

# Preface

This volume is dedicated to Prof. Jacek Żurada, Full Professor at the Computational Intelligence Laboratory, Department of Electrical and Computer Engineering, J.B. Speed School of Engineering, University of Louisville, Kentucky, USA, as a token of appreciation for his scientific and scholarly achievements, and his longtime service to many communities, notably—from the point of view of research interests topics—those of computational intelligence, in particular neural networks, machine learning, data analyses, and data mining, but also fuzzy logic, evolutionary computation, to just mention a few. On the other hand, from an institutional and organizational point of view, this is also a small token of appreciation for his longtime dedication and service to so many scientific, scholarly, and professional communities and societies, notably those of IEEE (Institute of Electrical and Electronics Engineers), the world largest professional technical professional organization dedicated to advancing science and technology in a broad spectrum of areas and fields related to its scope of interest.

Dr. Żurada's illustrious scientific and scholarly career spans over so many fields and areas of science and technology exemplified primarily by neural networks, the area he has been for years an iconic personality, but also many other areas from the broadly perceived fields of data sciences, machine learning, knowledge engineering, and—to put it most generally, maybe by using too general a name—for all kinds of intelligent systems. In a more applied direction, his influential works in the field of computer-assisted medicine deserve much appreciation, both because of their scientific quality and—which is maybe even more important—for their crucial relevance and value to the society.

The volume is divided into five parts that cover main issues related to the topic of the volume. Part I deals with theoretic, algorithmic, and implementation problems related to an intelligent use of data in the sense of how to get from data information and knowledge which can be in general useful for solving some relevant tasks, such as, data mining, machine learning, and knowledge discovery.

In his paper on “Tensor Networks for Dimensionality Reduction, Big Data and Deep Learning,” Andrzej Cichocki provides a comprehensive and critical state-of-the-art survey, complemented with a deep vision on some innovative links

between low-rank tensor network decompositions and deep neural networks. This survey and analysis is motivated by the fact that large-scale multidimensional data are often provided as multiway arrays or higher-order tensors, and they can be approximately represented in distributed forms via low-rank tensor decompositions and tensor networks. Due to the underlying low-rank approximations, tensor networks may help reduce the dimensionality and alleviate the infamous curse of dimensionality in many real-life cases, exemplified by large-scale optimization problems and deep learning. A novel view of links between the low-rank tensor network decompositions and the deep neural networks is provided and graphically illustrated. It is shown in an intuitively appealing way that due to low-rank tensor approximations and sophisticated contractions of core tensors, tensor networks attain a remarkable ability to perform distributed computations on otherwise prohibitively large volume of data/parameters. The approach is mainly related to the Hierarchical Tucker tensor train (TT) decompositions and the MERA tensor networks in some specific applications.

Jerzy Błaszczyński and Jerzy Stefanowski (“Local Data Characteristics in Learning Classifiers from Imbalanced Data”) deal with a very important yet difficult and challenging problem of learning classifiers from imbalanced data. Standard classifiers do not usually show a good performance due to many factors, notably those related to data difficulty related to internal and local characteristics of class distributions. Many of these difficulties can be alleviated by some approximation through an analysis of some neighborhoods of learning examples and the identification of different types of examples from the minority class. The authors assume a recent research direction for the evaluation of the types of examples that are based on the use of either the  $k$ -nearest neighbor or kernel-based methods. Some approaches are shown for tuning the size of both kinds of neighborhoods depending on the data set characteristics as well as for the evaluation of their usefulness in a series of both benchmark type and real data. Then, a claim is considered and analyzed that a proper analysis of these neighborhoods could be a basis for the development of new specialized algorithms for dealing with imbalanced data. For illustration, some generalizations of oversampling in preprocessing methods and neighborhood-based ensembles are discussed.

Paweł Szmeja, Maria Ganzha, Marcin Paprzycki, and Wiesław Pawłowski (“Similarity dimensions of semantic ontologies”) deal with a very important, yet difficult, problem of semantic similarity which is usually meant in the sense of tools, models, and methods applied in knowledge bases, semantic graphs, text disambiguation, and ontology matching, to just name a few more relevant problem classes. Many models and algorithms have been proposed for that purpose, and—though they are usually very different both with respect to the very idea, algorithm, and implementation—they are all meant to produce a single numerical score evaluation, termed a “semantic similarity” that is meant to capture all aspects of similarity. The authors claim that there are many ways in which semantic entities can be similar, and a single score may not be the best option. In their approach, a division of knowledge (and, consequently, the similarity) into categories (dimensions) of semantic relationships is performed, with each dimension

representing a different “type” of similarity, with this process guided by an interpretation of the meaning (semantics) of a similarity score in a particular dimension. Therefore, an add extra information to a similarity score can be added to emphasize differences and similarities between results obtained by using different methods.

Ryszard Tadeusiewicz (“Some interesting phenomenon occurring during self-learning process with its psychological interpretation”) discusses some interesting and general issues related to neural networks and artificial intelligence. The point of departure is that neural networks are very often useful for solving many practical problems but this usefulness can be viewed limited in the sense that it can be interesting and valid for a limited number of readers who are concerned with similar problems and applications. Therefore, a reasonable approach may be that some more interesting observations, which are related to phenomena observed, are selected during the neural network self-learning process. Since there is some intrinsic similarity to psychological processes that can be observed during a natural activity in the human mind, such phenomena are called “artificial dreams” meant here as spontaneous and unexpected processes emerging from natural self-learning procedures. These phenomena are very interesting and exciting, even mysterious, yet are rarely considered in a sufficient depth by the artificial intelligence or computational intelligence communities. The main reason may be viewed to be due to the fact that most contributions presenting methods and results of self-learning, even in neural networks which are main tool considered in this work, are mainly goal-oriented, and authors of almost all papers first try to obtain the best result in terms of solving a specified problem, for instance, by building a neural network based model of some process or finding a solution of a pattern recognition problem. Therefore, in the discussion of the self-learning results, the authors usually take into account only the final result exemplified by the value of a measure of the quality of the model or the correctness of classification. Issues discussed in this paper occur when the self-learning system has not been learned enough, and emphasis is on a rarely considered issue of a detailed analysis of behavior of a network, or other self-learning system, during the learning process, as well as some unexpected outcomes.

Part II is devoted to various aspects of neural networks and connectionist systems. Filippo Maria Bianchi, Lorenzo Livi, and Cesare Alippi, in their paper “On the interpretation and characterization of echo state networks dynamics: A complex systems perspective,” discuss some relevant, recently developed methods for characterizing the dynamics of recurrent neural network using some concepts and tools and techniques of complex systems theory. They focus on the so-called echo state networks which are a class of recurrent networks. They show a method for the characterization and analysis of the evolution of internal states, which makes it possible to provide a qualitative interpretation of the network dynamics, as well as to assess the very important problem, for theoretical and practical points of view, of stability of the system. Then, the identification of the onset of criticality in such networks is dealt with. The authors discuss an unsupervised method based on Fisher information which can be used to tune the network hyperparameters. It is shown that as compared to standard supervised

techniques, the proposed approach is effective and efficient for many problems, and shows better results.

Martha Pulido, Patricia Melin, and Olivia Mendoza (“Optimization of Ensemble Neural Networks with Type-1 and Interval Type-2 Fuzzy Integration for Forecasting the Taiwan Stock Exchange”) describe an optimization method based on the PSO (particle swarm optimization) for ensemble neural networks with type-1 and type-2 fuzzy aggregation for the forecasting complex time series, notably related to financial data. Notably, the optimization of the structure of the ensemble neural network with type-1 and type-2 fuzzy integration is concerned. For the comparison of the new hybrid method proposed with traditional methods, the data from the Taiwan Stock Exchange (TAIEX) are used, and the simulation results show that the ensemble approach produces good prediction results.

In his paper “Deep Neural Networks—A Brief History,” Krzysztof J. Cios provides a description on and insight into Deep Neural Networks (DNN), their history, and some related concepts and works. Basically, the DNNs—which are one of the most efficient tools that belong to the so-called deep learning—process input information in a hierarchical way in that each subsequent level of processing extracts more abstract/global/invariant features so that the DNNs (semi) automatically learn key features from data and then aggregate them for some purpose, such as the recognition of objects in the images. To be more specific, the author illustrates how the DNNs using some example from face recognition where the inputs are images from which at the first level (the first hidden layer) of processing simple image characteristics such as edges are extracted, then—at the second and subsequent levels—more complex parts of an image are formed, and—finally, at the output layer—human faces are recognized. Then, the author concentrates on the fully unsupervised DNNs, the field in which little progress has been reported so far. The focus here is on the DNNs, including those that use spiking neuron models and the corresponding learning rules.

Part III deals with broadly perceived tools and techniques for intelligent technologies in systems modeling. Grzegorz J. Nalepa (“Techniques for Construction and Integration of Rule Bases”) discusses issues related to the use of rules for capturing and executing knowledge. He deals with rule-based shells, software frameworks that support knowledge engineers by providing a rule language for encoding the rule base and a generic inference engine. One of the best known shells, CLIPS (C Language Integrated Production System) is now a multiparadigm programming language that provides support for rule-based, object-oriented, and procedural programming. This wide acceptance of CLIPS has implied the development of Jess which, although being similar, has been entirely written in Java which improved its integration capabilities. The development of intelligent systems in last decades shows that the rule-based systems (RBS) are still a technology with a great potential and many applications. However, it is also clear that rules, while very useful, need to be integrated with other paradigms, including those related to data and knowledge processing, software development, implementation, etc. In this paper, the author presents an identification of some issues that are relevant for the

integration of rule-based systems, notably: high-level modeling techniques for rule bases, integration architectures for rule-based systems, and rule interoperability. A human assisted and an automatic derivation of rules are discussed, and some challenging common problems, notably the handling of large rules sets through structuring, integration of rule-based components, as well as rule interoperability issues, are discussed.

Krystian Łapa, Krzysztof Cpałka, and Leszek Rutkowski (“New Aspects of Interpretability of Fuzzy Systems for Nonlinear Modeling”) discuss fuzzy systems as a well suited tool for modeling nonlinear systems. The authors emphasize that the fuzzy systems can be effectively and efficiently used if their structure and structure parameters are properly chosen, and the rules are clear and interpretable. A new algorithm for the automatic learning of fuzzy systems and new interpretability criteria of fuzzy systems are proposed. The interpretability criteria are related to all aspects of those systems, not only their fuzzy sets and rules, and also concern the choice and analysis of parameterized triangular norms, discretization points and weights of importance from the rules. Such a comprehensive solution is novel. The proposed criteria are taken into account in the learning process which proceeds using a new learning algorithm that combines the genetic algorithm and the firework algorithms, which makes it possible to automatically choose not only the parameters but also the structure of the system. The new approach is tested on some relevant simulation problems of nonlinear modeling.

Krassimir T. Atanassov and Peter Vassilev discuss in their paper “On the Intuitionistic Fuzzy Sets of  $n$ -th Type” the use of various extensions of the concept of a fuzzy set introduced by Zadeh, notably some extensions along the line of Atanassov’s intuitionistic fuzzy set that makes it possible not only to express imprecision of information but a very important problem related to the fact that the human beings tend to use in their everyday discourse, judgments, reasoning, etc., aspects for and against. The author clarifies some misconceptions and introduces a unified framework for such approaches.

In Part IV, “Intelligent Technologies in Decision Making, Optimization and Control,” the first paper by Jacek Mańdziuk (“MCTS/UCT in solving real-life problems”) deals with the Monte Carlo Tree Search (MCTS) supported by the Upper Confidence Bounds Applied to Trees (UCT) method, i.e., the so-called MCTS/UCT which is one of the state-of-the-art techniques in the game-playing domain. In particular, it is emphasized the spectacular success of this method (combined with the use of deep neural networks trained with the reinforcement learning algorithm) in the game of Go. The author summarizes his works and experience in the application of MCTS/UCT to domains other than games, with a particular emphasis on hard real-life problems with a large degree of uncertainty due to the existence of some stochastic factors in their definition, exemplified by the Capacitated Vehicle Routing Problem with Traffic Jams, and the Risk-Aware Project Scheduling Problem. It is shown how MCTS/UCT is a viable method in these two domains, notably due its ability to effectively and efficiently deal with uncertainty by online adaptation of the core MCTS simulations to the current situation.

Miłosz Kadziński, Michał K. Tomczyk, and Roman Słowiński (“Interactive Cone Contraction for Evolutionary Multiple Objective Optimization”) present a new interactive evolutionary algorithm for Multiple Objective Optimization (MOO) which combines the NSGA-II method with a cone contraction method. The new approach requires the Decision Maker (DM) to provide the preference information as a reference point and pairwise comparisons of solutions from a current population. This information is represented using a compatible Achievement Scalarizing Function (ASF) which is used to guide the evolutionary search toward the most preferred region of the Pareto front. The proposed algorithm is tested on a set of benchmark problems, and the results show its quick convergence to the DM’s most preferred region. Moreover, it also indicated the advantage of the new algorithm of the well-known NEMO-0, in particular when the DM provides a richer preference information composed of a greater number of pairwise comparisons of solutions.

Oscar Castillo, Carlos Soto, and Fevrier Valdez (“A Review of Fuzzy and Mathematic Methods for Dynamic Parameter Adaptation in the Firefly Algorithm”) are concerned with some issues related to the design and use of the firefly algorithm, a well-known meta-heuristic. The authors concentrate on the choice of parameters of the firefly algorithm, its analysis, and dynamic adjustments. Some relevant traditional and fuzzy logic-based approaches are analyzed and numerically compared.

In Part V, “Applications of Intelligent Technologies,” in the first paper by Adam E. Gawęda and Michael E. Brier (“Computational Intelligence Methods in Personalized Pharmacotherapy”), the authors are concerned with a pharmacologic therapy of chronic diseases that remains a big challenge to physicians, notably because individual dose-response characteristics of patients may vary significantly across patient populations, and—due to a chronic nature of the process—they may change over time within individual patients as well. Current state-of-the-art protocols for dose adjustment of pharmacologic agents rely heavily on data from the drug approval process and a physician’s expertise but they do not fuzzy utilize the wealth of knowledge hidden in patient data collected during his or her treatment. The authors review the application of two computational intelligence methods: the artificial neural networks and fuzzy sets theory, to personalized pharmacologic treatment of a chronic condition using patient data. As an example, the authors use data on patients with anemia and renal failure.

Zdzisław Kowalczuk and Michał Czubenko (“Embodying Intelligence in Autonomous and Robotic Systems with the Use of Cognitive Psychology and Motivation Theories”) discuss a coherent anthropological approach for the control of autonomous robots or agents. This modern approach is based on an appropriate modeling of the human mind using the available psychological knowledge. One of the main reasons that have inspired the authors is the lack of available and effective top-down approaches resulting from the some known results from the area of autonomous robotics. On the other hand, a system for a comprehensive and effective and efficient modeling of human psychology for the purpose of constructing autonomous systems is lacking. The authors review the recent progress in the understanding of the mechanisms of cognitive computations underlying

decision-making and existing challenges, notably those founded on cognitive ideas such as LIDA, CLARION, SOAR, MANIC, DUAL, and OpenCog. In particular, the idea of an Intelligent System of Decision-making (ISD) is emphasized that is based on the results of cognitive psychology (using the aspect of “information path”), motivation theory (where the needs and emotions serve as the main drives, or motivations, in the mechanism of governing autonomous systems), and several other detailed theories, which concern memory, categorization, perception, and decision-making. In the ISD system, in particular, an xEmotion subsystem is focused on that covers the psychological theories on emotions, including the appraisal, evolutionary, and somatic theories.

Krystian Łapa and Krzysztof Cpałka (“Evolutionary Approach for Automatic Design of PID Controllers”) present a new approach to an automatic design of the well-known and widely used PID controllers. It is based on a meta-heuristic hybrid algorithm which combines the genetic algorithm and the imperialist one. The main characteristic of the proposed approach is its capability to design the structure of the controller and the structure of its parameters. This eliminates the need for a trial-and-error process during the design of the controller structure. Moreover, in the proposed approach, various control criteria can be reflected.

Marcin Zalasinski, Krzysztof Cpałka, and Leszek Rutkowski (“Fuzzy-genetic Approach to Identity Verification Using a Handwritten Signature”) discuss a relevant biometric problem of the verification of the dynamic signature. There are many methods for the signature verification using dynamics of the signing process often based on the so-called global features. In this paper, a new approach to the signature verification using global features is proposed. Basically, it involves the classification of the signature which is performed using a fuzzy-genetic system; the selection of an individual set of features for each signer which uses a genetic algorithm with an appropriately designed evaluation function and works without access to the signatures called skilled forgeries; and the determination of weights of importance for evolutionarily selected features which are taken into account in the classification process. The main advantages of this new approach is that the feature selection via a fuzzy-genetic systems works with access to the signatures called skilled forgeries, and also that the proposed classifier can do without machine learning with respect to its work interpretation and possibility of an analytical determination of its parameters. Simulation results for the BioSecure signature database, distributed by the BioSecure Association, are performed and confirm the above mentioned good results.

S. Piasecki, R. Szmurlo, J. Rabkowski, and M.P. Kaźmierkowski (“A Method of Design and Optimization for SiC-based Grid-connected AC-DC Converters”) present a method of design and optimization for three-phase AC-DC converters. The main idea of presented work is to provide a tool which supports the design process and helps to achieve the main desired properties: efficiency, volume, weight, and cost. The proposed design method is described with a special attention paid to calculations regarding the power section of the converter. The authors concentrate on the new technology of SiC power devices. The method is illustrated on three SiC-based laboratory models rated at 10 and 20 kVA, respectively.

Each model is a result of an optimization process performed for different input requirements related to the volume and efficiency. Finally, the performance of all models is verified during the operation with a 3x400V AC grid.

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