PRIA JOURNAL SPECIAL ISSUE: PROCEEDINGS OF THE 8th INTERNATIONAL WORKSHOP "IMAGE MINING: THEORY AND APPLICATIONS" (IMTA-VIII-2022), MONTREAL, CANADA, AUGUST 21, 2022 WITHIN THE FRAMEWORK OF THE 26th INTERNATIONAL CONFERENCE ON PATTERN RECOGNITION, MONTREAL, CANADA, AUGUST 21–25, 2022

On Some Scientific Results of the IMTA-VIII-2022: 8th International Workshop "Image Mining: Theory and Applications"

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Abstract—The publication presents an introductory paper to the Special issue of the international journal *Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications* of the Russian Academy of Sciences. The main scientific results of the 8th International Workshop "Image Mining: Theory and Applications," held on August 21, 2022, Montreal, Canada, are presented. Historical information is given on this series of international workshops, and their significant role in the development of the theory and practice of automation of image analysis, pattern recognition, and artificial intelligence is emphasized. The list of papers of the Special issue of *PRIA*, prepared based on the invited and regular papers selected and recommended for publication by the Program Committee of the IMTA-VIII-2022, is presented.

Keywords: IMTA-8-2022, image mining, image analysis, mathematical theory of image analysis, pattern recognition, artificial intelligence, automation, data mining, data science, knowledge engineering, application problems, image analysis applications, pattern recognition applications

DOI: 10.1134/S1054661822030312

INTRODUCTION

The present issue of the international journal *Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications* of the Russian Academy of Sciences continues a long tradition of publishing the proceedings and selected papers of leading international conferences on informatics, cybernetics, and applied mathematics in the form of special issues of the journal. The present special issue of the journal is devoted to the main scientific results and trends presented at the 8th International Workshop "Image Mining: Theory and Applications" held on August 21–25, 2022, in Montréal, Canada, within the 26th International Conference on Pattern Recognition, the leading conference on pattern recognition and image analysis in the world.

The papers prepared based on the invited and regular presentations of the IMTA-VIII-2022 wokshop are published on the eve of the wokshop in the international journal *Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications* of the Russian Academy of Sciences (indexed in the Web of Science (Emerging Sources Citation Index), Scopus, Russian Science Citation Index on the Web of Science platform)), and extended versions of the presentations of IMTA-VIII-2022 will be published by Springer as a separate book in the "Lecture Notes in Computer Science" series after the ICPR-2022.

The special issue of the *PRIA* journal, Special Issue IMTA-VIII-2022: 8th International Workshop "Image Mining: Theory and Applications" was prepared by the National Committee for Pattern Recognition and Image Analysis of the Russian Academy of Sciences, a collective member of the International Association (IAPR), and by the IAPR Technical Committee no. 16 "Algebraic and Discrete Mathematical Methods in Pattern Recognition and Image Analysis."

Received June 10, 2022; revised June 10, 2022; accepted June 10, 2022

1. GOALS AND OBJECTIVES OF IMTA-VIII-2022

The main goal of the IMTA wokshop is to provide the integration and joint application of various modern mathematical approaches and methods for image analysis/pattern recognition in accordance with the applied problems to be solved.

This workshop is devoted but not limited to the following subjects:

A. Methodological progress in the field of image analysis and pattern recognition with special emphasis on the following directions:

A.1 Algebra

A.2 Discrete mathematics

A.3 Computational topology

A.4 Machine learning

B. Novel mathematical methods of image mining

B.1 Algebraic approaches

B.2 Image algebras, descriptive image algebras, and lattice algebras

B.3 Lattice-based deep hierarchical representations and neural networks

B.4 Methods of discrete mathematics

B.5 Descriptive image analysis

B.6. Processing and representation of ill-structured data

B.7 Syntactic and structural methods

B.8 Multialgorithmic classifiers and methods for combining the results of individual algorithms

B.9 Pattern recognition methods of knowledge extraction from images

B.10 Other mathematical methods

C. Models, representations, and features of images

C.1 Feature detectors

C.2 Features used in autoencoder networks

C.3 Formalized image models

C.4 Spatial data representation (combinatorial structures of local neighborhoods)

C.5 Dual image representations

D. Automation of intelligent analysis of images and other types of data

D.1 Image analysis and ill-structured data

D.2 Knowledge extraction from images, machine vision, and knowledge-based systems

D.3 Image databases

E. Methods of artificial intelligence in knowledge extraction from images

E.1 Knowledge representation, processing, extracting, and analyzing

E.2 Image knowledge bases

E.3 Linguistic tools for image mining (image ontologies; thesauri of images)

F. Applied image mining problems

F.1 Bioinformatics

F.2 Bioengineering

F.3 Medical applications

F.4 Industry and economics

F.5 Cultural heritage

F.6 Other important complex and interesting applied problems

The basic tasks of IMTA-VIII-2022 are as follows:

(1) to provide algebraists, specialists in discrete mathematics, and other mathematically oriented scientists, engineers, researchers, IT specialists in image analysis, pattern recognition, and artificial intelligence with new possibilities to better know and understand each other and to start to communicate on a regular basis;

(2) to provide an event for discussing current and promising areas of research and exchanging the latest achievements in algebra, discrete mathematics, and other mathematical methods workable in the field of image analysis and pattern recognition.

IMTA-VIII-2022, just as the previous workshop IMTA-VII-2021, is held within the ICPR (in this case, ICPR-2022) under the auspices of the IAPR.

ICPR is the main scientific event in the field of pattern recognition, image analysis, and applied scientific and technological fields. The methods of intelligent image analysis allow us to extract knowledge and distinguish patterns, which makes it possible to use them in very important applications such as medical diagnostics, precision agriculture, new industries, and many others. Mathematical principles, means and tools are of primary importance for this field of informatics. Actually, mathematical aspects of image analysis, pattern recognition, and, primarily, intelligent image analysis—the leading direction in the modern mathematical theory of image analysis—are the main subjects of interest for IMTA-VIII-2022.

Technological achievements and extended storage capabilities support the emergence of large and detailed, albeit, possibly noisy and damaged, sets of image data. Hence, the subjects of IMTA-VIII-2022 are of primary importance, providing a perfect ground for combining with other new fields, both theoretical and applied.

An example of how the main subject of intelligent image analysis could be profitably combined with other fields such as computational topology, lattice algebra, machine learning, and descriptive image analysis is the emergence of new concepts and trends such as topological features and invariants and their calculation for digital images, representation, and compression of multidimensional images based on

topology, learning based on lattices by the images of time series by the intelligent analysis of video images, application of fuzzy lattices in pattern recognition, and many others.

IMTA-VIII-2022 continues the successful series of workshop devoted to new and promising mathematical methods of intelligent image analysis and relevant applications:

• IMTA-I-2008, Funchal, Madeira, Portugal, as part of the 3rd International Conference on the Theory and Applications of Machine Vision (VISAPP 2008);

• IMTA-II-2009, Lisbon, Portugal, within the 4th International Joint Conference on Theory and Applications of Machine Vision, Visualization and Machine Graphics (VISIGRAPP 2009);

• IMTA-III-2010, Anger, France, within the 5th International Joint Conference on Theory and Applications of Machine Vision, Visualization and Machine Graphics (VISIGRAPP 2010);

• IMTA-IV-2013, Barcelona, Spain, within the 8th International Joint Conference on Theory and Applications of Machine Vision, Visualization and Machine Graphics (VISIGRAPP 2013);

• IMTA-V-2015, Berlin, Germany, within the 10th International Joint Conference on Theory and Applications of Machine Vision, Visualization and Machine Graphics (VISIGRAPP 2015);

• IMTA-VI-2018, Montreal, Canada, within the 1st International Conference on Pattern Recognition and Artificial Intelligence (ICPRAI 2018);

• IMTA-VII-2021, Milan, Italy, within the 25th International Conference on Pattern Recognition (ICPR 2020).

2. SCIENTIFIC PROGRAM OF THE WORKSHOP

Forty-four presentations from 11 countries were submitted to the workshop.

The subject of the workshop includes theoretical and applied aspects of a wide class of problems in the following fields:

(a) extraction, processing, analysis, comparison, clustering, and detection of objects, recognizing and assessing image quality;

(b) signal recognition, including spectral analysis;

(c) statistical problems, including development of special metrics;

(d) studies of the mathematical, including algebraic properties of multimodel image representations;

(e) methods for constructing, combining, and learning fast multialgorithmic and fuzzy classifiers;

(f) in-depth study and optimization of convolutional neural networks;

(g) applied problems of machine vision, artificial intelligence, and machine learning.

The main applied directions of research reported in the workshop are medical problems: histology, machine tomography, ophthalmology, electroencephalogram analysis, laser coagulation, neoplasm detection, diagnostics of neurodegenerative diseases, diagnostics of cardiac diseases, and other automation problems of medical diagnostics, as well as recognition of audiovisual emotions, classification of living natural objects, remote sensing, studies of variability of climate change factors, recognition of texts and symbols, document processing, automation of scientific research, and development of intelligent systems.

Analysis of the scientific contribution of IMTA-VIII-2022 allows us to make the following conclusions:

(1) The construction of a unified mathematical theory of image analysis is still under way.

(2) The number of contributions devoted to the theoretical aspects of image analysis decreases, which is explained by the commercialization of this direction to the detriment of scientific development; in the future, the organizers of the workshop plan to reduce the number of purely applied presentations and invite authors with theoretical results.

(3) Problems of artificial intelligence are based on the fundamental results of mathematical theories of pattern recognition, machine leaning, and image analysis.

(4) When developing new methods of image analysis and recognition, there is a tendency to expand the mathematical apparatus by involving the areas of mathematics that were not previously used in image analysis (in particular, lattice algebra, Turing machine, and topology).

(5) The gap between the capabilities of new mathematical methods of image analysis and recognition, as well as their actual use in solving applied problems, remains significant.

(6) There is still an excessive use of neural networks in solving applied problems of image analysis and image recognition, and quite often without proper justification of the solution method and interpretation of the results.

(7) Technological achievements and extended storage capabilities support the growth of large and detailed, albeit, possibly noisy and damaged, sets of data represented as images.

(8) Methods of intelligent data analysis allow us to extract valuable knowledge from complex, disaggregated, and ill-structured data, which makes it possible to successfully apply them in quite diverse applied fields: medical diagnostics, robotics, technical diagnostics and nondestructive control, precision agriculture, new computer and information systems for sup-

port of industrial and information technologies, remote sensing, anthropogenic and environmental forecasting and monitoring, automation of scientific research, and many others.

3. LIST OF PAPERS INCLUDED IN THE SPECIAL ISSUE

Invited Presentations

(1) V.V. Evdokimova, S.A. Bibikov, and A.V. Nikonorov "Meta-Learning Approach in Diffractive Lens Computational Imaging";

(2) I.B. Gurevich and V.V. Yashina" On Modelling Descriptive Image Analysis Procedures in a Specialized Turing Machine";

(3) N.Yu. Ilyasova and N.S. Demin "Application of Artificial Intelligence in Ophthalmology for the Diagnosis and Treatment of Eye Diseases";

(4) A.V. Khvostikov, A.S. Krylov, I.A. Mikhailov, and P.G. Malkov "Visualization of Whole Slide Histological Images with Automatic Tissue Type Recognition."

Contributed Papers

(1) N.A. Andriyanov "Combining Text and Image Analysis Methods for Solving Multimodal Classification Problems";

(2) N.A. Andriyanov, V.E. Dementiev, and A.G. Tashlinskiy "Development of a Productive Transport Detection System Using Convolutional Neural Networks";

(3) V. Antsiperov "Perceptual Images Compression Based on a System of Receptive Fields";

(4) P.O. Arkhipov and S.L. Philippskih "Building an Ensemble of Convolutional Neural Networks for Classifying Panoramic Images";

(5) V.B. Berikov and A.A. Vikent'ev "Classification with Incomplete Probabilistic Labeling based on Manifold Regularization and Fuzzy Clustering Ensemble";

(6) A. Bruno, M. Martinelli, and D. Moroni "Exploring Ensembling in Deep Learning";

(7) S. D. Dvoenko "Recovering Missing Values of Paired Comparisons";

(8) V.A. Fursov "Image Recognition with Selection of Informative Subspaces by the Conjugacy Criterion";

(9) I.B. Gurevich, V.V.Yashina, and A.T. Tleubaev "Research and Development of the Method for Automating the Diagnostic Analysis of Optical Coherent Tomography Angiography Human Fundus Images";

(10) K.A. Kachalov and S.S. Kharchenko "Scale-Invariant Feature Transform Improvement for Problems of Recognition of Similar Images";

(11) R. Kaur, G. Karmakar, and F. Xia "A Reliable Image Quality Assessment Metric: Evaluation Using Camera Impacts";

(12) M. Kharinov "An Object in an Image as a Dynamically Structured Pixel Set";

(13) M.M. Lange and A.M. Lange "Information-Theoretic Lower Bounds to Error Probability for the Models of Noisy Discrete Source Coding and Object Classification";

(14) D.V. Liakhov, N.S. Mityugov, I.A. Gracheva, A.V. Kopylov, O.S. Seredin, and Kh.P. Tiras "Scanned Plant Leaves Boundary Detection in the Presence of a Colored Shadow";

(15) L.A. Manilo and D.U. Kholmatov "Recognition of Congestive Heart Failure Based on a Complex Correlation Measure of the Heart Rate Signal";

(16) Yu. Mao, T. Zhang, B. Fu, and D.N.H. Thanh "Self-Attention-based Wasserstein Generative Adversarial Networks for Single Image Inpainting";

(17) D.M. Murashov "A New Quality Measure for Image Segmentation Based on Combination of Information Redundancy and Variation of Information";

(18) E. Myasnikov "A Feature Fusion Technique for Dimensionality Reduction";

(19) A.V. Nasonov and A.A. Nasonova "Linear Blur Parameters Estimation Using a Convolutional Neural Network";

(20) A.P. Nemirko "Convex Hull Proximity Estimation for Machine Learning Problems";

(21) A.N. Pankratov and N.M. Pankratova "Spectral Method for Detecting Inexact Repeats in Character Sequences";

(22) V.A. Pyatov and D.V. Sorokin "Affine Registration of Histological Images Using Transformer-Based Feature Matching";

(23) M. Reggiannini, O. Papini, and G. Pieri "An Automated Analysis Tool for the Classification of Sea Surface Temperature Imagery";

(24) A.L.Reznik and A.A.Soloviev "Software and Combinatorial-Probabilistic Tools for the Analysis of Random Point Structures";

(25) V. Ryazanov and A. Vinogradov "Multidimensional Analogs of Image Analysis Tools in the Problems of Detecting Hidden Regularities";

(26) A. Samarin, A. Savelev, A. Toropov, A. Dzestelova, V. Malykh, E.Mikhailova, and A. Motyko "One-Staged Attention-Based Neoplasms Recognition Method for Single-Channel Monochrome Computer Tomography Snapshots";

(27) A. Samarin, A. Savelev, A. Toropov, A. Dzestelova, V. Malykh, E. Mikhailova, and A. Motyko "Trainable Agents Movement Strategies for Advertising Sign Visual Descriptors";

(28) K. Sarin, I. Hodashinsky, and M. Svetlakov "Extracting Knowledge from Images of Meanders and Spirals in the Diagnosis of Patients with Parkinson's Disease";

(29) A.V. Savchenko and L.V. Savchenko "Audio-Visual Continuous Recognition of Emotional State in a Multi-User System Based on Personalized Representation of Facial Expressions and Voice";

(30) O. Seredin, D. Liakhov, O. Kushnir, and N. Lomov "Jaccard Index-Based Detection of Order 2 Rotational Quasi-Symmetry Focus for Binary Images";

(31) M. Svetlakov, I. Hodashinsky, and K. Sarin "Representation Learning for Electroencephalogram-Based Biometrics Using Holo-Hilbert Spectral Analysis";

(32) S. I. Vyatkin and B. S. Dolgovesov "Generation and Reconstruction of the Human Face."

CONCLUSIONS

The co-chairmans of IMTA-VIII-2022 would like to thank all the members of the Scientific Committee who helped to peer-review the papers and provided useful comments and remarks that contributed to the success of the workshop.

The National Committee on Pattern Recognition and Image Analysis of the Russian Academy of Sciences and the IAPR TC 16 plan to continue the series of IMTA workshops.

FUNDING

This study was supported in part by the Russian Foundation for Basic Research, project no. 20-07-01031.

Conflict of Interest

The authors declare that they have no conflicts of interest.

Igor B. Gurevich. Born August 24, 1938. Dr.-Eng. diploma engineer (Automatic Control and Electrical Engineering), 1961, Moscow Power Engineering Institute, Moscow, USSR; Cand. Sci. (Mathematical Cybernetics), 1975, Moscow Institute of Physics and Technology (National Research University), Moscow, Soviet Union. Leading Researcher at the Federal Research Center "Computer Science and Control" of the Russian Academy of Sciences, Moscow, Russia. He has worked from 1960 until now as an engineer, researcher, and lecturer in industry, research institutions, medicine, universities, and from 1985 in the USSR/Russian Academy of Sciences. Area of expertise: mathematical theory of image analysis, image mining, image understanding, mathematical theory of pattern recognition, theoretical computer science, medical informatics, applications of pattern recognition and image analysis techniques in biology, medicine, automation of scientific research, and knowledge-based systems.

Gurevich proposed, proved, and developed with his pupils the descriptive approach to image analysis and recognition (DAIA). Within DAIA a new class of image algebra was introduced, defined, and investigated (descriptive image algebras); new types of image models were introduced, classified and investigated; axioms of descriptive theory of image analysis were introduced; a common model of image recognition process was defined and investigated; new settings of image analysis and recognition problems were introduced; a notion of image equivalence was introduced and investigated; new classes of image recognition algorithms were defined and investigated; and an image formalization space was introduced, defined, and investigated.

The listed results were used in the development of software kits for image analysis and recognition, as well as for the solution of important and difficult applied problems of automated biomedical image analysis.

Gurevich is the author of 2 monographs and 307 papers in peer-reviewed journals and proceedings indexed in the Web of Science, Scopus, and Russian Science Citation Index on the platform of the Web of Science, 31 invited papers at international conferences, and holder of 8 patents. Web of Science: 22 papers; Scopus: 76 papers, 287 citations in 148 documents; Hirsh index, 10; Russian Science Citation Index on the platform of Web of Science: 129 papers; 910 citations; Hirsh index, 11.

Vice-Chairman of the National Committee for Pattern Recognition and Image Analysis of the Russian Academy of Sciences, Member of the International Association for Pattern Recognition (IAPR) Governing Board (representative from RF), IAPR Fellow. He has been the PI of 63 R&D projects as part of national and *international research programs. Vice-Editor-in-Chief of the Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications*, the international journal of the RAS, member of editorial boards of several international scientific journals, and member of the program and technical committees of many international scientific conferences. Teaching experience: Lomonosov Moscow State University, Russia (Assistant Professor), Dresden Technical University, Germany (Visiting Professor), and George Mason University, United States (Research Fellow). He was supervisor of 6 PhD students and many graduate and master students.

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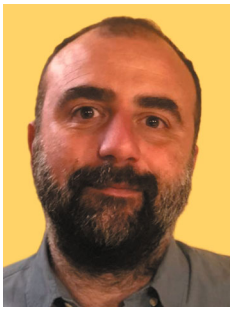
The main results were obtained in mathematical theory of image analysis: descriptive image algebras with one ring were defined, classified, and investigated; a new topological image formalization space was specified and investigated; descriptive generating trees were defined, classified, and investigated. The listed results were applied in biomedical image analysis.

She is the scientific secretary of the National Committee for Pattern Recognition and Image Analysis of the Presidium of the Russian Academy of Sciences. She is a member of the Educational and Membership Committees of the International Association for Pattern Recognition. She is a Vice Chair of Technical Committee No. 16 on Algebraic and Discrete Mathematical Techniques in Pattern Recognition and Image Analysis of the International Association for Pattern Recognition. She has been the member of many R&D projects as part of national and international research programs. Member of editorial board of *Pattern Recognition and Image Analysis. Advances in Mathematical Theory and Applications*, the international journal of the RAS. Author of 79 papers in peer-reviewed journals, as well as conference and workshop proceedings. Web of Science: 11 papers; Hirsh index, 4; Scopus: 40 papers, 162 citations in 75 papers; Hirsh index, 8; Russian Science Citation Index on the platform of Web of Science: 56 papers; 255 citations; Hirsh index, 9.



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Maria Antonietta Pascali received her MSc in Mathematics honors degree from the University of Pisa in 2005 and PhD in Mathematics at the University of Rome "La Sapienza" in 2010. She is Researcher at CNR in Pisa since February 1, 2010. Member of the IAPR TC16 on "Algebraic and Discrete Mathematical Techniques in Pattern Recognition and Image Analysis." Research interests: modeling the protein 3D motion, 3D virtual environment in cultural heritage, and heterogeneous and multimodal data integration for underwater archaeology; 3D shape analysis for e-health, thermal imaging, statistical data analysis of health-related data, applied computational topology, interplay of topological data analysis and artificial intelligence, and deep learning applied to mp-MRI images.