Multidimensional Signal Processing and Applications—New Approaches

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Abstract. This chapter is a short introduction in the contemporary approaches aimed at the multidimensional processing and analysis of various kinds of signals, investigated in related research works, which were presented at the Third International Workshop "New Approaches for Multidimensional Signal Processing", (NAMSP), held at the Technical University of Sofia, Bulgaria in July 2022. Some of the works cover various topics, as: moving objects tracking in video sequences, automatic audio classification, representation of color video чрез 2-level tensor spectrum pyramid, etc., and also introduce multiple applications of the kind: analysis of electromyography signals, diagnostics of COVID based on ECG, etc. Short descriptions are given for the main themes covered by the book, which comprises the following three sections: multidimensional signal processing; applications of multidimensional signal processing, and applications of blockchain and network technologies.

Keywords: Multidimensional signal processing · Tensor decomposition · Deep learning · Blockchain · Medical decision support · Audio classification · Paraconsistent logic · Deep faith network model · Ant colony

1 Introduction

In contemporary life, multidimensional signal processing covers all signal processing performed in complicated systems and networks in manufacturing and development. As far as multidimensional signal processing is a subset of signal processing, it has its own specifics in sense that it deals specifically with data of more than one dimension [1]. Typical examples in this area are the multi-sensor radar information, medical imagery, surveillance systems, big data databases, satellite multi-view and multispectral images, etc., which use multiple sensors to sample signals and form images by manipulating the obtained signals [2, 3]. These specifics imply the use of more complex algorithms, compared to 1D and 2D cases. As a result, one of the big topics of the present day is the development of new efficient methods and algorithms which utilize the natural high correlation and information redundancy existing in multidimensional signals. Together with the application area widening, the number of various new techniques and theories,

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aimed at the efficient processing and analysis of such information, is increasing significantly, covering more and more areas and applications. One of the basic mathematical forms used for the efficient representation of multidimensional signals and data, are multidimensional tensors [4, 5]. By using various decomposition methods, each multidimensional tensor could be represented as a weighted sum of first-order coefficients (tensors), arranged in accordance with their weight lessening, after which the small members are neglected. In result, the multidimensional signal processing is transformed to processing of a limited number of first-order tensors, whose weights are higher than a preset threshold value, imposed by the application. Combined with the methods for NN [6] deep learning, tensor decomposition methods became a powerful tool for efficient analysis and processing of multidimensional signals and data in systems for medical decision support [7, 8], object and situation recognition [9, 10], etc. Based on this, and other related approaches, together with original ideas and implementations, significant number of applications and solutions are presented in this book, in such areas as homogeneous and heterogeneous protocols to maximize the lifetime of wireless sensor network for precision agriculture, smart logistic warehouse management with IOT, development of intelligent traction system for bulk cargo terminal and many others.

2 Main Topics Presented at NAMSP'22

In this book, some new aspects are presented in the processing of multidimensional signals of various kind. The book chapters are divided into three sections: (1) Multidimensional signal processing; (2) Applications of multidimensional signal processing; and (3) Applications of blockchain and network technologies.

Section 1 comprises 7 chapters, including this one. In chapter "Video Tracing of Moving Objects by Fusing Three-Term Decompositions", new algorithm is offered for moving objects tracking in video sequences, based on three-term decompositions. The analyzed input video is modelled as a 3-way tensor and over it are applied separately: 3-way-decomposition, Motion-assisted matrix restoration, Robust motion-assisted matrix restoration and Alternating direction method of multipliers. The results obtained for the moving objects detection make the proposed algorithm applicable in fields such as video surveillance, vehicle traffic control, crowd monitoring and others. In chapter "Deep Learning Approaches for Classroom Audio Classification Using Mel Spectrograms", new approach for automatic audio classification of classroom activities, aimed to support the training in science, technology, engineering, and mathematics (STEM), is proposed. For this, various approaches for deep learning are used for classroom audio classification (such as for example, the convolution neural network, and the long short-term memory (LSTM)). In the presented research, the models of three kinds of class activities are evaluated, defined as "single voice", "multiple voice" and "no voice", based on classroom recording. The model is trained on the Mel spectrogram extracted from the recorded audio. Highest accuracy of 97% is acknowledged for the 2D Convolutional Neural Network. In chapter "Tensor Spectral Pyramid for Color Video Sequences Representation, Based on 3D FO-AHKLT", new structure is introduced for representation of video sequence of RGB frames. For this, the RGB components are first transformed into tensors, which after unfolding are represented in the reduced vector space. To realize this,

2-level tensor spectrum pyramid (2LTSP) is used, based on the 3D frequency-ordered adaptive hierarchical KLT (3D FO-AHKLT). The new structure ensures high energy concentration of the transformed tensor into small number of spectrum coefficients, whose calculation needs operations of low computational complexity. The 3D FO-AHKLT is executed in three sequential stages and in each, the input tensor is transformed into a vector with different spatial orientation: horizontal, vertical or lateral (in time). The analysis of the computational cost of 2LTSP and its comparison with the closest decompositions H-Tucker and Tensor Train shows that it decreases together with the vector size growth. Also, there is proved that 2LTSP based on the 3D adaptive fast Walsh–Hadamard transform additionally reduces the needed calculations number. The main advantages of the new structure are its flexibility in respect of the reduced coefficients number in the sequential decomposition levels, the lack of iterative calculations and the low computational complexity. In chapter "Electromyography Signal Acquisition, Processing, Optimization and Its Applications" the contemporary approaches for features extraction and analysis of Electromyography Signals (EMG) are discussed, aimed at their efficient processing, and classification. The approach is based on the development of optimization methods so that to achieve high accuracy in detection of stress and anomalies in biomechanics and movement. In chapter "Research on the Radar Signal Classification Method Based on the Deep Faith Network Model", a method is introduced for classification of radar signals based on the Deep Faith Network Model. Combined with the basic concept analysis of deep learning with multi-layer structure of the hidden layer, this approach is aimed at the detection of the hidden features of data in the construction of multi-layer neural network model. As a result of the investigation, a reliable method for radar signal classification is developed. In chapter "Measuring Machine Intelligence Using Black-Box-Based Universal Intelligence Metrics", the metrics for evaluation of the complicated artificial intelligent (AI) systems intelligence regarding their ability to solve difficult problems are studied, and are presented reliable and accurate intelligence comparisons between such systems. The most important property of the intelligence metrics is its universality imposed by the diversity of the already developed complex intelligent systems. In the research are presented black-box-based intelligence metrics, which can also treat and evaluate such aspects as intelligence changeability and extreme intelligence (manifestation of extremely low or high intelligence in various situations). The offered universal black-box-based machine intelligence metrics is a new tool aimed to support the intelligent systems developers, because it is not influenced by the existing architecture diversity.

Section 2 comprises 8 chapters. At the top of the list (chapter "COVID Detection Using ECG Image Reports: A Survey"), is a survey of a group of research works dedicated to the opportunity for diagnostics of COVID disease by means of electrocardiogram (ECG) image reports. The idea is to detect symptoms and changes in the ECG peaks and intervals. In addition are presented another techniques also used for ECG reports analysis and aimed at the COVID detection. The main limitations and future trends of the investigation are illustrated and outlined very well and is shown that the ECG image report is close to the acceptable level in the COVID disease detection. The conclusion is that ECG reports analysis ensures high efficiency, which in many cases surpasses other similar protocols. In the next chapter "Disease Detection Techniques in Plants: Transition

from Manual to Automation" are analyzed methods for plants disease detection, based on the use of neural networks with deep learning, as AlexNet, DenseNet, ResNet, VGG and GoogLeNet CNN. The results obtained through modeling of these architectures with various datasets show that the last-mentioned CNN ensures accuracy of 99% for plant disease detection. In chapter "On Applying Gradient Based Thresholding on the Canny Edge Detection Results to Improve the Effectiveness of Fuzzy Hough Transform for Colonoscopy Polyp Detection Purposes", the possibilities for efficiency enhancement of the fuzzy Hough transform aimed at the detection of polyps in colonoscopy images, preprocessed with Canny operator, are investigated. The presented algorithm was tested for three open-access databases of colonoscopy images. For this, the authors first define a general threshold for the gradients classification. The modeling results show that it is not possible to define a normalized database-independent threshold which to be used to eliminate the useless edges in the images. Chapter "Development of IoT Indoor Monitoring System for Independent Elderly" is pointed at the need for the development of intelligent monitoring system at home, which to support lonely old people. In this work, an IoT Indoor monitoring system for the independent elderly which allows families to feel at ease even in remote locations, is presented. In chapter "Improving the Process of Evaluating User Stories Using the Paraconsistent Annotated Evidential Logic Eτ", a model for validation of user story (technique used in agile methods to elicit requirements) using the Para-analyzer algorithm, based on the Paraconsistent Annotated Evidential Logic Eτ, is introduced. For this, an investigation based on flexible methods was carried out with a team of researchers. The presented model utilizes the favorable and contrary proofs for each criterion INVEST as input variables. The implemented mathematical model supports decision making and serves as an instrument assisting teams, product owners, managers, etc. In the experimental part, four user stories were analyzed by nine experts, which evaluated the criteria for each of them. The interpretation of the experts evaluations was done on the basis of global analysis in the unit square of the Cartesian plane, where were shown the degrees of favourable/contrary evidence detected. The introduced research demonstrates the ability of the Evidence Noted Paraconsistent Logic Eτ concepts to validate and present perspectives on dealing with situations of uncertainty and inconsistency. In chapter "Neural Network Algorithm Applied in Electrical Engineering Automation", on the basis of the advantages of AI technology applied in the automation of electric equipment diagnostics, is empirically investigates new algorithm based on RBF neural network. The final simulation results show that the algorithm not only permits to identify quantitatively the equipment characteristics, but also—to improve the condition evaluation. The presented application algorithm can accurately identify the feature quantity of the state in the simulation experiment, which proves that it can also complete the learning in judging the new state types. In chapter "Truss Structure Optimization Design Based on FE-PSO-SQP Algorithm", one new Particle Swarm Optimization (PSO) algorithm is offered, in which are overcome the problems related to its low computational accuracy, relatively slow convergence and bad population varieties in the following calculation of the model. To overcome all this, and also—to solve better the problem with the structure optimization, is developed the algorithm FE-PSO-SQP, which combines PSO with the algorithms for Sequential Quadratic Programming (SQP) and Finite Element (FE). A set of programs was developed for the ANSYS software.

For the case when the independent program is used for the simulation calculation of the truss structure optimization, obtained results show that the algorithm FE-PSO-SQP has faster convergence and higher computation accuracy, compared to these of the basic algorithm FE-PSO. In chapter "Practice System of Ant Colony Optimization Algorithm in Business Administration", new approach for business administration optimization is offered, which can also improve the practical work efficiency and reduce the work pressure faced by the industrial and commercial departments. The presented idea is based on the PSO algorithm combined with Ant Colony Optimization (ACO). The new approach was tested experimentally and the obtained results confirm the suggested achievements.

Section 3 comprises 8 chapters. The first one there (chapter "Literature Review of Smart Contracts Using Blockchain Technology") is a survey on the use of Blockchain technologies in various areas, as cryptocurrency, smart contracts, etc., which is a result of its decentralised and digitally distributed peer-to-peer network featuring elevated speed, efficiency and security. Nowadays, Blockchain offers contemporary solutions for contracts management by consensus mechanism, scalability and reliability on 'off-chain' resources. The presented work is focused on rectifying bugs and cybersecurity attacks, such as (for example) re-entrancy attacks with utilization of vaults, GHOST protocol, Bitcoin-NG, botnet C&C command, ERLAY protocol, bug prevention tools like Oyente and SolidiFi and fuzzing tools like ReGuard and Contract-Fuzzer. Chapter "A Comprehensive Study of 5th Generation Scheduling Algorithms" is a survey on the the key points of 5th Generation (5G) communication technology, the basic concepts of the 5G network concepts, its architecture for both standalone and non-stand-alone mode, different existing scheduling algorithms used in 5G, namely Proportional Fair (PF), Modified Least Weighted Delay First (MLWDF), Exponential Proportional Fair (EX-PF), Frame Level Schedular (FLS), Round Robin (RR) and also—a detailed review on various scheduling algorithms anticipated by great number of researchers. This work points out scheduling areas in which improvement is required and the analysis can provide better results in the form of a new strategy. Chapter "A Comparative Analysis of Homogeneous and Heterogeneous Protocols to Maximize the Lifetime of Wireless Sensor Network for Precision Agriculture" is focused on the Wireless Sensor Networks (WSN) which contain big number of battery-powered Sensor Nodes (SN). As a result of the fact that SN are battery-operated and the power source cannot be replaced, is implied the objective to maximize the network lifetime by choosing some low energy path using energy-efficient protocols, so that at the end, the path which needs lowest energy, to be detected. Multiple use of a low-energy part can result in battery discharge for SN in the area and as a sequence—to the creation of energy holes, because all SN in the neighborhood are "dead". The aim is to choose a protocol which to prolong the WSN lifetime through including all SN in the process. The approach is based on the proposed Heterogeneous Energy Efficient and Reliable Routing (HEERR), which is an advanced version of the Distributed Energy Efficient Clustering (DEEC) protocol. The comparison with other hierarchical routing techniques proves that HEERR not only enhances the network lifetime but also increases the throughput. Besides, the authors cleared that the heterogeneous approach is more reliable and energy efficient than the homogeneous approach. Chapter "The Integration Development and Upgrading Path of Industry 4.0 Architecture Industrial Engineering Network Driven by Big Data" is devoted to studies in understanding big background, on

the basis of data driven according to the basic connotation of industrial engineering network integration. The aim is to clear the basic route of industrial architecture engineering network integration, and carry on the empirical research about the mode selection, so that to enhance the competitive advantage of industrial products and upgrade new forms. In chapter "SAAS Application Prospect Analysis in Hrm and Methods to Upgrade the Contemporary System", methods for inventive problem solving to analyze potential new approaches are used, based on preceding scientific works in the field of "Software as a Service". In chapter "All Digital Phase Locked Loop (ADPLL) and Its Blocks—A Comprehensive Knowledge" the systems All Digital Phase Locked Loop (ADPLL) are analyzed, used to synchronize the signals frequency and phase. The investigated ADPLL implements all basic PLL blocks in a digital form. Besides, in this chapter is also presented a detailed search on each block of the ADPLL architecture and the changes in these blocks, introduced together as the research advanced. The best ADPLL solutions are compared in terms of their parameters number, and the implemented techniques. In chapter "On Realization of Smart Logistic Warehouse Management with Internet of Things", an architecture of intelligent warehouse system is offered. The IOT-based system successfully manages the complicated supply chain network by combining cloud servers, Radio Frequency Identification (RFID), devices and sensors, tags, bar codes, mobility Wifi, surveillance and other smart utilities connected into an organic whole, which is equally applicable and feasible by the developers and business stakeholders. Cloud solutions are introduced in the IOT platform, aimed at the intelligent warehouse system mobility improvement, and together with this, to integrate multiple plug-play peripheral devices into one whole. Application Programming Interface (API), varying from Message Queuing Telemetry Transport (MQTT), Constrained Application Protocol (COAP) up to Lightweight Machine to Machine (LWM2M), is applicable and compatible with various plug-play devices, or new-developed contemporary applications. In the IOT and RFID business equipment environment, devices and processes create new efficiency, incomes and various possibilities for warehouse management and control. In chapter "Development and Design of Intelligent Traction System for Bulk Cargo Terminal", new kind of integrated unmanned intelligent traction loading system for bulk cargo terminal is proposed. The system combines the development of key technologies such as sliding contact power supply, vehicle number identification, decoupling control, continuous and accurate loading control and bridging control, and builds a high-quality communication network architecture to solve the defects of the traditional iron ox traction loading process. The presented study effectively improves the bulk cargo shipping capacity, reduces the potential safety hazards in the loading area, and achieves the expected effect of energy saving, cost reduction and efficiency increase in the overall operation process.

3 Conclusions

The research works, described in brief above, introduce the main contents of the studies, presented at the Third International Workshop on New Approaches for Multidimensional Signal Processing (NAMSP'2022), and held at the Technical University of Sofia, Sofia, Bulgaria in July 07–09, 2022. They cover part of the multidimensional signal processing, analysis and applications and outline new trends and ideas in this area.

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