On Some Scientific Results
of the 15th International Conference PRIP-2021

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Abstract—The paper considers and analyzes the main scientific results of the 15th International Conference on Pattern Recognition and Information Processing (PRIP-2021), Minsk, Republic of Belarus, September 2021. The history of this series of conferences is outlined and its significant role in the development of the theory and practice of image analysis, pattern recognition, and artificial intelligence is indicated. A list of articles in the special issue prepared on the basis of reports selected by the PRIP-2021 program committee is provided.

In this issue, *Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications* continues the long tradition of publishing the works and selected reports of leading international conferences on computer science and cybernetics. This special issue of the journal focuses on some of the scientific results and trends presented at the 15th International Conference on Pattern Recognition and Information Processing (PRIP-2021), Minsk, Republic of Belarus, September 2021.

The reader is offered the full texts of selected reports presented at PRIP-2021.

It was the 15th anniversary conference. It has also been 30 years since the first USSR All-Union Conference "Pattern Recognition and Image Analysis. New Information Technologies."

In the mid-1950s, within the framework of cybernetics, a new scientific direction began to form, associated with the development of theoretical foundations and the practical implementation of devices and automatic and automated systems designed to recognize objects, events, and processes. This direction has received the general name "Pattern recognition." The first applications were devoted to the problems of astronomy, nuclear physics, biophysics, and character recognition.

In the Soviet Union, this scientific direction began to develop intensively from the beginning of the 1960s and especially in the 1970s at the Computing Center of the Academy of Sciences of the USSR, Moscow (Academician of the Russian Academy of Sciences Yu.I. Zhuravlev and his scientific school); the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR, Kiev (Corresponding Member of the National Academy of Ukraine A.G. Ivakhnenko and his scientific school, T.K. Vintsyuk, M.I. Shlezinger); Institute of Mathematics of Siberian Branch of RAS; (Yu.I. Zhuravlev and his scientific school); the Institute for Information Transmission Problems of the USSR Academy of Sciences, Moscow (Academician of the USSR Academy of Sciences A.A. Kharkevich, L.P. Yaroslavsky); the Institute for Control Problems of the Russian Academy of Sciences, Moscow (M.A. Aizerman and his scientific school, A.Ya. Lerner, V.N. Vapnik, and A.Ya. Chervonenkis); the Institute of Engineering Cybernetics of the National Academy of Sciences of the Republic of Belarus, Minsk (Academician of the National Academy of Sciences of the Republic of Belarus S.V. Ablameyko and his scientific school); the Research Institute of Biotechnical Systems of St. Petersburg State Electrotechnical University, St. Petersburg (V.M. Akhutin and his scientific school);

the Research Institute of Applied Mathematics and Cybernetics, Lobachevsky Nizhny Novgorod State University (Yu.G. Vasin and his scientific school); Samara State Aerospace University, Samara (Academician of the Russian Academy of Sciences V.A. Soifer and his scientific school).

In the second half of the 1970s, fundamental scientific research carried out at the institutes of the USSR Academy of Sciences led to fundamental results in the field of the mathematical theory of pattern recognition. Among them, as shown by the further development of the direction, the most important were as follows:

(a) An algebraic approach to the problems of recognition and classification by Yu.I. Zhuravlev, within which methods for the synthesis of correct recognition algorithms were studied and for the first time the concept of a multi-algorithmic classifier as a mathematical object was formulated and substantiated.

(b) V.N. Vapnik and A.Ya. Chervonenkis posed and investigated the problem of recovering dependencies from empirical data, which made a fundamentally important contribution to the development of the statistical theory of learning pattern recognition machines.

In the 1980s, All-Union conferences in the field of pattern recognition and image analysis began to be held in the Soviet Union. All work was coordinated by the informatics section of the Scientific Council on the Complex Problem "Cybernetics" of the USSR Academy of Sciences. The scientific management of this activity was carried out by Yu.I. Zhuravlev, and the coordination, scientific and organizational work was carried out by I.B. Gurevich. In 1988, USSR Academy of Sciences was admitted to The International Association for Pattern Recognition (IAPR) as a collective member. In 1991 it was decided to hold the first USSR All-Union Conference "Pattern Recognition and Image Analysis. New Information Technologies" on the basis of the Institute of Engineering Cybernetics of the Academy of Sciences of the BSSR. It took place in October 1991. 171 reports from all the leading scientific centers of the USSR were presented at the conference.

Starting from 1995, the representative of the Russian Academy of Sciences in IAPR was the Russian Association for Pattern Recognition and Image Analysis, and since 2006 it has been the National Committee of the Russian Academy of Sciences for Pattern Recognition and Image Analysis (Chairman-Academician of the Russian Academy of Sciences Yu.I. Zhuravlev (2006−2022)).

Belarusian scientists in December 1992 founded the Belarusian Association for Image Analysis and Recognition, which in 1993 became a member of the IAPR. In October 1993 in Belarus, with the active support of Russian colleagues, the 2nd conference "Pattern Recognition and Image Analysis. New Information Technologies" was held. It featured 85 presentations from four countries.

In 1995 in the Republic of Belarus, this series of conferences was continued independently of the Russian Academy of Sciences under the title "Pattern Recognition and Information Processing" (PRIP) and for the first time was held in two languages, Russian and English. One volume of the three proceedings of the conference was published in English. Since 1997, the conference has been held under the auspices of IAPR on a regular basis every two−three years.

PRIP conferences have become renowned and acknowledged in the scientific world. Information on PRIP is included in all major international databases on image analysis and pattern recognition, including InSpec. Currently, the PRIP conferences represent the leading international conference on image analysis and pattern recognition in Central and Eastern Europe, and it is the only conference on this subject in the former Soviet Union with international recognition and a high scientific reputation.

In recent years, extended articles prepared on the basis of selected conference reports have been published in the international journal of the Russian Academy of Sciences *Pattern Recognition and Image Analysis. Advances in Mathematical Theory and Applications* (indexed in Web of Science (Emerging Sources Citation Index), Scopus, and the Russian Science Citation Index on the Web of Science platform), and also published as a separate book by Springer in the series "Lecture Notes in Computer Science."

PRIP is conducted by three leading scientific institutions of the Republic of Belarus: Belarusian State University, Belarusian State University of Informatics and Radioelectronics, and the United Institute for Informatics Problems of the National Academy of Sciences of Belarus.

We would like to acknowledge the scientists who started this series of conferences with us. These are professors A.N. Semashko and R.Kh. Sadykhov, who, unfortunately, have already left us. Great help in the 1990s was provided by V.P. Shmerko, at that time a professor at the University of Szczecin, Poland.

Scientific and information support of the conference is always provided by Russian scientists. We especially want to note the enormous assistance that the National Committee of the Russian Academy of Sciences for Pattern Recognition and Image Analysis (I.B. Gurevich and V.V. Yashina) provided to Belarusian colleagues. They and other members of NCROAI have participated in many events held in the Republic of Belarus, organized special issues of the journal *Pattern Recognition and Image Analysis. Advances in Mathematical Theory and Applications* based on the results of PRIP, led joint Russian−Belarusian fundamental research projects, and much more.

PRIP-2021, like previous conferences, was held under the auspices of IAPR. PRIP-2021 received 90 submissions from 18 countries, which were reviewed by program committee members and external reviewers. The conference was held at the United Institute for Informatics Problems of the National

Fig. 1. Opening of the conference. From left to right: A. Belotserkovsky (Chairman of the Program Committee), A. Tuzikov (Chairman of PRIP-2021), S. Ablameyko (Deputy Chairman of PRIP-2021), S. Gaponenko (Chairman of the Belarusian Republican Foundation for Fundamental Research).

Academy of Sciences of Belarus from September 21–24, 2021, mainly remotely due to restrictions caused by the coronavirus pandemic. The conference was held in one track and was also broadcast on YouTube (Fig. 1).

75 reports from 18 countries were presented at the conference. The subject of the conference, which usually includes theoretical and applied aspects of computer vision and processing and recognition of signals and images, this time was expanded to include problems of artificial intelligence. There were many reports on the subject of applications of neural networks and fuzzy systems. Distributed and parallel applications and embedded systems were considered. Much attention was paid to expert systems and decision-support systems, grid and cloud information technologies and infrastructures were considered.

Analysis of the scientific contribution of PRIP-2021 allows us to draw the following conclusions:

(1) The construction of a unified mathematical theory of image analysis continues;

(2) The problems of artificial intelligence are based on the fundamental results of mathematical theories of pattern recognition, machine learning, and image analysis.

(3) The mathematical apparatus in the development of new methods for analyzing and recognizing images is being expanded due to the involvement in this process of areas of mathematics that were not previously used in image analysis.

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

(5) 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 for choosing a solution method and interpreting the results.

(6) Technological advances and increasing storage capacity support the growth of large and detailed, but possibly noisy, image datasets.

(7) Data-mining methods are able to extract valuable knowledge from complex disparate and poorly structured data, which allows them to be successfully applied in a wide variety of application areas: medical diagnostics, robotics, technical diagnostics and non-destructive testing, precision agriculture, new industrial and information-technology support systems, remote sensing, anthropogenic and environmental forecasting and monitoring, automation of scientific research, and many others.

The special issue includes articles prepared on the basis of the best reports of the PRIP-2021 conference, selected by the PRIP-2021 Program Committee. These reports were expanded by their authors and underwent additional peer review. The articles of the special issue deal with theoretical issues of pattern recognition and image analysis, as well as applied problems devoted to the application of image- and information-processing methods in industry, medicine, and other fields.

LIST OF PAPERS INCLUDED INTO THE SPECIAL ISSUE

1. Huafeng Chen, Rykhard Bohush, Ivan Kurnosov, Guangdi Ma, Yang Weichen, Sergey Ablameyko, "Detection of people with atypical appearance and behavior from video from a stationary camera using convolutional neural networks."

2. A.A. Doudkin, A.A.Voronov, S.M. Awakaw, "Algorithms and vision systems in integrated-circuit manufacturing technology."

3. Alexey Kharin, Ton That Tum, "Sequential decision rules for statistical discrimination of patterns in stochastic data."

4. V. Krasnoproshin, D. Mazouka, "A New approach to building a graphics pipeline for visualization tasks."

5. A.A. Kroshchanka, V.A. Golovko, M. Chodyka "Method of reduction of neural network models of computer vision."

6. Olga Nedzved, Sergey Ablameyko, Igor Gurevich, Vera Yashina, Tiaojuan Ren, and Fangfang Ye, "Motion description of dynamic objects for a mobile camera."

7. Mara Sangiovanni, Nadia Brancati, Maria Frucci, Luigi Di Perna, Francesca Simonelli, Daniel Riccio, "Segmentation of pigment signs in fundus images with a hybrid approach: A case study."

8. Valery V. Starovoitov, Yuliya I. Golub, Marina M. Lukashevich, "Universal retinal image template for automated diabetic retinopathy screening."

9. Shiping Ye, Alexander Nedzved, Chaoxiang Chen, Huafeng Chen, Aliaksandr Leunikau, Alexei Belotserkovsky, "Shadow detection in urban satellite images based on building texture."

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COMPLIANCE WITH ETHICAL STANDARDS

This article is a completely original work of its authors; it has not been published before and will not be sent to other publications until the PRIA Editorial Board decides not to accept it for publication.

Conflict of Interest

The process of writing and the content of the article do not give grounds for raising the issue of a conflict of interest.

Sergey Ablameyko. Born in 1956, Dip-Math in 1978, PhD in 1984, DSc in 1990, Prof. in 1992. Professor of Belarusian State University. Scientific interests: image analysis, pattern recognition, digital geometry, knowledge-based systems, geographical information systems, medical imaging. Member of Editorial Board of Pattern Recognition and Image Analysis, Nonlinear Phenomena in Complex Systems, and many other international and national journals. Fellow of IAPR, Fellow of AAIA, Academician of National Academy of Sciences of Belarus, Academician of the European Academy, and many other academies. First Vice-President of International Association for Pattern Recognition IAPR (2006–2008), Chairman of Belarusian Association for Image Analysis and Recognition.

Igor B. Gurevich. Born August 24, 1938, Dr.-Eng. diploma engineer (Automatic Control and Electrical Engineering), 1961, Moscow Power Engineering Institute, Moscow, USSR; Dr., Mathematical Cybernetics, 1975, Moscow Institute of Physics and Technology (National Research University), Moscow, USSR. Leading Researcher at the Computer Science and Control Federal Research Center, Russian Academy of Sciences, Moscow, Russian Federation. He has worked since 1960 as an engineer, researcher, and lecturer in industry, research institutions, medicine, and universities, and since 1985 at 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, and automation of scientific research; knowledge-based systems.

Gurevich suggested, 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 studied (descriptive image algebras); new types of image models were introduced, classified, and studied; axioms of the descriptive theory of image analysis were introduced; a common model of the image-recognition process was defined and investigated; new settings of image analysis and recognition problems were introduced; the notion of "image equivalence" was introduced and studied; new classes of image-recognition algorithms were defined and studied; and an image-formalization space was introduced, defined, and studied.

The listed results were used in the development of software kits for image analysis and recognition and for the solution of important and challenging applied problems of automated bio-medical image analysis.

Gurevich is the author of two monographs; 307 papers in peer-reviewed journals and proceedings indexed in Web of Science, Scopus, and the Russian Science Citation Index on the platform of Web of Science; and 31 invited papers at international conferences. He holds 8 patents. Web of Science: 22 papers; Scopus: 76 papers, 287 citations in 148 documents; Hirsh index is 10; Russian Science Citation Index on the platform of Web of Science: 129 papers, 910 citations; Hirsh index is 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* international journal of the RAS, member of editorial boards of several international scientific journals, member of the program and technical committees of many international scientific conferences. Teaching experience: Moscow State University, RF (assistant professor); Dresden Technical University, Germany (visiting professor); George Mason University, USA (research fellow). He has supervised six PhD students and many graduate and master students.

V. V. Krasnoproshin. Born in 1947. Graduated from Belarusian State University in 1974. Received PhD degree in 1979 and DSc degree in 2007. Currently is full professor of Belarusian State University and the Head of the Information Management Systems Department, Faculty of Applied Mathematics and Computer Sciences. Research interests: artificial intelligence, pattern recognition, image analyses, computer graphics, information and computing technologies. Author of more than 350 papers, including 9 books.

Alexander V. Tuzikov. Head of Mathematical Cybernetics Department of the United Institute of Informatics Problems of the National Academy of Sciences of Belarus, Belarus State Prize Laureate (2002), Belarus representative in IAPR (International Association of Pattern Recognition, http://www.iapr.org/). Graduated from Belarus State University, Minsk, 1980; received the Candidate of Physics and Mathematics degree from Institute of Mathematics (1985) and doctor of physics–mathematical sciences degree of the Institute of Engineering Cybernetics of the National Academy of Sciences of Belarus (2000); Professor (2005); Corresponding Member of the National Academy of Sciences of Belarus (2014). General Director of the United Institute of Informatics Problems of the National Academy of Sciences of Belarus from 2009 to January 2022. His research subjects include bioinformatics, computational biology, image processing and analysis, medical imaging, mathematical morphology, remote sensing, and discrete applied mathematics. Author of more than 400 publications in these fields.

Vera V. Yashina. Born September 13, 1980. Diploma mathematician, Moscow State University (2002), Dr. (Theoretical Foundations of Informatics), 2009, Dorodnicyn Computing Center of the Russian Academy of Sciences, Moscow. Leading researcher at the Department for Recognition, Security, and Analysis of Information at the Computer Science and Control Federal Research Center of the Russian Academy of Sciences, Moscow, Russian Federation. She has worked since 2001 at the Russian Academy of Sciences. Scientific expertise: mathematical theory of image analysis, image algebras, models and medical informatics.

Her main results were obtained in the mathematical theory of image analysis: descriptive image algebras with one ring were defined, classified, and studied; a new topological image formalization space was specified and studied; descriptive generating trees were defined, classified, and studied. The listed results were applied in bio-medical imaging analysis.

She is 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. 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 the *Pattern Recognition and Image Analysis. Advances in Mathematical Theory and Applications* international journal of the RAS. Author of 79 papers in peer-reviewed journals, conference, and workshop proceedings. Web of Science: 11 papers; Hirsh index is 4; Scopus: 40 papers, 162 citations in 75 papers; Hirsh index is 8; Russian Science Citation Index on the platform of Web of Science: 56 papers; 255 citations; Hirsh index is 9.