BULLETIN OF THE POLISH ACADEMY OF SCIENCES
TECHNICAL SCIENCES, Vol. 68, No. 2, 2020
DOI: 10.24425/bpasts.2020.131851

EDITORIAL

SPECIAL SECTION

# Computational Intelligence and Optimization Techniques in Communications and Control

J. SZCZEPAŃSKI, J. KLAMKA, K. WĘGRZYN-WOLSKA, I. ROJEK and P. PROKOPOWICZ

The objective of this Special Section on *Computational Intelligence and Optimization Techniques in Communications and Control* is to present recent advances and applications of Ordered Fuzzy Numbers (OFNs), computational intelligence (CI) and other optimization methods for communication security, assessing the effectiveness of routing techniques in wireless networks, automatic sound recognition, the analysis of brain signals, routing and switching in optical networks, and process control.

The inspiration for this Special Section was the International Conference on Professor Witold Kosiński's Heritage and the Workshop on Ordered Fuzzy Numbers held in Bydgoszcz in 2016. The papers comprised in the present issue of the *Bulletin of the Polish Academy of Sciences: Technical Sciences* are grouped into two main categories: "Computational Intelligence", exploring fuzzy numbers, and "Optimization Techniques in Communications and Control".

Many phenomena in physics, economics, biochemistry, and meteorology exhibit unpredictable features because of their inherent stochasticity and high variability [1]. They require a mathematical description which takes into account their complex nature. This has led the scientists to formulate and develop appropriate mathematical tools to handle them. The main approaches range from the theory of stochastic processes and random dynamical systems to information theory and, recently, fuzzy numbers [2]. They are associated with optimization issues and the application of artificial intelligence (AI), computer intelligence and machine learning (ML) based algorithms.

Fuzzy numbers play an important role in optimization and data mining as decision criteria. They have been successfully implemented in multi-modal function optimization, the prediction of exchange rates, the aggregation of norms, and facial pattern recognition [3]. Their mathematical structure even enables biological systems to be described, including gene expression analysis. Many scientists have attempted to extend the concept of fuzzy numbers. In this field, Professor Kosiński's proposal of Ordered Fuzzy Numbers [4] has been attracting increasing attention in recent years. It is, in a way, an alternative to Zadeh's fuzzy numbers approach [5] for managing vagueness in quantitative data. The OFNs are based on the idea of splitting membership functions. The order of such parts is independent of the values from these functions' domain. In this way, a new feature, the so-called direction, which allows the data trend and tendency to be described, is included. It is noted that research and publications using the OFN method are appearing increasingly frequently in soft computing, natural language processing, and biomedical signal classification. The development of CI allows a new direction for real-world problem modeling to be determined and a more precise exploration of the uncertainty of the parameters in the evaluation process to be performed. This contributes to the design of the next generation of computers, which will be able to self-solve complex problems and learn from their own experiences. Also, intensive research on the application of CI in biomedical engineering is ongoing. This will support the intelligent monitoring of patients and help deliver targeted and personalized medicine, while ensuring smooth communication and high productivity in medical units.

This Special Section includes papers on topics briefly described below.

## 1. Application of computational intelligence inspired by fuzzy numbers

Paper [6] is devoted to theoretical aspects of the defuzzification method, which can be implemented in fuzzy controllers. Fuzzy logic is a form of intelligence software which allows for translation from logic statements into nonlinear mapping. The authors compare the proposed center of circles intersection method with a similar geometric solution. It is shown that the proposed methodology works correctly and provides unique results for traditional and Ordered Fuzzy Numbers.

Manuscript submitted 2020-03-09, revised 2020-03-20, initially accepted for publication 2020-03-21, published in April 2020

Gait analysis for post-stroke rehabilitation purposes using fuzzy numbers, fractal dimension, and neural networks is presented in [7]. Fuzzy numbers modeling is supported by the statistical analysis of biomedical signal processing to benefit from enhanced computation technology possibilities.

Product lifecycle modeling is considered using the CI approach in papers [8–9]. The first one compares the effectiveness of selected ML methods (RBF networks, Kohonen networks, and random forest) as modeling tools supporting the selection of materials in eco-design. In turn, paper [9] is devoted to the end-of-life oriented product design. To support the designers during the process of design, agent technology operating in the PLM environment is used. These technologies allow, among others, for boosting the recycling properties of products.

## 2. Optimization techniques in communications and control

The downlink of an orthogonal frequency division multiplexing based cell that accommodates calls from different service-classes with different resource requirements is considered in [10]. The important performance metrics are modeled using a multi-rate loss model. The optimization techniques proposed lead to reducing the calculation complexity based on a product form solution of the steady-state models' probabilities.

Optimization of information transmission and its processing in the brain is studied in paper [11]. To analyze the transmission efficiency, Shannon's information theory was applied. The probabilistic Levy-Baxter neuron model, which comprises essential information transfer mechanisms, is used. The results obtained support the hypothesis that basic components of neurons and brain architecture evolve to address optimization of the transmission efficiency.

Computer methods for calculating tuple solutions of polynomial matrix equations and their conditions are described in [12]. The special scheme of development of solution in the matrix continued fraction allows to optimized iterative process in solving matrix equations, including Riccati equation.

An optimal solution against denial of service (DoS) attacks is analyzed in work [13]. The authors present a concept of user authentication in IP communication, which consists of providing the receiver with the possibility to determine the sender's identity at the Internet layer level.

A replacement methodology in the context of heart rate variability (HRV) computation was proposed in paper [14]. To simulate removed data, authors implement a random suppression data procedure. This methodology allows for modeling stress based on HVR signals.

Paper [15] is devoted to the optimization of information transmission in a network servicing elastic traffic. The authors propose the balanced bandwidth-based concept to model the traffic. Bandwith discretization is applied to obtain the dependencies from the assumptions adopted in the generalized Kaufman-Roberts equation. The analytical results are successfully verified numerically.

A new methodology for the implementation of cloud manufacturing (CM) architecture is presented in paper [16]. CM is a current paradigm in which dynamically scalable and virtualized resources are provided to users as services over the Internet. The CM architecture is employed to map users and providers of manufacturing resources. The aim is to reduce costs and development time during a product lifecycle. The basic idea proposed in the paper is to apply semantic web technologies such as ontologies to tackle this issue. It turns out that the CM ontology contributes more effectively to intelligent and automated service discovery.

**Acknowledgments.** We would like to thank all authors who have contributed to this Special Section of the *Bulletin*. We would like to express our deep gratitude to the reviewers for their efforts and valuable comments, which contributed significantly to improving the quality of the papers. Very special acknowledgments are addressed to Professor Marian Kaźmierkowski, Editor-in-Chief, and all members of the Editorial Board for allowing Guest Editors to present this Special Section. Finally, we would like to thank Ms. Renata Podraza, Copy Editor, for her professional assistance.

## References

[1] J. Klamka, "Controllability of dynamical systems. A survey", *Bull. Pol. Ac.: Tech.* 61(2), 335–342 (2013).

[2] W. Kosiński, P. Prokopowicz, and A. Rosa, "Defuzzification functionals of ordered fuzzy numbers", *IEEE Transactions on Fuzzy Systems* 21(6), 1163–1169 (2013).

[3] P. Prokopowicz, "The use of ordered fuzzy numbers for modeling changes in dynamic processes", *Information Sciences* 470, 1–14 (2019).

[4] W. Kosiński, P. Prokopowicz, and D. Ślęzak, "Ordered fuzzy numbers", *Bulletin of the Polish Academy of Sciences, Mathematics* 51(3), 327–338 (2003)

[5] L.A. Zadeh, "Fuzzy sets", *Information and Control* 8, 338–353 (1965).

[6] H. Zarzycki, W. Dobrosielski, T. Vince, and Ł. Apiecionek, "Center of circles intersection, a new defuzzification method on fuzzy numbers", *Bull. Pol. Ac.: Tech.* 68(2), 185–190 (2020).

[7] P. Prokopowicz, D. Mikołajewski, K. Tyburek, and E. Mikołajewska, "Computational gait analysis for post-stroke rehabilitation purposes using fuzzy numbers, fractal dimension and neural networks", *Bull. Pol. Ac.: Tech.* 68(2), 191–198, (2020).

[8] I. Rojek, and E. Dostatni, "Machine learning methods for optimal compatibility of materials in ecodesign", *Bull. Pol. Ac.: Tech.* 68(2), 199–206 (2020).

[9] J. Diakun, and E. Dostatni, "End-of-life design aid in PLM environment using agent technology", *Bull. Pol. Ac.: Tech.* 68(2), 207–214 (2020).

[10] J.P. Panagoulias, I. Moscholios, P. Sarigiannidis, M. Piechowiak, and M. Logothetis, "Performance metrics in OFDM wireless networks supporting quasi-random traffic", *Bull. Pol. Ac.: Tech.* 68(2), 215–223 (2020).

[11] B. Paprocki, A. Pregowska, and J. Szczepanski, "Optimizing information processing in brain-inspired neural networks", *Bull. Pol. Ac.: Tech.* 68(2), 225–233 (2020).

[12] J. Dorożyński, and M. Nedashkovskyy, "Computer methods for calculating tuple solutions of polynomial matrix equations", *Bull. Pol. Ac.: Tech*. 68(2), 235–243 (2020).

[13] Ł. Apiecionek, J.M. Czerniak, M. Romantowski, D. Ewald, B. Tsizh, H. Zarzycki, and W.T. Dobrosielski, "Authentication over internet protocol", *Bull. Pol. Ac.: Tech*. 68(2), 245–253 (2020).

[14] T. Amira, I. Dan, and K. Wegrzyn-Wolska, "Missing-data imputation using wearable sensors in heart rate variability context", *Bull. Pol. Ac.: Tech.* 68(2), 255–261 (2020).

[15] P. Zwierzykowski, M. Piechowiak, M. Stasiak, B. Nowak, "An analytical model of a system with priorities servicing a mixture of different elastic traffic streams", *Bull. Pol. Ac.: Tech*. 68(2), 263–270 (2020).

[16] E. Talhi, J.-C. Huet, V. Fortineau, S. Lamouri "A methodology for cloud manufacturing architecture in the context of industry 4.0", *Bull. Pol. Ac.: Tech.* 68(2), 271–284 (2020).

e-mail: jszczepa@ippt.pan.pl

**Janusz Szczepański** received M.Sc. degree (1979) in Mathematics (Functional Analysis) from Warsaw University, Ph.D. degree (1985) in Applied Mathematics and Habilitation degree with distinction (2007) in Computer Sciences from the Polish Academy of Sciences. In 2014, he received the title of Full Professor from the President of the Republic of Poland. He received the special PAS Award (Huber) in 1989. Currently, he is a professor at IFTR PAS and member of the Scientific Council and Deputy Director for Research, IFTR PAS. In 2001–2004, he was a consultant in cryptography with the Certification Authority "Centrast" Co. for Public Key Infrastructure in Poland. He was a visiting scientist at Miguel Hernandez University, Spain and the University of California, San Diego. His research interests include information theory, neuroinformatics, and the application of stochastic processes in biological systems and cryptography.

e-mail: jerzy.klamka@iitis.pl

**Jerzy Klamka** received M.Sc. (1968) and Ph.D. (1974) degrees in control engineering from the Silesian Technical University in Gliwice, Poland. He also received M.Sc. (1971) and Ph.D. (1978) degrees in mathematics from the Silesian University in Katowice, Poland. In 1981, he received a Habilitation degree in control engineering, and in 1990, the title of professor from the Silesian Technical University in Gliwice. Since 1968, he has been working for the Institute of Control Engineering of the Silesian Technical University in Gliwice, where he is now a full professor. Since 1999, he has been working as a full professor at the Institute of Theoretical and Applied Informatics, Polish Academy of Sciences in Gliwice. In 2012 he became a full PAS member. He was the President of the Katowice PAS branch and in 1978, 1982 and 1990, he received the awards of the Ministry of Education, in 1994, and the award of the Polish Mathematical Society Award. In 2017, he was honored with the Prime Minister's Award for outstanding scientific achievements. His research interest includes controllability theory for linear and nonlinear dynamical systems, controllability of distributed parameter systems, dynamical systems with delays, and quantum informatics.

e-mail: katarzyna.wegrzyn-wolska@efrei.fr

**Katarzyna Węgrzyn-Wolska** received M.Sc. degree (1987) in electronic engineering at the Silesian Technical University of Gliwice, Poland (1987), M. Sc. Degree (1997) in computer science delivered by University of Val d'Essonne, l'ENSIIE and Télécom SudParis, France, and Ph.D. degree (2001) in automatic, real-time computer science and computer science at Mines ParisTech in France. In 2012, she became a full professor after receiving the French Habilitation (H.D.R). She was, for many years, chief of the Computer and Network Department then the head of a SITR team, and finally, scientific director of ESIGETEL. Currently, she is director of research at EFREI Paris and associated professor at MinesParisTech and at Télécom Paris-Sud. Katarzyna has been involved as a Chair and as a member of Programme Committees of many international conferences, as well as an expert for the Information Society Technologies (IST) in the European Community. Her main interests are: social network analysis, information retrieval, search engines, web-based support systems, and web intelligence.

e-mail: izarojek@ukw.edu.pl

**Izabela Rojek** received M.Sc. degree in computer science and Ph.D. (2000) degree in mechanical engineering and operation from Poznan University of Technology. She received the D.Sc. Habilitation degree in mechanical engineering and operation in 2017. Since 2018, she has worked as an associate professor at Kazimierz Wielki University in Bydgoszcz. She is member of the Polish Information Processing Society (since 2004), member of Polish Association for Knowledge Management (PSZW) since 2003, Vice President of the Bydgoszcz IT Cluster (since 2015), and Member of the International Association of Engineers (since 2016). Her main research interest is in knowledge discovery, intelligent support systems and applications of artificial intelligence in enterprise.

e-mail: piotrekp@ukw.edu.pl

**Piotr Prokopowicz** received his Ph.D. (2005) degree from the Institute of Fundamental Technological Research, Polish Academy of Sciences in computer science. He is currently an associate professor in the Institute of Computer Science at the Kazimierz Wielki University, Bydgoszcz, Poland. He was leading editor of the monograph Theory and Applications of Ordered Fuzzy Numbers published in the Springer series, Studies in Fuzziness and Soft Computing. His main research fields are computational intelligence methods with a focus on fuzzy sets and systems. He is a member of the Polish Information Processing Society (PTI), and the Polish Artificial Intelligence Society (PSSI).