices of**

Ministry of Science and Education of the Republic of Croatia  
Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia  
Ministry of Economy, Entrepreneurship and Crafts of the Republic of Croatia  
Ministry of Public Administration of the Republic of Croatia  
Ministry of Regional Development and EU Funds of the Republic of Croatia  
Ministry of Environment and Energy of the Republic of Croatia  
Ministry of Demography, Family, Youth and Social Policy of the Republic of Croatia  
Ministry of Agriculture of the Republic of Croatia  
Primorje-Gorski kotar County  
City of Rijeka  
City of Opatija  
Croatian Regulatory Authority for Network Industries - HAKOM  
Croatian Power Exchange - CROPEX

**patrons**

University of Zagreb  
University of Rijeka  
Juraj Dobrila University of Pula  
Ruđer Bošković Institute, Zagreb  
University of Zagreb, Faculty of Electrical Engineering and Computing  
University of Zagreb, Faculty of Organization and Informatics, Varaždin  
University of Rijeka, Faculty of Maritime Studies  
University of Rijeka, Faculty of Engineering  
University of Rijeka, Faculty of Economics and Business  
Zagreb University of Applied Sciences  
Croatian Academy of Engineering - HATZ  
Croatian Regulatory Authority for Network Industries - HAKOM  
Ericsson Nikola Tesla, Zagreb  
T-Croatian Telecom, Zagreb  
Končar - Electrical Industries, Zagreb  
HEP - Croatian Electricity Company, Zagreb  
AI Hrvatska, Zagreb

**sponsors**

HEP - Croatian Electricity Company Zagreb  
Končar-Electrical Industries Zagreb  
Storm Computers Zagreb  
InfoDom Zagreb  
AI Hrvatska Zagreb  
Mjerne tehnologije Zagreb  
Selmet Zagreb  
Institute SDT Ljubljana  
Nomen Rijeka

All papers are published in their original form

For Publisher:

**Karolj Skala**

Publisher:

Croatian Society for Information, Communication and  
Electronic Technology – MIPRO  
Office: Kružna 8/II, P. O. Box 303, HR-51001 Rijeka, Croatia  
Phone/Fax: (+385) 51 423 984

Printed by:

**GRAFIK, Rijeka**

**ISSN 1847-3946**

**Copyright © 2020 by MIPRO**

All rights reserved. No part of this book may be reproduced in any form, nor may be stored in a retrieval system or transmitted in any form, without written permission from the publisher.

# CONTENTS

## LIST OF PAPER REVIEWERS

## LIST OF AUTHORS

## FOREWORD

# MICROELECTRONICS, ELECTRONICS AND ELECTRONIC TECHNOLOGY

## INVITED PAPER

<b>Infrared Quantum Detectors</b>	5
D. Grubišić, D. Babić	

## PAPERS

<b>Ge-on-Si Avalanche Photodiodes for LIDAR Applications</b>	15
M. Wanitzek, M. Oehme, D. Schwarz, K. Guguieva, J. Schulze	
<b>Processing Sequence for a PureB Bipolar Junction Transistor</b>	20
A. Čaušević, H.S. Funk, D. Schwarz, K. Guguieva, J. Schulze	
<b>Carrier Mobilities in Heavily Doped Pseudomorphic Ge<sub>1-x</sub>Sn<sub>x</sub>-epilayers</b>	24
M.M. Dettling, D. Weißhaupt, H.S. Funk, M. Kern, F. Berkmann, C. Clausen, M. Oehme, D. Schwarz, J. v. Slageren, J. Schulze	
<b>On the Modelling of Interface Roughness Scattering in AlGa<sub>N</sub>/Ga<sub>N</sub> Heterostructures</b>	29
I. Berdalović, M. Poljak, T. Suligoj	
<b>Modeling of Electrical Properties of Al-on-Ge-on-Si Schottky Barrier Diode</b>	35
L. Marković, T. Knežević, T. Suligoj	
<b>Material and Device Properties of Bismuthene Nanoribbons from Multi-orbital Quantum Transport Simulations</b>	41
M. Poljak	
<b>Single-band Quantum Transport Study of Resonant Tunneling Diodes Based on Silicene Nanoribbons</b>	46
M. Mihaljević, M. Širić, M. Poljak	



<b>Predicting the Transport Properties of Silicene Nanoribbons Using a Neural Network</b>	51
T. Župančič, I. Stresec, M. Poljak	
<b>Introduction to the Design and Simulation of Reflectionless Filters</b>	56
G. Lemire, B. Pejčinović	
<b>Microwave Interferometry Measurements of Yeast Cell Suspension and Sediment Process</b>	61
M. Zhang, T. Marković, B. Nauwelaers	
<b>Energy Harvesting on Power Amplifiers Based on Application of Thermoelectric Generators</b>	65
I. Škalic, I. Marinović	
<b>Doherty Power Amplifier in Horizontal Current Bipolar Transistor (HCBT) Technology</b>	69
Ž. Osrečki, J. Žilak, M. Koričić, T. Suligoj	
<b>Design Considerations for Mid-Power Receiver in Resonant Wireless Power Transfer System</b>	74
D. Vinko, D. Bilandžija I. Biondić	
<b>Semi-Analytical Estimation of On-Chip Intertwined Rectangular Transformer Parameters in 180 nm CMOS Technology</b>	78
I. Brezovec, J. Mikulić, G. Schatzberger, A. Barić	
<b>Multi-Topology DC-DC Converter for Low-Voltage Energy Harvesting Systems</b>	84
M. Kováč, D. Arbet, L. Nagy, M. Šovčík, V. Stopjaková	
<b>Design and Measurements of Low Power 32-kHz Oscillators and a Test Interface in 180-nm CMOS Technology</b>	90
I. Kuljak, I. Tomić, R. Bertolan, J. Mikulić, G. Schatzberger, J. Fellner, A. Barić	
<b>Programmable Low-Frequency Divider in 180-nm CMOS Technology</b>	96
D. Tomić, J. Mikulić, G. Schatzberger, J. Fellner, A. Barić	
<b>Design of a Tunable Temperature Coefficient Voltage Reference with Low-Dropout Voltage Regulator in 180-nm CMOS Technology</b>	100
D. Osmanović, I. Skeledžija, K. Špoljarić, D. Tomić, J. Mikulić, G. Schatzberger, J. Fellner, A. Barić	
<b>Mismatch Reduction Techniques for Current-Mirror Based Potentiostats</b>	106
M. Haberler, I. Siegl, C. Steffan, M. Auer	

<b>Design of CMOS Temperature Sensors Based on Ring Oscillators in 180-nm and 110-nm Technology</b>	111
I. P. Tolić, J. Mikulić, G. Schatzberger, A. Barić	
<b>A Circuit for Identifying Oldest Ready Instructions in Reservation Stations</b>	116
D. Spasov	
<b>An Improvement in the Convergence of Superscalar Processors</b>	121
D. Spasov	
<b>Sequential Register Renaming</b>	125
D. Spasov	
<b>Improved Circuits for a Random Pulse Computer</b>	130
M. Batelić, M. Stipčević	
<b>Two Approaches for Solving Rubik's Cube with Hardware-Software Co-design</b>	135
E. Baručija, A. Akagić, S. Ribić, Ž. Jurić	
<b>A Methodology for Frequency-Measurement Characterization Based on Increment of Input Signal Phase</b>	141
A.N. Serov	
<b>Comparative Analysis of the Active Power Measurement Methods in Time Domain</b>	147
A.N. Serov, A.A. Shatokhin, N.A. Serov	
<b>Comparison of Pearson Correlation Coefficient and Distance Correlation in Correlation Power Analysis on Digital Multiplier</b>	153
J. Kandrata, D. Fujimoto, Y. Hayashi, A. Barić	
<b>A Realization of Adaptive Compressive Sensing System</b>	159
K. Sever, T. Vlašić, D. Seršić	
<b>Delta/Alpha Ratio for Diagnosis of Autism Spectrum Disorder</b>	165
Z. Šverko, S. Vlahinić, M. Vrankić, I. Markovinović	
<b>Group Delay of Fractional <math>n+\alpha</math>-Order Bessel Filters</b>	170
A. Čoza, V. Županović, D. Vlah, D. Jurišić	

# DATA SCIENCE AND BIOMEDICAL ENGINEERING

## INVITED PAPER

- Information Communication Society - a Possible Ecology of the Future** 181  
Z. Šojat

## PAPERS

### DATA SCIENCE

- Comparison of Machine Learning Methods in Classification of Affective Disorders** 193  
I. Kinder, K. Friganović, J. Vukojević, D. Mule, T. Slukan, D. Vidović,  
P. Brečić, M. Cifrek
- Evaluating Microsoft Face API in the Context of Student Classroom Attendance** 198  
M. Marjanović, T. Kramberger, R. Kramberger, I. Cesar
- A Scalable K-Nearest Neighbor Algorithm for Recommendation System Problems** 202  
A. Sagdić, C. Tekinbas, E. Arslan, T. Kucukyilmaz
- Retinal OCT Image Segmentation: How Well do Algorithms Generalize or How Transferable are the Data?** 208  
M. Melinščak, S. Lončarić
- Smartphone Based Range of Motion Measurement in Physiotherapy** 213  
M. Njirjak, E. Otović, M. Budimir, H. Vlahović, M. Tomić, V. Marijančić
- Comparative Analysis of Network Embeddings for Functional Annotation in Protein Interaction Networks** 219  
I. Ivanoska, E. Petreska, B.R. Stojkoska, S. Kalajdziski, K. Trivodaliev
- Modernization of the PIC Codes for Exascale Plasma Simulation** 225  
I. Vasileska, P. Tomšič, L. Kos
- GPU Accelerated RBF-FD Solution of Poisson's Equation** 230  
M. Jančić, J. Slak, G. Kosec
- Parallel Point Sampling for 3D Bodies** 235  
U. Duh, M. Depolli, J. Slak, G. Kosec
- Sarajevo War Tunnel - Mobile Virtual Cultural Heritage Application** 240  
I. Prazina, I. Ivković-Kihić, T.A. Chahin, A. Jajčanin, S. Rizvić, V. Okanović

<b>Modeling Agricultural Production Activities Using Weather and Soil Parameters</b>	244
T. Kovačević, L. Mrčela, A. Merćep, Z. Kostanjčar	
<b>Improving 3D Printing of Garments by Using HPC Cloud</b>	249
D. Tomić, D. Davidović, T. Šubić, J. Mesarić, K. Skala	
<b>Global Repeat Map Algorithm (GRM) Reveals Differences in Alpha Satellite Number of Tandem and Higher Order Repeats (HORs) in Human, Neanderthal and Chimpanzee Genomes – Novel Tandem Repeat Database</b>	253
I. Vlahović, M. Glunčić, K. Dekanić, L. Mršić, H. Jerković, I. Martinjak, V. Paar	
<b>Air Traffic Control Competencies Measurements Based on Functional Near-Infrared Spectroscopy</b>	259
I. Kesedžić, J. Božek, M. Radoš, S. Popović, K. Čosić	
<b>Public Transport Analyzing Using Bee Colony</b>	265
M. Babič, B. Soldo, J. Povh	
<b>Measure for Traffic Anomaly Detection on the Urban Roads Using Speed Transition Matrices</b>	268
L. Tišljarić, Ž. Majstorović, T. Erdelić, T. Carić	
<b>Calculating the Fire Weather Index for US Wildfires Using a GPU</b>	276
J. Kuzmanova, M. Gusev, V. Zdravski	
<b>Iris Identification Using Wavelet Wecomposition and Gabor Filter</b>	2816
H. Nitz Petterson, J. Rehnholm, S. Vikström, M. Åslund, E. Åstrand, I. Tomašić	
<b>An Analytics Toolbox for Cyber-Physical Systems Data Analysis: Requirements and Challenges</b>	287
M. Zanin, E. Menasalvas, A. Rodriguez González, P. Smrz	
<b>Assisting Motorists Using Parking Prediction through a Car App</b>	293
C. Attard, A. Naudi, S. Mallia, D. Gauci, R. Farrugia	
<b>BIOMEDICAL ENGINEERING</b>	
<b>Automatic Brain Extraction in Nissl-Stained Histological Sections</b>	301
T. Smolčić, T. Petković, S. Škokić	
<b>Laser Speckle Stereo System in Biomedical Imaging</b>	306
F. Salgueiro, P.A. Assunção, R. Fonseca-Pinto	

<b>Lung Cancer Typology Classification Based on Biochemical Markers Using Machine Learning Techniques</b> J. Nuhić, J. Kevrić	310
<b>Self-Help for Elderly Individuals with Morning Gymnastics “1000 Movements” and “Method 23+5”</b> B. Širaiy, U.J. Stanič, Z. Katkič, N. Grishin	316
<b>Design of a Non-invasive ECG-based Glucose Measurement System</b> M. Gusev, E. Guseva, L. Poposka	321
<b>Analysis of Diabetes Dataset</b> L. Beqiri, A. Velinov, B. Fetaji, L. Loku, A. Buçuku, Z. Zdravev	327
<b>Trends from Minimally Invasive to Non-invasive Glucose Measurements</b> M. Gusev, L. Poposka, E. Guseva, M. Kostoska, B. Koteska, M. Simjanoska, N. Ackovska, A. Stojmenski	333
<b>Respiration Extraction from Single-Channel ECG using Signal-Processing Methods and Deep Learning</b> E. Merdjanovska, A. Rashkovska	339
<b>Simultaneous Phonocardiography and Electrocardiography Using Smartphone in Dogs, Cats and Horses</b> V. Kadunc Kos, M. Brložnik, A. Domanjko Petrič, V. Avbelj	345
<b>Phonocardiography and Electrocardiography with a Smartphone</b> V. Avbelj, M. Brložnik	350
<b>Detection of Uninterpretable ECG Signal Segments</b> E. Ajdaraga Krluku, M. Gusev	355
<b>A Programmatic Approach for Development of the ViewHRV Service Platform with Accurate and Reliable Results</b> E. Shaqiri, M. Gusev	361
<b>Impact of Subthreshold Transcutaneous Auricular Vagus Nerve Stimulation on the Heart Rate Variability and Atrial Arrhythmias</b> R. Trobec, M. Lindén, M. Šinkovec	367
<b>Clinical Decision Support Systems in Practice: Current Status and Challenges</b> A. Jović, I. Stančin, K. Friganović, M. Cifrek	373
<b>MOVIDA.eros : an eHealth Solution for Cardiac Rehabilitation Programs</b> R. Fonseca-Pinto, E. Silva, R. Martinho, R. Rijo, F. Januário, A. Antunes	379
<b>Smart Healthcare Ecosystem for Elderly Patient Care</b> A. Abugabah, N. Nizamuddin	383

<b>High-Throughput Virtual Screening Web Service Development and its Applications to SARS-CoV-2 Target Protein Inhibitors Drug Design</b>	389
V. Miletić, M. Ašenbrener Katić, Ž. Svedružić	
<b>Drug Screening with the Autodock Vina on a Set of Kinases without Experimentally Established Structures</b>	395
D. Tomić, D. Davidović, V. Jandel, J. Mesarić, K. Skala, T. Lipić	

## TELECOMMUNICATIONS & INFORMATION

### INVITED PAPERS

<b>Cybersecurity Risk is a Board-Level Issue</b>	407
B. Cerin	
<b>Govorna komunikacija čovjek-stroj X &amp; Y vs Z &amp; <math>\alpha</math> generacije</b>	409
V. Delić	

### PAPERS

#### TOWARDS 5G NETWORKS

<b>LTE and 5G NR – Coexistence and Collaboration</b>	415
T.B. Iliev, G.Y. Mihaylov, I.S. Stoyanov, E.P. Ivanova	
<b>Decoding of LTE Turbo Codes Initialized with the Two Recursive Convolutional Codes</b>	419
D. Spasov	
<b>Evaluation of Commercial Off-The-Shelf LTE Antennas for Use on Unmanned Aerial Vehicles</b>	423
K. Kainrath, H. Flühr, W. Stocksreiter, R. Findenig, E. Leitgeb, M. Gruber	
<b>Techno-Economic Analysis of Deployment Options for Converged 5G Wireless-Optical Access Networks</b>	427
M. Bongard, K. Grunert, S. Aleksić	
<b>Resource Utilization – QoS Isolation Trade-Off in 5G Networks Considering Network Slicing Reconfiguration Interval</b>	433
S. Demirović, P. Kiš, J. Janković, Ž. Ilić	
<b>Bounding Reliability in Service Function Chaining</b>	439
A. Engelmann, W. Bziuk, A. Jukan	

## **INTERNET DEVELOPMENT & ENERGY EFFICIENCY**

- IoT Cloud-Based Services in Network Management Solutions** 447  
O. Jukić, I. Heđi, E. Ciriković
- Innovation Platform – A Novel Energy Service Utility** 453  
A. Višković, D. Šimunić, V. Franki
- Modeling of Energy Consumption of Sensor Nodes** 459  
F. Tsvetanov, I. Georgieva
- Čimbenici adresiranja i povezivanja za IoT usluge i aplikacije** 465  
D. Švelec, M. Blažeković

## **SMART CITIES & CHALLENGES**

- Establishing the Utility Charges Spatial Database Using Digital Twin Technology** 473  
V. Mihoković, L. Zalović, V. Zalović
- Smart Home IVR-Based System with South Slavic Language Integration** 478  
M. Spahić, A. Šečerbegović, V. Mesić, H. Hadžić, A. Hasanbašić, O. Jahić
- Software Prototype Based on Augmented Reality for Mastering Vocabulary** 482  
M. Begić, M. Cirimotić, I. Farkaš, I. Skorić, Ž. Car, I. Rašan, M. Žilak
- The Perception of the Fake News Phenomenon on the Internet by Members of Generation Z** 488  
L. Prelog, Lj. Bakić-Tomić
- Smart Cities as an Opportunity and Challenge for People with Disabilities** 492  
D. Švelec, N. Bjelčić, M. Blažeković

## **COMPUTING IN TELECOMMUNICATIONS**

- Cloud Computing Virtualization: A Comprehensive Survey** 501  
A. Rista, J. Ajdari, X. Zenuni
- Algorithms for Computing in Fog Systems: Principles, Algorithms, and Challenges** 512  
N. Soni, R. Malekian, D.C. Bogatinoska
- DNN Placement and Inference in Edge Computing** 518  
M. Bensalem, J. Dizdarević, A. Jukan

## **MACHINE LEARNING APPLICATIONS**

- Predicting and Analyzing Absenteeism at Workplace Using Machine Learning Algorithms** 527  
A. Rista, J. Ajdari, X. Zenuni
- Example of Using Algorithms for Switching Hybrid FSO/RF Systems** 533  
R. Haluška, L. Ovseník, P. Šul'aj
- Crime Analysis and Prediction Using Machine Learning** 538  
O. Llah
- A Machine Learning Approach for Analysis of Spectrum Availability in Kosovo based on Experimental Measurements** 544  
Z. Limani Fazliu, H. Maloku, M. Ibrani, M. Limani, B. Gashi

## **SIGNAL PROCESSING**

- The Influence of Multipath Propagation of the Signal on the Accuracy of the GNSS Receiver** 553  
T.B. Iliev, I.S. Stoyanov, S.A. Sokolov, I.H. Beloev
- Error Correction with Systematic RLNC in Multi-Channel THz Communication Systems** 557  
C.V. Phung, A. Engelmann, A. Jukan
- Measurement-Based Optimized Propagation Model for Urban, Suburban and Rural Environments for UHF Bands in Kosovo** 563  
H. Maloku, Z. Limani Fazliu, M. Ibrani, M. Limani, B. Gashi

## **BUSINESS PROCESSES & DATABASES**

- Transforming Product Catalogue Relational into Graph Database: a Performance Comparison** 571  
J. Lorincz, V. Huljić, D. Begušić
- Značajka analitičkog pristupa u dizajnu, optimizaciji i održavanju poslovnih procesa** 577  
D. Markulin, K. Musa, A. Mršić
- Komparativna analiza upravljanja obrtnim kapitalom u odjeljcima područja djelatnosti Informacije i komunikacije u Republici Hrvatskoj** 582  
D. Korent
- Pregled performansi djelatnosti J61 Telekomunikacije u Republici Hrvatskoj** 588  
M. Bubanić



## **IMPLEMENTATIONS OF STANDARDS & BEST PRACTICES**

<b>Implementation of NETCONF Standard by Major Customers in Croatia</b> D. Valenčić	597
<b>Vendors' Implementation of NETCONF Standard on Routers and Switches</b> D. Valenčić	604
<b>Dohvat novih ključeva za mobilnu aplikaciju na bankomatu prema ITIL najboljoj praksi</b> D. Muratović, R. Barišić	610
<b>Uvođenje usluge bežičnog pristupa internetu pomoću ITIL smjernica</b> K. Brodnjak, R. Barišić	616

## **COMPUTERS IN EDUCATION**

### **PAPERS**

<b>Parents' Attitudes toward Programming in Elementary Schools in City of Osijek</b> A. Papić, I. Čosić	627
<b>Artificial Intelligence and Education</b> H. Jaakkola, J. Henno, A. Lahti, J.P. Järvinen, J. Mäkelä	633
<b>Teaching Physics Using Programming of Simulations</b> R. Repnik, P. Bernad, M. Krašna	641
<b>Improving the Quality of Entrepreneurial Education by ICT Education of HEI Pedagogical Staff</b> D. Pařová, M. Vejačka	649
<b>How to Educate Students for the Future?</b> L. Révészová	655
<b>Game Design Based Learning of Programming for Girls</b> M. Bevčić, J. Rugelj	661
<b>Gamification Tools Improving University Students' Involvement in the Education Process</b> D. Pařová, M. Vejačka	666

<b>Continuous Summative Assessment Sessions as a Motivational Tool for STEM students: a Case Study</b> G. Đurović	672
<b>Increasing the Learning Efficiency in Decision-Making Field Using the Workshop Activity in Moodle</b> N. Kadoić, B. Šlibar	677
<b>Studying Dynamic Mathematics Software in the Professional Training of Teachers of Computer Science, Mathematics, and IT Specialists</b> I.V. Shishenko, V.H. Shamonia, V.S. Loboda, V.V. Punko, Yu.V. Khvorostina, A.A. Voitenko	683
<b>The Automated Control of Students Achievements by Using Paper Clicker Plickers</b> M.G. Drushlyak, O.V. Semenikhina, S.M. Kondratiuk, T.M. Kryvosheya, A.V. Vertel, N.M. Pavlushchenko	688
<b>The Use of Electronic Textbooks in the Learning Process: a Statistical Analysis</b> O.M. Udovychenko, M.M. Ostroha, A.E. Chernysh, O. Kudrina, Yu.A. Bondarenko, A.V. Kurienkova	693
<b>Influence of Moodle and MS Teams on Teaching-Learning-Studying (TLS) Processes</b> M. Krašna, I. Pesek	697
<b>The Impact of Distance Learning on Student Success for Electrical Engineering Professional Courses</b> M. Sokele, T. Alajbeg, F. Brkić	702
<b>Use of Open Training Portals to Host Developed STEM Courses</b> T. Hryhorova, V.P. Lyashenko, I. Hvozdeva, I. Getman	707
<b>Internationalization and Student Mobility: STEAM Students Case Study</b> P. Cuculić, T. Babić, M. Pavlica	711
<b>Educating the Educators for Introducing Internet of Things to Primary and Secondary Schools' Curriculums</b> A. Jaklič	717
<b>An Algorithm for Assessment of Students Using Gamification</b> D. Keremedchiev, D. Borissova, G. Tuparov	721
<b>Effective Decision Making: the Added Value of Including Humanities in STEM Studies</b> M. Pavlica, T. Babić, P. Cuculić	726
<b>Using BBC Micro:bit in Primary and Secondary Schools for Creating Simple Smart Home</b> P. Voštinár, J. Knežník	733

<b>Using mBot Robots for the Motivation of Studying Computer Science</b> P. Voštinár	738
<b>Investment of European Enterprises in ICT Education of Their Employees: Relationship with Country Competitiveness and Digital Economy Development</b> M. Pejić Bach, J. Zoroja, I. Strugar	743
<b>Project Based Teaching with Digital Tools in Primary Education</b> J. Mezak, P. Pejić Papak	749
<b>University Teachers' Needs for the Efficient Use of ICT in the Pedagogical Process</b> N. Špur, E. Kranjec, M. Puhek, K. Breznik, L. Klasinc, S. Frumen	754
<b>Analysis of Social Networks Usage Among Students</b> M. Lončar, D. Kermek	760
<b>Digital Technologies in Education of Preschool Children – Preparing for Future</b> J. Gunčaga, E. Severini, B. Kožik Lehotayová, P. Ostradický	766
<b>Impact of Education on Communication Etiquette</b> G. Kirinić, Lj. Bakić-Tomić	774
<b>Harmonization of Curriculum with Needs and Requests of Fourth Industrial Revolution: Case of Faculty of Economics and Business Rijeka</b> H. Bezić, D. Balaž, B. Buljat	779
<b>A Comparative Study of Gamification in Programming Education in a Croatian High School</b> M. Schatten, M. Schatten	785
<b>Computer-Based Education in the Course “Digital Electronics” Teaching the Topic “Adders-Subtractors”</b> A.N. Borodzhieva, I.I. Stoev, I.D. Tsvetkova, S.L. Zaharieva, V.A. Mutkov	790
<b>Low Cost Rapid Control Prototyping – a Useful Method in Control Engineering Education</b> W. Werth, L.M. Faller, H. Liechtenecker, C. Ungermanns	796
<b>Digital Literacy as a Part of Continuing Education Library Efforts</b> R. Vrana	801
<b>The Model of Collaborative Terminology Contribution to the Art &amp; Architecture Thesaurus: Application and Improvement of Crowdsourcing Methods in an Educational Context</b> G. Zlodi, T. Ivanjko, P. Štefičar, M. Marochini	807

<b>ICT for Innovative Education and Science: Smart Environment for Networked Strategies</b>	812
V. Omelyanenko, O. Kudrina, H. Shevtsova, O. Prokopenko, V. Petrenko	
<b>Student Social Media Usage and Its Relation to Free-recall Memory Tasks</b>	816
V. Vidaček Hainš, M. Kućar, R. Kovačić	
<b>Modernized Courses in Automotive Software Engineering</b>	822
I. Kaštelan, B. Pavković, M. Vranješ, M. Popović	
<b>Intuitive and Rational Information Management</b>	826
I. Mikšić, T. Babić, Lj. Bakić-Tomić	
<b>Artificial Intelligence – a New Topic in Computer Science Curriculum at Primary and Secondary Schools: Challenges, Opportunities, Tools and Approaches</b>	832
Z. Tkáčová, L. Šnajder, J. Guniš	
<b>Inquiry-Based Python Programming at Secondary Schools</b>	835
J. Guniš, L. Šnajder, Z. Tkáčová, V. Gunišová	
<b>Sentiment Analysis of Open-Ended Student Feedback</b>	840
T. Hynninen, A. Knutas, M. Hujala	
<b>Comparative Analysis of Students' Attitudes on Teaching Quality and its Assessment in Higher Education</b>	845
K. Pavlina, A. Pongrac Pavlina, V. Juričić	
<b>Students' Attitudes toward Value-Driven Digital Marketing</b>	849
A.M. Jadanec, T. Babić	
<b>The Web-based Lectures as Leverage for Developing the Sense of Belonging in the All-Russian Creative School-Contests</b>	855
O.S. Fomichova, V.A. Fomichov	
<b>STEAM Students and Their Expectations from Future Business Life: a Values-driven Workplace</b>	861
Y. Borysiuk, T. Babić	
<b>Cryptocurrency as the Currency of the Future: a Case Study among Algebra University College Students</b>	867
A. Knežević, T. Babić, Z. Musa	
<b>New Teaching Methods in Higher Education - Management of Information Systems Course</b>	873
K. Aleksić-Maslač, P. Vranešić, B. Debić	

<b>Non-Determinism in Nowadays Computing and IT Education</b> J. Henno, H. Jaakkola, J. Mäkelä	879
<b>An Experiential Learning Approach to Research Methods in Computer Science Based on SMART Goals</b> N. Caporusso	887
<b>Adaptive Drum Kit Learning System: Impact on Students' Motivation</b> M. Konecki	893
<b>Impact of Distance Learning on Motivation and Success Rate of Students during the COVID-19 Pandemic</b> M. Konecki	898
<b>Analysis and Development of a Robotic Disk Mounting Stand</b> F. Koefler, M. Edlinger, N. Jausz, W. Egger, W. Werth, L.M. Faller	903
<b>SJSU GO</b> R. Fatoohi, S. Ehrman, L. Francesca, C. Chong, J. Khoury, A. Minaire, D. Pham, M. Abhyankar, J. Chen, R. Chen, A. Corona-Sanchez	908
<b>Online and In-Class Computer Science Teacher Training - Oracle Academy Program Experiences</b> F. Urem, D. Jureković, E. Ban	913
<b>A Novel System for Automatic, Configurable and Partial Assessment of Student SQL Queries</b> M. Fabijanić, G. Đambić, B. Fulanović	917
<b>Experience with E-learning in Teaching Combinatorics and Data Processing</b> M. Pokorný	923
<b>Assessment of the Role of Technology in the Process of Tolerance</b> E. Gürbüzler, G. Dağlı, F. Altınay, Z. Altınay	928
<b>Distance Learning: Examples of Good Practice, Analysis and Experience</b> M. Mačinko, A. Sović Kržić, I. Mudri	933
<b>Understanding the Factors that Influence Secondary Teachers' Intention to Use e-Learning Technologies for Teaching after the COVID-19 Pandemic</b> S. Babić, S. Križan Sučić, G. Sinković	938
<b>Distance Learning Caused by the COVID-19 Pandemic in Croatia: What do Newspaper Portals Actually Deliver to Readers?</b> M. Kuzelj, K. Šamija	944
<b>The Significance of Transformational Team Members</b> T. Babić, Z. Musa	950

<b>Digital Transformation as a Process of Using Digital Technologies for Monitoring and Designing the User Experience</b>	956
I. Radoš, T. Babić	
<b>The Immigrant Integration Online Training Program in Finland</b>	962
A. Hartikainen, M. Ahola, M. Apiola, E. Sutinen	
<b>Assessing the Impact of Mobile Educational Games on Student's Success within Mathematics Subject in Primary Schools</b>	968
M. Fetaji, E. Kajtazi, B. Fetaji, H. Snopce, M. Apostolova	
<b>The Teacher's Role in Discovery, Preparation, and Development of Gifted Students in the Field of Informatics</b>	972
G. Atanasova, P. Hristova	
<b>Word Cloud Analytics of the Computer Science Research Publications' Titles over the Past Half Century</b>	977
L. Abazi-Bexheti, A. Kadriu, M. Apostolova	
<b>Using WebIDE as a Distance Learning Tool for High School Programming</b>	983
M. Mesihović, V. Ljubović, I. Muharemović	
<b>Ability of the Information Science Teachers to Teach Programing in the Lower Grades of Primary School</b>	989
J. Žufić, A. Žufić	
<b>Perception of Using VAR Technology in Football after Completion of Training and Education and Experiences of Croatian Video Assistant Referees (VARs) and Assistant VARs (AVARs)</b>	995
I. Lucić, S. Babić, D. Vučkov	
<b>Implementacija sustava za automatsko praćenje prisutnosti na Visokom učilištu Algebra</b>	1002
B. Fulanović, A. Lacković, D. Bele	
<b>Nauči me igrati - igrifikacijom do boljih rezultata</b>	1006
T. Ređep, T. Pavičić Zajec, B. Marčinković	
<b>Vrednovanje digitalnih kompetencija putem CRISS projekta</b>	1012
M. Mirković	
<b>Implementacija različitih robotskih modela u nastavi tehničke kulture i informatike</b>	1017
P. Dobrić, M. Mačinko, D. Kager	

<b>Suvremen pristup učenju putem projektne nastave</b> N. Boj, A. Tonković, E. Glavaš	1023
<b>Raspberry PI mini računalo kroz nastavnu cjelinu</b> D. Vrbanc	1028
<b>Sustav upravljanja zadacima iz područja micro:bit</b> T. Adamović	1033
<b>Aplikacije za fotografsko prepoznavanje i rješavanje matematičkih zadataka</b> H. Kovač, I. Nađ	1038
<b>Micro:bit-na biometrija</b> B. Raičković, B. Musović	1042
<b>Glazba2Go, mobilna aplikacija za promoviranje glazbene kulture</b> I. Britvić, F. Meštrović	1045
<b>Mobilne aplikacije u obrazovnom okruženju</b> J. Pažanin, M. Rosić	1049
<b>Intermedijalnost autorskih slikovnica Ivane Guljašević Kuman</b> M. Verdonik, V. Vitas	1056
<b>Predikcija uspjeha u studiranju primjenom Bayesovih mreža</b> D. Šimić, J. Gusić	1060
<b>Modifikacija arkadnih igara Space Invaders i Super Mario u edukativne inačice za učenje matematike i hrvatskog jezika</b> I. Franković, M. Ivašić-Kos	1064
<b>Izazovi poučavanja o računalnim mrežama</b> K. Blažeka	1070
<b>Rudarenje edukacijskih podataka: korištenje klasteriranja za predikciju studentskog uspjeha</b> K. Kačapor, Z. Lagumdžija	1075
<b>Robotika u funkciji razvoja vještina 21. stoljeća</b> I. Ružić	1081
<b>Informacijska i komunikacijska tehnologija (ICT) – ključna karika između različitih oblika obrazovanja</b> M. Božurić, R. Bogut, M. Tretinjak	1084
<b>Laboratorijski 3-osni model realiziran pomoću servo sustava</b> M. Lučan, I. Vlašić, G. Malčić	1090

<b>Laboratorijska maketa redundantnog sustava upravljanja</b> A. Omrčen, M. Lučan, G. Malčić	1095
<b>Samoregulacija učenika u virtualnoj učionici nastave matematike</b> R. Soldo, J. Domac, I. Olujić	1100
<b>Primjena alata Xmpl za brzo pokretanje naredbi u podučavanju Linuxa</b> I. Krpan, I. Capan, M. Davidović	1105
<b>Održivi razvoj ruralnog područja – Croduino setovi i dronovi</b> J. Domac	1109
<b>Stavovi studenata o računalnom načinu razmišljanja i vještine rješavanja testa računalnog načina razmišljanja</b> N. Tatković, P. Radulović, S. Tatković	1112
<b>Percipirana kvaliteta sustava za upravljanje verzijama programskog koda od strane studenata informatike</b> T. Orehovački, S. Babić, D. Etinger	1118
<b>Usporedba nastave na daljinu i učioničke nastave iz predmeta Informatika i Računalstvo</b> S. Deljac, M. Berović	1124

## COMPUTERS IN TECHNICAL SYSTEMS

### PAPERS

#### ROBOTICS AND AUTOMATION

<b>Application of PandaPower Tool in Evaluating the Potential of Using PV Distributed Generation for Voltage Regulation in Electrical Power Networks</b> N. Bogunović, S. Vlahinić, D. Franković, V. Komen	1135
<b>Resilience to Cascading Failures: a Complex Network Approach for Analysing the Croatian Power Grid</b> Z. Sičanica, I. Vujaklija	1141
<b>Analysis of Justification for Using Capacitor Banks in Distribution Network with Low Power Demand</b> D. Četković, S. Vlahinić, D. Franković, V. Komen	1146
<b>AVR and PSS Coordination Strategy by Using Multi-Objective Ant Lion Optimizer</b> T. Špoljarić, I. Pavić	1151



<b>Integrated Production Optimization at INA d.d. Upstream Supported by Osisoft PI</b>	1157
B. Žeželj, Ž. Frkin, F. Beznea, M. Gojić	
<b>Predictive Lane-Keeping System for an Autonomous Vehicle</b>	1161
P. Makarun, Š. Ileš, J. Matuško	
<b>Sliding Mode Control of Custom Built Rotary Inverted Pendulum</b>	1166
M. Švec, Š. Ileš, J. Matuško	
<b>A Simulator for Training Human Operators of a Remote Controlled Anti-Terrorism Ground Vehicle</b>	1171
J. Fulir, Ž. Mihajlović, M. Seder	
<b>INTERNET BASED SYSTEMS, APPLICATIONS AND TECHNOLOGIES</b>	
<b>Tools for Analytics and Cognition Framework for a Car-Sharing Use Case</b>	1179
A. Karadimce, D.C. Bogatinoska, M. Sefidanoski, N. Paunkoska Dimoska, N. Marina	
<b>Experimenting with Means to Store and Monitor IoT based Measurement Results for Energy Saving</b>	1185
M. Saari, J. Grönman, J. Soini, P. Rantanen, T. Mäkinen	
<b>An Open-Source Solution for Mobile Robot based Environmental Sensing</b>	1191
J. Grönman, J. Viljanen, J. Vihervaara, M. Saari	
<b>Providing Facilities in Health Care via Brain-Computer Interface and Internet of Things</b>	1196
M. Ullah, A. Hekmatmanesh, D. Savchenko, R. Moioli, P. Nardelli, H. Handroos, H. Wu	
<b>The Success Factors of a National Healthcare Ecosystems Maturation: Preliminary Results</b>	1202
M. Trkman, S. Bajrić, R. Malkoč	
<b>Interface Digital Twins: Rendering Physical Devices Accessible to People Who are Blind</b>	1207
N. Caporusso, N. Elleman, S.S. Cho	
<b>Evaluation of Resource Management System for InfaaS-adaptive Disaster Management Application Platform</b>	1212
Y. Watashiba, Y. Matsui, S. Date	
<b>IoT Protocol Selection for Smart Grid Applications: Merging Qualitative and Quantitative Metrics</b>	1218
M. Ullah, S.R. Ullah Kakakhel, T. Westerlund, A. Wolff, D. Carillo, J. Plosila, P. Nardelli	

**A Survey on Parallel Architectures and Programming Models** 1224  
B. Pervan, J. Knezović

**HPC-Based Parallel Software for Solving Applied Boolean Satisfiability Problems** 1231  
V.G. Bogdanova, S.A. Gorsky, A.A. Pashinin

## **SOFTWARE DESIGN AND AUTOMATION IN INDUSTRY**

**Sample Based Synthesis of Car Engine Noise** 1239  
D. Miljković

**Fault Detection of Aircraft Piston Engine Based on Exhaustive Database Search** 1245  
D. Miljković

## **PROFESSIONAL PAPER IN CROATIAN**

**Automatizacija pročištača otpadnih voda** 1253  
M. Ilijanić, M. Lučan, G. Malčić

## **INTELLIGENT SYSTEMS**

### **PAPERS**

**Automation of a Decision Tree Conversion into a Fuzzy Inference System Using ANTLR** 1263  
S.S. Sosinskaya, R.S. Dorofeev, A.S. Dorofeev, T.R. Usenko

**A Randomized Load Balancing Criteria Using Traffic Flow in SDN** 1267  
P. Choudhary, P. Thota

**Data Cleaning Techniques in Detecting Tendencies in Software Engineering** 1272  
P.V. Georgieva, E. Nikolova, D. Orozova

**Automatic Machine Translation of Poetry and a Low-Resource Language Pair** 1278  
I. Dunder, S. Seljan, M. Pavlovski

**Human Quality Evaluation of Machine-Translated Poetry** 1284  
S. Seljan, I. Dunder, M. Pavlovski

**Using Decision Diagrams of Special Kind for Compactification of Conflict Data Bases Generated by CDCL SAT Solvers** 1290  
V. Kondratiev, I. Otpuschennikov, A. Semenov

<b>Detecting Objects in Drone Imagery: a Brief Overview of Recent Progress</b> S. Sambolek, M. Ivašić-Kos	1296
<b>Individualization of Anonymous Identities Using Artificial Intelligence (AI)</b> T. Bronzin, B. Prole, A. Stipić, K. Pap	1302
<b>Towards the Open Ontology for IoT Ecosystem's Security</b> I. Tomičić, P. Grd	1308
<b>Decision Tree Algorithm for Control of Compressor Multiset in Refrigeration Industry</b> I. Šulekić, D. Milinković, T. Špoljarić	1314
<b>GIS Analysis of Basketball Courts and Healthy Stores Relationship for Young Population in the City of Skopje</b> N. Stojanova, R. Vignjevikj, A. Naumoski	1319
<b>Decentralized Trustless Gossip Training of Deep Neural Networks</b> R. Šajina, N. Tanković, D. Etinger	1324
<b>Discrete Bat Algorithm for Event Planning Optimization</b> S. Delalić, A. Alihodžić, M. Tuba, E. Selmanović, D. Hasić	1329
<b>A Conceptual Network Analysis of Gamification Practices in Primary and Secondary Education</b> I. Tomičić, M. Schatten	1335
<b>Adaptive Rolling Window Selection for Minimum Variance Portfolio Estimation Based on Reinforcement Learning</b> B. Gašperov, F. Šarić, S. Begušić, Z. Kostanjčar	1342
<b>Synthetic Astronomical Image Sequence Generation</b> A. Gribl, D. Petrinović	1347
<b>Novel Class Detection in Non-stationary Streaming Environment with a Discriminative Classifier</b> R. Šajina, N. Tanković, D. Etinger	1353
<b>Evaluation of Diatoms Biodiversity Models by Applying Different Discretization on the Class Attribute</b> A. Naumoski, G. Mirceva, K. Mitreski	1358
<b>Classifying Protein Structures by Using Protein Ray Based Descriptor, KNN and FuzzyKNN Classification Methods</b> G. Mirceva, A. Naumoski, A. Kulakov	1364
<b>An Analysis of Early Use of Deep Learning Terms in Natural Language Processing</b> B. Dalbelo Bašić, M.P. di Buono	1369

<b>On Automated Workflow for Fine-Tuning Deepneural Network Models for Table Detection In Document Images</b>	1374
I. Cherepanov, A. Mikhailov, A. Shigarov, V. Paramonov	
<b>StimSeqOnt: An Ontology for Formal Description of Multimedia Stimuli Sequences</b>	1378
M. Horvat	
<b>Machine Learning Model for Detecting High School Students as Candidates for Drop-Out from a Study Program</b>	1384
Đ. Pašić, D. Kučak	
<b>Evaluation of Structural Hyperparameters for Text Classification with LSTM Networks</b>	1389
M. Frković, N. Čerkez, B. Vrdoljak, S. Skansi	
<b>On Checking Controllability of Specification Languages for DES</b>	1395
A. Davydov, A. Larionov, N. Nagul	
<b>A Note on Geometric Calibration of Multiple Cameras and Projectors</b>	1401
T. Petković, S. Gasparini, T. Pribanić	

## ROBOTICS TECHNOLOGIES AND APPLICATIONS

### PAPERS

<b>Estimating Robot Manipulator End-effector Forces Using Deep Learning</b>	1411
S. Kružić, J. Musić, R. Kamnik, V. Papić	
<b>Prediction of the Behavior of a Pneumatic Soft Robot Based on Koopman Operator Theory</b>	1417
E. Kamenar, N. Črnjarić-Žic, D. Haggerty, S. Zelenika, E.W. Hawkes, I. Mezić	
<b>Conceptual Design of an Autonomous Rover with Ground Penetrating Radar: Application in Characterizing Soils Using Deep Learning</b>	1422
P. Linna, T. Aaltonen, A. Halla, J. Grönman, N. Narra	
<b>Increasing the Accuracy of Robotic Neurosurgical Procedures through Robot Calibration</b>	1428
L. Drobilo, M. Švaco, B. Jerbić	
<b>Implementation of a Low-Cost Autonomous Underwater Vehicle Using Open Source ROS Components with Consumer Class Sonar Technologies</b>	1437
T. Aaltonen, M. Saarivirta, T. Kerminen, J. Grönman	

<b>Improving Markerless Registration Accuracy by Mapping Facial Deformation</b> A. Žgaljić, M. Švaco, B. Jerbić	1443
<b>Programiranje robota u učionici budućnosti</b> D. Vrbanec	1448

## INFORMATION SYSTEMS SECURITY

### PAPERS

<b>Genetic Algorithm and Artificial Neural Network for Network Forensic Analytics</b> D. Oreški, D. Andročec	1457
<b>Using FireEye Endpoint Security for Educational Purposes</b> M. Dujmić, D. Delija, G. Sirovatka, M. Žagar	1463
<b>Constructing a Set of Weak Values for Full-Round MD4 Hash Function</b> I. Gribanova, A. Semenov	1469
<b>Bug Detection in Embedded Environments by Fuzzing and Symbolic Execution</b> J. Vijić, L. Perkov, A. Krog	1475
<b>Forensic Analysis of Windows 10 Sandbox</b> A. Đuranec, S. Gruičić, M. Žagar	1481
<b>Linux Forensic Triage: Overview of Process and Tools</b> A. Anđelković, K. Hausknecht, G. Sirovatka	1487
<b>Overview of Mac System Security and its Impact on Digital Forensics Process</b> D. Sladović, D. Topolčić, D. Delija	1493
<b>Red Teams - Pentesters, APTs, or Neither</b> I. Kovačević, S. Groš	1499
<b>File Fragment Classification with Focus on OLE and OOXML Classes</b> K. Skračić, F. Rukavina, K. Miličić, J. Petrović, P. Pale	1507
<b>AI Safety: State of the Field through Quantitative Lens</b> M. Jurić, A. Sandić, M. Brčić	1511

# BUSINESS INTELLIGENCE SYSTEMS

## INVITED PAPER

- The Linked Data Enterprise as Enabler for Both Intra – and Inter-organizational Business Data Integration and Usage** 1521  
A M. Tjoa

## PAPERS

- Time Series Model for Sales Predictions in the Wholesale Industry** 1527  
T. Hlupić, D. Oreščanin, A.M. Petrić
- Business Intelligence Approach to Support Decision Making in Publishing Sector** 1532  
D. Borissova, N. Keremedchieva, D. Keremedchiev
- ERP Solutions in Cloud Technologies as a Driver for Digital Transformation of Businesses** 1538  
S. Križanić, T. Šestanjan-Perić, A. Kutnjak
- Towards an Agile Framework for Business Intelligence Projects** 1544  
M. Prouza, S. Brodinová, A M. Tjoa
- A Different Approach for Clique and Household Analysis in Synthetic Telecom Data Using Propositional Logic** 1550  
S. Skansi, K. Šekrst, M. Kardum
- Sentiment Analysis of Tweets about COVID-19 Disease during Pandemic** 1554  
G. Matošević, V. Bevanda
- Role of Business Intelligence Systems in Croatian Higher Education Quality Assurance** 1560  
M. Cvitanušić Brečić
- Study of Customer Behavior in Online B2B Shopping** 1565  
E. Exenberger, J. Bucko
- Fruit Firmness Prediction Using Multiple Linear Regression** 1570  
T. Ivanovski, G. Zhang, T. Jemrić, M. Gulić, M. Matetić
- Applying the Decision Tree Method in Identifying Key Indicators of the Digital Economy and Society Index (DESI)** 1576  
A. Kutnjak, L. Hrustek, S. Križanić

<b>Determining the Location of Postal Centers in B&amp;H Using Machine Learning Clustering Method and GIS</b>	1582
A. Kosovac, E. Muharemović, M. Begović, E. Šimić	
<b>Defining ERP System Selection Methodology – Research Carried Out in Small and Medium-Sized Production Companies in Croatia</b>	1587
A. Mahmutović, M. Nikitović	
<b>Implementacija ERP sustava iz perspektive konzultanata</b>	1593
I. Kostanjevec, R. Picek	

## **DIGITAL ECONOMY AND DIGITAL SOCIETY**

### **PAPERS**

<b>E-Democracy Tools Adoption: Experience of Austria, Croatia, Italy, and Slovenia</b>	1603
V. Roblek, I. Strugar, M. Meško, M. Pejić Bach, B. Jaković	
<b>The Importance of Digitizing the Management Processes of Sports Associations in the City of Zadar</b>	1610
J. Miočić	
<b>Youth Perception on 5G Networks in Osijek</b>	1615
D. Turkalj, I. Kelić, J. Rašić	
<b>Digitalization Impacts on Innovation Networks: Policy and Estimations Issues</b>	1621
O. Kudrina, V. Omelyanenko, H. Shevtsova, V. Samoday, Yu. Mashyna, V. Bilyk	
<b>A Literature Review of Digital Transformation in Healthcare</b>	1625
L. Ivančić, Lj. Milanović Glavan, V. Bosilj Vukšić	
<b>Creating of Digital Life in Art Museums</b>	1630
D. Ilišević, N. Banović-Čurguz, S. Vujković	
<b>SWOT Analysis of Selected Digital Technologies in Transport Economics</b>	1635
M. Jović, E. Tijan, D. Žgaljić, P. Karanikić	
<b>Shared Services Business Model in ICT Environment</b>	1641
T. Žilić	
<b>Optimization of Cargo Container Loading on Railway Wagons</b>	1647
S. Aksentijević, E. Tijan, M. Jović, N. Munitić	

<b>Applying Adaptive Neuro-Fuzzy Inference System (ANFIS) while Analysing Interdependencies of Tax Burden and Capital Structure of Croatian Hotel Companies</b>	1653
S. Brlečić Valčić, A. Samodol, M. Valčić	
<b>Synergy of Innovation Procedures and Communication Skills as a Success Predictor in IT Supported Management</b>	1660
J. Dvorski, A. Bernik, D. Radošević	
<b>Cloud-based Services Approach as Accelerator in Empowering Digital Transformation</b>	1664
H. Mydyti, J. Ajdari, X. Zenuni	
<b>Performance Analysis of Aruba Wireless Local Network in Croatian Pension Insurance Institute</b>	1671
A. Skendžić, B. Kovačić, L. Ljubičić	
<b>A Study of Coordination Challenges in Digital Policy Implementation and Evaluation in Finland</b>	1676
O.C. Osifo	
<b>Port Community System Feasibility Analysis – Case Study Split</b>	1684
I. Torlak, E. Tijan, S. Aksentijević, A. Jugović	
<b>Digital Business Models in the Logistics Services</b>	1690
A. Gačić, T. Poletan Jugović, E. Tijan, A. Jugović	
<b>Using Fuzzy Logic in Analysing and Modelling the Reflection of Monetary and Fiscal Conditions on GDP Per Capita in Croatia</b>	1696
A. Samodol, S. Brlečić Valčić, A. Ostojić	
<b>The Role of Perception in the Adoption of Digital Platforms in Agriculture</b>	1703
K. Tomičić-Pupek, I. Pihir, M. Tomičić Furjan	
<b>Social Entrepreneurial Intention: Does the Classroom Matter?</b>	1709
I. Kedmenec	
<b>Digital Transformation of Monitoring Customer Behaviour in the Cars Sales</b>	1715
I. Radoš, M. Hajnić, I. Radoš	
<b>“Financial” Aspects of Spotify Streaming Model</b>	1720
J. Lozić, G. Vojković, M. Milković	
<b>Value of Innovation Platforms in Agriculture</b>	1725
M. Tomičić Furjan, L. Hrustek, I. Pihir	
<b>Decision Making on Digital Platforms in Agriculture</b>	1731
N. Kadoić, K. Tomičić-Pupek, N. Vrček	



<b>Inovacije i tehnološki napredak u poslovanju morskih luka i njihov utjecaj na gospodarstvo</b> G. Mudronja	1737
<b>Digitalna transformacija pomorskog transporta kao dijela Plave ekonomije</b> M. Jović, A. Agatić, A. Jugović	1743
<b>Specifičnosti Uberovog modela prijevoza s primjenom u Republici Hrvatskoj</b> K. Jugović, A. Jugović, S. Hess	1749

## INFORMATION AND COMMUNICATION TECHNOLOGY LAW

### PAPERS

<b>Application of the General Data Protection Regulation in Schools: A Qualitative Study with Teachers, Professional Associates and Principals</b> L. Vejmelka, T. Katulić, M. Jurić, M. Lakatoš	1759
<b>IoT Devices and the Need to Inform Utility Users of Collecting, Controlling and Processing of Personal Data</b> G. Vojković, M. Milenković	1766
<b>Use of Security Settings on Social Networks of Elementary and High School Students in the Split-Dalmatia County</b> R. Matković, L. Vejmelka, Ž. Ključević	1772
<b>Visual Analysis of Similarity and Relationships between Legal Texts</b> J. Opiša, T. Pelech-Pilichowski	1778
<b>Privacy Policy Understandability Analysis of Croatian Electronic Publications</b> M. Alić	1784

## ENGINEERING EDUCATION

### PAPERS

<b>Closing the Gender Gap in Engineering: Students Role Model Program</b> E. Vidal, E. Castro, S. Montoya, K. Payihuanca	1793
---	------

<b>Integrating Industry Seminars within a Software Engineering Module to Enhance Student Motivation</b> G.J. Collins	1797
<b>From Framework Programs to Teaching: Integrating Experience from European Research Projects in Teaching Engineering</b> W. Brenner, N. Adamović	1803
<b>Teamwork Challenges and Solution Strategies of First-Semester Engineering Students</b> A. Gorup, M. Grzunov, J. Petrović, P. Pale	1809
<b>Differences in the Students' Achievements between Traditional and Project-Based Learning of Basic Engineering Competencies: A Quasi-experimental Study</b> D. Purković, M. Prihoda	1814
<b>Computer-Based Question and Exam Evaluation in Summative Knowledge Assessment</b> S. Tomić, V. Paunović, I. Bosnić	1820
<b>Students' Perception of Summative Peer Review Grading</b> L. Zrnić, L. Korov, J. Petrović, P. Pale	1826
<b>Assessing Students' SQL Knowledge and Skills in Gamification Manner</b> G. Tuparov, D. Keremedchiev	1831
<b>Changing the Assessment Process in Mathematics for Students in Engineering</b> P.V. Georgieva, E. Nikolova	1837
<b>Design of Rubrics for Student Outcomes in 2019-2020 ABET Criteria</b> B. Pejčinović	1843
<b>Electronic Learning Experience Setup: Power Electronics and Electrical Drive Education</b> P.J. van Duijsen, D.C. Zuidervliet, J.B. Woudstra	1849
<b>Study of Switching Forward Single-ended DC/DC Converter in the Course "Power Supplies"</b> S.L. Zaharieva, I.I. Stoev, A.N. Borodzhieva, S. Stoyanov	1855
<b>Designing an Interactive Multimedia Application for the Course "Communication Circuits"</b> A.N. Borodzhieva	1861
<b>Integrated Laboratory Complex</b> R. Simionov, S. Mollova, R. Dolchinkov	1867

<b>Elastic Collisions Visualization Using OpenCV Object Motion Tracking</b> M. Hajba, E. Ciriković, M. Pecimotika	1873
<b>Educational Computer Games and Gamification at the Higher Education – Students’ Points of View</b> D. Tuparova, G. Tuparov, D. Orozova	1879
<b>Using Moodle e-Learning Platform in Mechanical Engineering Lectures</b> P. Tomšič, I. Demšar, T. Finkšt	1885
<b>Creation of Software Platform for Distance Use of Lab Equipment and Data in Virumaa College at Tallinn University of Technology</b> O. Shvets, K. Murtazin, G. Piho	1891
<b>FPGA Design of Boolean Functions Using a Cascade of Decoders and Logic Gates</b> A.N. Borodzhieva, I.I. Stoev, I.D. Tsvetkova, S.L. Zaharieva, V.A. Mutkov	1896
<b>Interactive Approach to Digital Logic</b> M. Špoljarić, M. Hajba, M. Pecimotika	1901
<b>Analysis of Secure Data Deletion and Recovery with Common Digital Forensic Tools and Procedures</b> S. Žulj, D. Delija, G. Sirovatka	1907
<b>MS Excel-Based Application for Implementing the Cryptographic Algorithm Shamir's Secret Sharing</b> A.N. Borodzhieva	1911

## SOFTWARE AND SYSTEMS ENGINEERING

### PAPERS

#### SOFTWARE SYSTEM ARCHITECTURES

<b>Database Integration Systems</b> J. Dončević, K. Fertalj	1923
<b>Microservice Performance Degradation Correlation</b> M. Samardžić, R. Šajina, N. Tanković, T. Galinac Grbac	1929
<b>Robust and Scalable Online Code Execution System</b> H.Z. Došilović, I. Mekterović	1933
<b>Adapting CERIF for a National CRIS: A Case Study</b> D. Kremenjaš, P. Udovičić, O. Orel	1939

**Knowledge-Based System for Data Modelling Based on Verbalisation – an Architecture Proposal** 1945  
S. Šuman, A. Jakupović, M. Kaluža

## **QUALITY ASPECTS**

**Investigation of the Accessibility of Non-Text Content Published on Websites** 1953  
K. Kous, S. Kuhar, A. Rajšp, B. Šumak

**RESCCUE RAF App – Using Technology to Mitigate Climate Change Urban Impacts** 1959  
P. Lopes, A. Oliveira, C. Pereira, R.S. Brito, M.A. Cardoso, R. Martins, M. David, J. Gomes, J. Pina

**The Advantage of Using SWOT Analysis for Companies with Implemented ITIL Framework Processes** 1964  
A. Granulo, A. Tanović

## **TECHNOLOGIES**

**Smart Contracts as a Diploma Anti-Forgery System in Higher Education - a Pilot Project** 1973  
D. Čeke, S. Kunosić

**A Review on Generating Random Numbers in Decentralised Environments** 1979  
S.D. Simić, R. Šajina, N. Tanković, D. Etinger

**Accessibility Standards and Their Implementation in Custom Data-Driven Maps** 1985  
I. Serna-Marjanović, A. Tanović, A. Čerimagić

**Improvements of Computer Assisted Virtual Environment (CAVE)** 1991  
M. Fandáková, K. Záborská, B. Bučko, M. Zábovský

## **APPLICATIONS**

**The Order Batching Concept Implemented In Real Smart Warehouse** 1999  
S. Delalić, E. Žunić, A. Alihodžić, E. Selmanović

**Integration of Photogrammetry within Laser Scanning Approach** 2005  
P. Kudela, M. Palčák, K. Záborská, B. Bučko

**Some Elements for Assessing the Radiated Heat in Urban Areas** 2009  
I. Kožar, K. Peša, M. Cuculić, N. Torić Malić

## PROFESSIONAL PAPER IN CROATIAN

**Unity – 3D i virtualna stvarnost** 2015  
B. Fulanović, V. Šepl

## MIPRO JUNIOR - STUDENT PAPERS

### PAPERS

**Development of Portable System for Determination of Aircraft Motion** 2023  
S. Marijan, D. Franjković

**Small Piston Engine Aircraft Vibration Measurement and Analysis** 2029  
F. Juretić, D. Gerhardinger, A. Domitrović, J. Ivošević

**Mazzilli Oscillator as a Tool in Education** 2035  
L. Matić, S. Stojanović, V. Šimović

**An Interactive Punch Power Tracker for Heavy Bag Training** 2040  
A. Vinković, I. Linardić, D. Meštrović, J. Petrović, P. Pale

**Simulink Model of Oxygen Distribution in Skeletal Muscle** 2044  
A. Džuho, A. Aleta, S. Pandža, I. Ramić, N. Mamatzarov, L. Spahić

**Multi-Model Databases - Introducing Polyglot Persistence in the Big Data World** 2048  
I. Košmerl, K. Rabuzin, M. Šestak

**Hot Topic Detection Using Twitter Streaming Data** 2054  
T. Jagić, Lj. Brkić

**Processing and Visualization of Collected Data Based on Open-Source Tools and Principles** 2060  
S. Grbac Babić, K. Cetina

**Web Application Dashboards as a Tool for Data Visualization and Enrichment** 2064  
M. Holjevac, T. Jakopec

**Razvoj sustava za upravljanje rasporedom sati** 2070  
A. Šturlan, K. Vučković, T. Orehovački

**Enhancing Performance of Cloud-based Software Applications with GraalVM and Quarkus** 2076  
M. Šipek, D. Muharemagić, B. Mihaljević, A. Radovan

<b>Achieving Efficient Structured Concurrency through Lightweight Fibers in Java Virtual Machine</b>	2082
P. Pufek, D. Beronić, B. Mihaljević, A. Radovan	
<b>Use of Keystroke Dynamics and a Keystroke-Face Fusion System in the Real World</b>	2088
J. Stavanja, P. Peer, Ž. Emeršič	
<b>Digital Forensics Appliance in Corporate Ecosystem Considering Limitations in the EU Legal Framework</b>	2094
V. Rajič, M. Milenković, G. Vojković	
<b>Using Convolutional Neural Network for Chest X-ray Image Classification</b>	2101
M. Sorić, D. Pongrac, I. Inza	

## **SMART, SUSTAINABLE AND RESILIENT CITIES AND INFRASTRUCTURE**

### **PAPERS**

<b>Creating Sustainable Solutions for Photovoltaics</b>	2111
W. Brenner, N. Adamović	
<b>Use of Drone to Improve Healthcare Efficiency and Sustainability</b>	2117
L. Faramondi, G. Oliva, L. Ardito, A. Crescenzi, M. Caricato, M. Tesei, A. Onetti Muda, R. Setola	
<b>A Privacy-Oriented Solution for the Improvement of Workers Safety</b>	2123
L. Faramondi, P. Bragatto, C. Fiorevanti, M.G. Gnoni, S. Guarino, R. Setola	
<b>LoRa-SDN: Providing Wireless IoT Edge Network Functions via SDN</b>	2129
F. Holik, U. Roedig, N. Race	
<b>Analyses of Ecological and Energy Footprint as Indicators of Energy Management in the Transition to Sustainability Using Social Networks</b>	2135
B. Mihajlovski, B. Fetaji, L. Abazi-Bexheti, M. Fetaji	
<b>Review of Discrete Simulation Modelling Use in the Context of Smart Cities</b>	2141
M. Jadrić, M. Čukušić, D. Pavlić	
<b>Traffic State Estimation Using Speed Profiles and Convolutional Neural Networks</b>	2147
L. Tišljarić, T. Carić, T. Erdelić, M. Erdelić	

<b>Stakeholder Support as Critical Success Factor in Adopting Big Data Technologies for Smart Cities</b> J. Pivar, N. Vlahović	2153
<b>Enhancing Occupants Comfort and Well-being through a Smart Office Setup</b> A. Barišić, V. Amaral, M. Challenger	2159
<b>Innovative Predictive Model for Smart City Security Risk Assessment</b> L. Franchina, A. Socal	2165
<b>Digitalization and Smart Islands in the Kvarner Archipelago</b> M. Mimica, G. Krajačić, D. Medved, D. Jardas	2171
<b>Autonomous Mobility and User Perception: A Case of City as a Lab in Slovenia</b> I. Zajc, R. Sernec, G. Lenart, A. Pucihar	2177
<b>The European Infrastructure Simulation and Analysis Centre (EISAC) Initiative and Its Technological Assets</b> V. Rosato, A. Tofani, A. Di Pietro, M. Pollino, S. Giovinnazzi, L. Lavalle, G. D'Agostino	2182
<b>Comparative Analysis of the Selected Practices in the Field of Urban Logistics of the Polish Cities</b> M. Zysińska	2186
<b>Unleashing the Power of Urban Living Labs to Make our Cities Humanly Smart</b> F. Molinari, B. Kovačić	2192
<b>The Potential of Mobile Energy Storage in Microgrids</b> H.H. Abdeltawab, Y.A.I. Mohamed	2198

## OPTOELECTRONICS AND PHOTONICS

### PAPERS

<b>Analysis of a-Si:H p-i-n Photodiode Detection of HeLa Cells Luminescence</b> V. Gradišnik	2209
<b>Plasmonic Enhanced Photodetectors for Near Infra-red Light Detection</b> D. Giubertoni, G. Paternoster, F. Acerbi, X. Borrísé, A. Cian, A. Filippi, A. Gola, A. Guerrero, F. Perez Murano, F. Romanato, E. Scattolo, P. Bellutti	2214
<b>Variable Angle Spectroscopic Ellipsometry Study of Poly(3,4-ethylenedioxythiophene):Polystyrene Sulfonate Thin Films in Contact with Air</b> G. Pathak, D. Čakara	2219

<b>Radiation Pressure Sensor</b>	2228
M. Karuza, D. Božičević, G. Cantatore, M. Vretenar	
<b>Measurement of the Human Cadaver Ossicle Vibration Amplitude by Fiber-Optic Interferometry</b>	2232
Z. Djinovic, M. Tomic, R. Pavelka, G. Sprinzl, H. Traxler	
<b>Marine Fiber Optic and Spinning Mass Gyrocompasses</b>	2237
A. Škrobonja, I. Jurdana , I. Panić, N. Wakabayashi	

## DEW COMPUTING

### PAPERS

<b>Microservice Approach to the Qualitative Study of Attractors of Binary Dynamic Systems Based on the Boolean Constraint Method</b>	2247
G.A. Oparin, V.G. Bogdanova, A.A. Pashinin	
<b>Impact of Dew Computing on Cyber-Physical Systems and IoT</b>	2253
M. Gusev	
<b>The Rainbow through the Lens of Dew</b>	2259
Z. Šojat, K. Skala	
<b>A Disaster-Resilient Messaging Protocol Based on Dew Computing</b>	2265
Y. Wang	
<b>Ensuring Resource Availability with MRU/FRU Caching: A Dew-Blockcloud Model</b>	2270
C. Chukwuocha, R.K. Thulasiram, P. Thulasiraman, Y. Wang	
<b>The Relevance of Blockchain with Dew Computing: a Review</b>	2277
R.N.A. Sosu, C.N. Babu, S.A. Frimpong, J. Essuman	



# Measurement of the human cadaver ossicle vibration amplitude by fiber-optic interferometry

Z. Djinovic\*, M.Tomic \*\*, R. Pavelka\*\*\*, G. Sprinzi\*\*\*\*, H. Traxler\*\*\*\*\*

\* ACMIT Gmbh, Wiener Neustadt, Austria

\*\* Institute of Technical Sciences of SASA, Belgrade, Serbia

\*\*\*ENT specialist, Wiener Neustadt, Austria

\*\*\*\*University Hospital St. Pölten, Austria

\*\*\*\*\*Medical University of Vienna, Centre for Anatomy and Cell Biology, Vienna, Austria

[zoran.djinovic@acmit.at](mailto:zoran.djinovic@acmit.at)

**Abstract** – In this paper we present the results obtained by contactless measurement of vibration of the incus inside the middle ear of a human cadaver, exposed to an external calibrated sound source. The measurement configuration was a Michelson fiber-optic interferometer based on a 3x3 fiber optic coupler, with a VCSEL source. The interferometric signal fading was solved using two quasi-quadrature signals and specialized signal processing. The ossicle reflection was augmented by a very light piece of retroreflective material attached to the bone. We measured the amplitude of vibration at different sound pressure levels, independently monitored by a decibel meter placed in the proximity of the cadaver ear. The accuracy of the measurement technique was proved by using a calibrated piezo transducer exposed to vibrate with amplitude of 7nm at 1kHz. We performed the experiments on 8 cadavers in total. The measured amplitudes were found to be in the range between 1 pm and 1 nm, under the sound excitation of 40-90 dB SPL @ 1kHz, respectively.

**Keywords** - fiber-optic sensors; vibration measurement; implantable microphone; hearing aid;

## I. INTRODUCTION

Two main hearing insufficiencies, middle ear otosclerosis and sensorineural impairment, lead to partial or total hearing loss in millions of people all around the world [1-2]. Very often, they can be overcome by common external hearing aids. However, some patients, having sensorineural malfunction, need to have an implantable hearing device such as cochlear implant (CI) [3-4]. Most implantable cochlear devices today can operate thanks to external microphone that receive the ambiental sound pressure and transmit the processed audio signal through the skull bone to the CI. Basically, this helps a lot to the patients, especially to children to develop the speech in the early age [5]. However, the external microphone is always associated with some drawbacks such as difficulties to perform common life activities including sleeping and swimming as well as social stigmatization.

Many groups in the art [6-10] trying to develop a totally implantable hearing aid having implantable microphone within the device. It is a challenge task, since several requirements have to be fulfilled including high sensitivity and robustness in terms of long-term application in biologically active environment [11]. In this scope it is very important to meet a few clinical requirements including biocompatibility, hermeticity, corrosion resistance against body fluids, overall size and energy consumption and safety application [12].

It appears that fiber-optic sensing technology can fulfill many of aforementioned demands. We already demonstrated capability of this technology [13-14] to be applied for the design and manufacturing of implantable microphone. However, we also met some issues, which require improvements in order to claim a list of technical demands of an implantable microphone. For this reason, we investigated sensitivity and dynamic range of a fiber-optic interferometric technique aimed to be used for manufacturing an implantable microphone as a part of a totally implantable hearing aid.

In this paper we present the results obtained by contactless measurement of vibration of the incus inside the middle ear of a human cadaver, exposed to an external calibrated sound source. We measured the amplitude of vibration at different sound pressure levels (SPL), independently monitored by a decibel meter placed in the proximity of the cadaver ear. The accuracy of the measurement technique was proved by using a calibrated piezo transducer (PZT). We performed the experiments on eight cadaver heads in total. The amplitudes of vibration at 1 kHz were found to be in the range between 1 pm and 1 nm, under the common speech range of sound pressure level.

## II. PRINCIPLE OF OPERATION

The sensing configuration, based on modified Michelson interferometer using a single mode 3x3 fiber-optic coupler (FOC3x3), is presented in Fig.1. The middle input arm of the FOC3x3 is connected to a pigtailed laser diode (LAS).

---

This work was sponsored by the NÖ Forschung & Bildung (NFB), Austria and ACMIT Gmbh in the frame of the project: "Totally implantable fiber-optic sound sensing system for cochlear- and middle-ear hearing aids", Life Science grant: LS14-026.

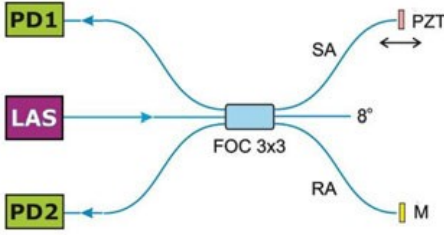


Figure 1. Principle of operation: the fiber-optic Michelson interferometer based on a 3x3 coupler. LAS – laser source, PD1, PD2 – photodiodes, FOC3x3 – single mode 3x3 fiber optic coupler. SA – sensing arm, RA – reference arm, M - mirror, PTZ – vibrating target.

The third arm, which is not necessary, is obliquely cleaved, in order to suppress back reflections. The other two input arms, acting in this case as the outputs, are connected to photodiodes (PD1, PD2), providing two quasi-quadrature interferometric signals [15].

The probe beam in SA is directed to the target, a vibrating PTZ, which is independently calibrated. The RA, being approximately equal in the optical length to the SA, is directed to the fixed mirror (M). A vibration of the target changes the length of the optical path in the SA and, consequently, the optical phase difference (OPD) between the two coupler arms. This OPD's changes generate the raw interferometric signals in both photodetectors, which can be represented by:

$$V_{PD1}(t) = V_{DC1} + V_{A1} \cos(k \cdot A \sin \omega t + L(t)) \quad (1)$$

$$V_{PD2}(t) = V_{DC2} + V_{A2} \cos(k \cdot A \sin \omega t + L(t) + \Psi)$$

where  $A$  and  $\omega$  are the amplitude and the frequency of the target vibration;  $\Psi$  is the phase shift ( $\sim 120^\circ$ ) introduced by the 3x3 coupler;  $V_{DC1}$  and  $V_{DC2}$  are DC signal levels at PD1 and PD2;  $V_{A1}$  and  $V_{A2}$  are interferometric amplitudes, which depend on the target reflection, the coherence degree between the beams and the alignment and state of polarization of the probing beam.  $L(t)$  is a random motion of the target, mainly caused by external vibrations. Since  $L(t)$  causes the change of the working point in the interferometric sinusoidal transfer function, neither photodetector signal alone can provide a stable amplitude detection. However, the constant phase shift  $\Psi$  between coupler arms allows elimination the influence of  $L(t)$ , by the suitable signal processing algorithm, based on the phase extraction from two photodiode signals [13]. The dependence on variable amplitudes  $V_{A1}$  and  $V_{A2}$  is also removed in this phase demodulation process. Two signals and its processing are absolutely necessary if the amplitude of measured vibration is smaller than half of the wavelength, which is certainly the case of human middle ear bone vibrations.

### III. EXPERIMENT

We employed the sensing configuration presented in Fig. 1 in the measuring set-up (Fig. 2), used for determination of amplitude of vibration of middle ear ossicles, examined on human cadavers.

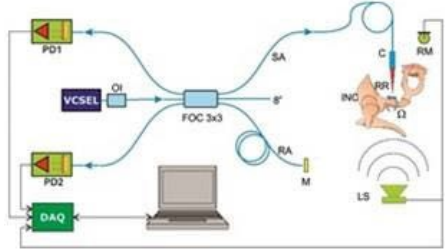


Figure 2. Setup for investigation of fiber-optic sensing configuration based on the miniaturized 3x3 coupler; VCSEL- Vertical Cavity Surface Emitting Laser, OI-optical isolator, SA, RA-sensing and reference arm, C- collimator, RR-retroreflector, M-mirror, PD-photodiode, DAQ-acquisition system, LS- loudspeaker, INC-incus, RM-reference microphone/decibelmeter

Experiments have been performed in a dissection room under the relatively quiet conditions at the Anatomy Division of the Medical University Vienna.

A pigtailed VCSEL diode, emitting at 1310nm, was used as a high-coherence light source. The laser pigtail was connected to the input arm of a single mode 3x3 fiber optic coupler via an optical isolator (OI), in order to suppress backreflections. The VCSEL was driven by low noise driver, with a current of 3mA, giving an optical power of about  $240\mu\text{W}$  out of the pigtail. Two lateral arms were connected to two InGaAs photodiodes (PD1 and PD2), which were further connected to the accompanied low-noise transimpedance amplifiers. Sensing and reference arms were very short, just about 100 mm in length, that was an acceptable length for the implantation. On the other hand, such a short length significantly contributed to decreasing the polarization effects. The sensing fiber was terminated by a spherical collimator (C), with  $450\mu\text{m}$  in diameter, aimed to the target. The reference arm was terminated by a 100% reflective golden surface layer (M).

The surgical procedure was performed in order to assure access to the incus of a human cadaver skull. It included a mastoidectomy and posterior epitympanotomy, with exposition of the short process and the body of the incus, which was the target in these experiments. The incus was equipped with a small piece of the retro-reflecting tape (RR), attached to the bone by a specially designed clip ( $\Omega$ ). The fiber-optic probe composed of reference and sensing arms, packed in a medical steel guiding needle, was directed and adjusted versus target in order to obtain the maximal signals on the PD1 and PD2. The use of the RR has been necessary to provide sufficiently amount of the reflected radiation [16].

The acoustical measurements have been performed by Affinity audiometer of Interacoustics Co. The calibrated system for generation of acoustic signals use the loudspeaker from JBL Incorporated®, Northridge, CA, control® CM52, set to be of about 70-80cm far away from the skull, capable to produce a pure acoustical stimuli in the range from 40 dB to 90 dB SPL re  $20\mu\text{Pa}$ . The reference microphone signal and two raw photodiode signals have typically been acquired with 32ks/Ch/s, in time duration of about 31 s, that makes 1 million of measuring points.

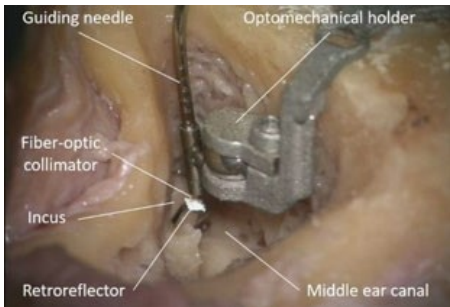


Figure 3. Close look at the middle ear canal and retroreflector firmly fixed over incus; fiber-optic probe set into the guiding needle

The decibel meter values have been recorded manually as an average data. The raw signals have been later offline processed by arctan algorithm, using the specially made software packet.

Before any measurement, the system was tested using a calibrated PZT actuator (Fig. 4), placed at the same distance from fiber-optic probe where the incus will be, about 2.5 mm from the fiber end. An identical piece of retroreflective material was adhesively bonded to the PZT actuator. The PZT was driven by a sinusoidal signal at 1kHz@1Vp-p, producing an amplitude of 7.4 nm.

#### IV. RESULTS AND DISCUSSION

The acquired photodiode signals by DAQ system obtained in the prior checking experiments, with the calibrated PZT, can be seen in Fig. 5, graph down right, in the form of Lissajous figure, after the first stage of processing. The PZT was driven by sinusoidal voltage 1V @1kHz, in the time interval from 1.5 s to 5.5 s. The very beginning of the period of acquisition is used to calculate the noise. Top left graph in Fig. 5 shows the demodulated and stabilized interference signal, i.e. the interferometer phase, obtained by the offline signal processing while the pilot signal is on, using the arcus tangent algorithm.

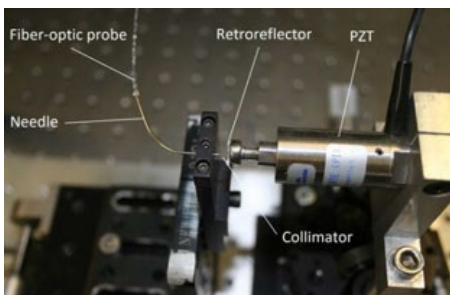


Figure 4. Close look at the fiber-optic sensing probe directed to the retroreflector bonded onto a calibrated PZT driven at 1 kHz, 7.4 nm amplitude

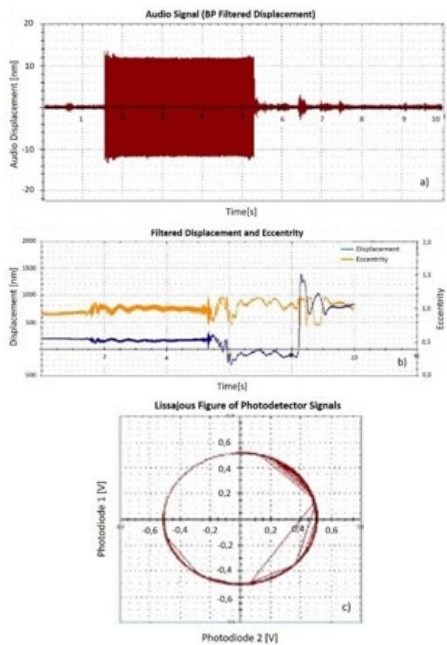


Figure 5. Processed data of PZT vibrations at 1Vp-p, 1kHz, representing: a) overall displacement, b) overall change of OPD of interference arms (blue line) and eccentricity of circle after processing (orange line) and c) Lissajous presentation of the processed signals

The processed signal reveals an RMS amplitude of PZT vibration of about 8 nm, that is in a good agreement with calibration data for 1kHz@1V of 7.4 nm. The accuracy of the measurement technique can be estimated to be better than 10%.

Figure 6 shows the signal and noise spectral density expressed in (nm/ $\sqrt{\text{Hz}}$ ), obtained by FFT analysis of processed signal over the acoustic frequency range. A sharp peak at 1kHz relates to the PZT vibration at this frequency. Several curves (gray and purple) correspond to the noise and pilot signal (green and magenta) parts of acquired data, with and without A-weighting. Based on these results, we calculated the minimum detectable amplitude of vibration of about 1,2  $\mu\text{m}/\sqrt{\text{Hz}}$ .

Fig. 7 presents the measured amplitudes of incus vibration of eight human cadavers, measured at 1kHz for SPL over 40 to 90 SPL. We can see that amplitude of incus vibrations at 40 SPL span from about 1 $\mu\text{m}$  to about 10 $\mu\text{m}$  depending on the cadaver specimen. Similarly, for 90 SPL the amplitude of incus vibrations take values from about 150 $\mu\text{m}$  to about 3nm depending on the subjected cadaver specimen.

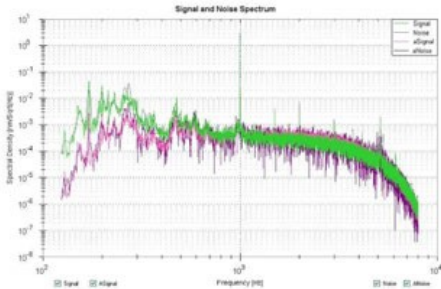


Figure 6. Signal and noise spectrum of PZT vibration at 1V@1kHz, with and without A-weighting

These results show a difference between the measured amplitude of vibrations that is in the range of one order of magnitude among the subjected cadaver specimens. It can be explained by various anatomic characteristic of the middle ear, age and previous health history of human cadavers as well as method of preparing of specimens (e.g. if they were deep forsen or not).

Generally, the obtained results are in relatively good agreement with literature data, which are obtained by amplitude measurement on temporal bones utilizing the Laser Doppler Vibrometry [17]. However, there is a discrepancy between the literature and our data concerning the amplitude measurement at 90 dB SPL and 1kHz. We obtained for about 10 to 20nm smaller amplitude of vibrations. Although, it is difficult to explain this difference without knowledge of the exact measurement and analysis techniques applied, we believe that the main reason is different hitting point of laser light. The literature data relate to the umbo instead incus displacement. The presented fiber-optic sensing technique demonstrated a high sensitivity. The minimum detectable amplitude of vibrations is about 1pm i.e. slightly below of 40 dB SPL.

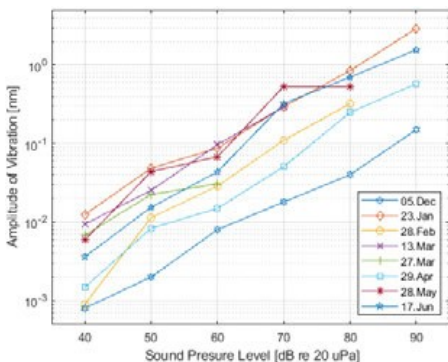


Figure 7. Amplitudes of eight human cadaver incus vibrations measured by fiber-optic interferometry at 1kHz

## V. CONCLUSION

The presented fiber-optic sensing technique, investigated by the human cadavers, demonstrated some promising features necessary for a prospective implantable microphone in terms of small dimensions and high sensitivity. The minimum detectable amplitude of incus vibrations of about 1pm corresponds with required technical demand of a totally implantable hearing aid [12]. It was experimentally found that amplitude of incus vibrations at 40 SPL spans from about 1pm to about 10pm, depending on the cadaver specimen. Similarly, for 90 SPL the amplitude of incus vibrations takes values from about 150pm to about 3 nm. The incus response shows a high linearity to acoustical excitation, with a sensitivity of 1-5 pm/mPa @1kHz.

## ACKNOWLEDGMENT

The authors thank to the ACMIT GmbH and NÖ Forschung & Bildung (NFB), Austria, which sponsored this work in the frame of the project: "Totally implantable fiber-optic sound sensing system for cochlear- and middle-ear hearing aids", Life Science grant: LS14-026. Many thanks to Miss Nina Tomic for creating some of the figures.

## REFERENCES

- [1] D. Young, and P. Cong, "Wireless implantable sensors: from lab to technology breakthrough ambitions". *Sensors and Actuators A*, Vol. 294, pp. 81–90, August 2019.
- [2] S.Park, X. Guan, Y. Kim, F. P. X. Creighton, E. Wei, I. J. Kymissis, H. H. Nakajima, and E. S. Olson, "PVDF-Based Piezoelectric Microphone for Sound Detection Inside the Cochlea: Toward Totally Implantable Cochlear Implants", *Trends in Hearing*, Vol. 22, pp. 1–11, April 2018.
- [3] A. M. Innes, R. P. Morse, Irving and P. Begg, "Implantable microphones as an alternative to external microphones for cochlear implants", *Cochlear Implants International*, Vol. 18, pp. 304-313, September 2017.
- [4] J. M. Ge'rrard, L. Demanez, C. Salmon, F. Vanpoucke, J. Walraevens, A. Plasmans, D. De Siaty, and P. Lefe'bvre, "Feasibility of an implanted microphone for cochlear implant Listening", *Eur Arch Otorhinolaryngol*, Vol. 274, pp. 1383–1390, November 2017.
- [5] H. A. Jenkins and K. Uhler, "Speech Perception Comparisons Using an Implanted and an External Microphone in Existing Cochlear Implant Users". *Otology & Neurotology*, Vol. 33, pp. 13-19, January 2012.
- [6] S. H. A. Woo, S. T. Woo, B. S. Song, and J. H. Cho, "Feedback characteristics between implantable microphone and transducer in middle ear cavity", *Biomed Microdevices*, Vol. 15, pp. 867–877, October 2013.
- [7] A. G. Bittencourt, P. R. Burke, I. S. Jardim, R. Brito, R. K. Tsuji, A. C. O. Fonseca, and R. F. Bento, "Implantable and Semi-Implantable Hearing Aids: A Review of History, Indications, and Surgery", *Int Arch Otorhinolaryngol*, Vol.18, pp. 303–310, April 2014.
- [8] F. Pfiffner, L. Prochazka, D. P'eus, I. Dobrev, A. Dalbert, J. H. Sim, R. Kesterke, J. Walraevens, F. Harris, C. Röö'sli, D. Obrist, and A. Huber, "MEMS Condenser Microphone-Based Intracochlear Acoustic Receiver", *IEEE Transactions on Biomedical Engineering*, Vol. 64, pp. 2431 – 2438, December 2017.
- [9] S. T. Woo, D. H. Shin, H. G. Lim, K. W. Seong, P. Gottlieb, S. Puria, K. Y. Lee and J. H. Cho, "A New Trans-Tympanic Microphone Approach for Fully Implantable Hearing Devices", *Sensors*, Vol. 15, pp. 22798-22810, September 2015.
- [10] D. Calero, S. Paul, A. Gesing, F. Alves and J. A. Cordioli, "A technical review and evaluation of implantable sensors for hearing

devices”, *BioMed Eng OnLine*, Vol. 17, pp. 1-26, February 2018.

- [11] J. W. Zwartenkot, “Auditory Implants in Otology-Active Middle Ear Implants and Direct Acoustic Cochlear Stimulation: Indications and Outcome”, PhD Thesis, Radboud University, 2017.
- [12] D. Calero, S. Paul, and J. A. Cordioli, “On implantable sensors for totally implantable hearing aids, 5th Joint Meeting of the ASA and ASJ, Honolulu - November 29, 2016.
- [13] M. C. Tomic, Z. V. Djinovic, and S. J. Petricevic, “Demodulation of quasi-quadrature interferometric signals for use in the totally implantable hearing aids”, *Biomed. Opt. Express*, Vol. 8, pp. 3404–3409, July 2017.
- [14] Z. Djinović, R. Pavelka, M. Tomić, G. Sprinzl, H. Plenke, U. Losert, H. Bergmeister, R. Plasenzotti, “In-vitro and in-vivo measurement of the animal's middle ear acoustical response by partially implantable fiber-optic sensing system”, *Biosensors and Bioelectronics*, Vol. 103, pp. 176–181, October 2018.
- [15] K. P. Koo, A. B. Tveten, and A. Dandridge, “Passive stabilization scheme for fiber interferometers using (3x3) fiber directional couplers,” *Appl. Phys. Lett.*, Vol. 41, pp. 616–618, July 1982
- [16] M. Koch, T. M. Essinger, T. Stoppe, N. Lasurashvili, M. Bornitz, and T. Zahnert, “Fully implantable hearing aid in the incudostapedial joint gap”, *Hearing Research* vol. 340, pp. 169-178, March 2016.
- [17] U. B. Willi, “Middle-ear Mechanics: The Dynamic Behavior of the Incudo-Malleolar Joint and its Role During the Transmission of Sound,” PhD Thesis, Uni. Zürich, 2003.