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Research Tendencies and Prospect Domains for AI Development and Implementation

Editors:

Yuriy P. Kondratenko, Anatolii I. Shevchenko



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Research Tendencies and Prospect Domains for AI Development and Implementation

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Preface

This River Publishers Rapid book analyzes artificial intelligence (AI) implementation priorities, prospect domains as well as some new research tendencies and trends for AI development and implementation. The book consists of seven chapters in the AI field and may be conditionally divided into two parts.

Part 1 is devoted to the world's priorities in AI's implementation and its main components (Chapters 1 and 2) and is based on (a) analysis of the 50 national strategies for AI development as well as the world's and NATO's priorities in AI implementation; (b) methodological aspects for creating the Ukrainian AI conception and strategy, key priority areas for the introduction of AI in Ukraine, the conscience approach to AI systems design, as well as a discussion on new generation computer systems with embedded AI. Special attention is paid to perspectives of AI implementation in education and interrelation and inter-influence between AI and educational systems.

Part 2 (Chapters 3–7) is devoted to some new tendencies in AI development and implementation. Many scientific results and discussions are directed to some new trends in contemporary AI research: (a) AI systems and tools for shipping and shipbuilding; (b) quantum computing and color optical fuzzy computing in applied AI R&D; (c) AI for increasing the efficiency of the decision-making processes; (d) neural networks for solving classification and recognition tasks.

This book provides an overview of the recent developments in advanced AI systems including new theoretical findings and successful examples of practical implementation of the AI tools in different areas of human activities.

The monograph consists of research-analytic-oriented chapters presented by invited high-caliber scientists from different countries (Ukraine, the United States of America, Poland, Norway, and P.R. of China).

The chapter “Analysis of the Prospect Domains in AI Implementation: Nationals, NATO and Ukraine AI Strategies” presents an overview of the national AI strategies in different developed countries, NATO approaches and Ukrainian AI conception and strategy with focuses on the perspective domains of AI implementation. Special attention is paid to the analysis and example demonstrations of AI advances, challenges, and dangers as well as current steps in the AI regulation policy on the national and international levels.

The chapter “Interrelation and Inter-influence of Artificial Intelligence and Higher Education Systems” analyzes recent developments, applications, and perspectives of AI tools for increasing the efficiency of education processes. The important role of AI academia and academia/IT-industry consortia in training AI specialists, and sharing AI resources and qualified cadres is discussed in detail with examples of successful such type consortia in the USA, United Kingdom, Sweden, Thailand and Africa.

The chapter “Multivariate Information Systems and Polymetric Sensors: AI Implementation Perspective in Shipping and Shipbuilding” discusses the increasingly global impact of AI's methods and instruments on accelerating the dual transition of the maritime industry, including shipping, shipbuilding, and critical maritime infrastructure. The purpose of the research is a concise and structured review of some gaps in the development and implementation of the concepts of e-navigation, Digital Twins, Industrial Internet of Things, etc., and their potential influence on the safety and overall efficiency of commercial ships and onshore transshipment terminals.

The chapter “There is Still Plenty of Room at the Bottom: Feynman's Vision of Quantum Computing 65 Years Later” discusses the historical aspects of the appearing quantum computing and interrelation of quark computing and color optical computing as perspective tools (approaches) for creating advanced AI systems with further speed up computation processes.

The chapter “Decision Support System for Maintenance Planning of Vortex Electrostatic Precipitators Based on IoT and AI Techniques” addresses the issue of introducing an intelligent decision support system (DSS) for efficient maintenance planning of vortex electrostatic precipitators (VEPs) in industrial settings. Leveraging the integration of the Internet of Things and AI techniques, the proposed DSS aims to significantly reduce equipment downtime through the optimization of cleaning modes and schedules. In light of the increasing importance of production efficiency and continuous improvement of intelligent technologies, this study becomes particularly relevant as it offers a comprehensive solution for optimizing VEP performance using AI.

The chapter “Leveraging Pre-trained Neural Networks for Image Classification in Audio Signal Analysis for Mobile Applications of Home Automation” presents an in-depth analysis of innovative approaches in the field of audio signal classification using convolutional neural networks and their integration with image processing techniques. The authors investigate the effectiveness of transfer learning from image to audio domains, examining various neural network architectures like VGG16, DenseNet201, MobileNetV3Small, and EfficiencyNet. Special emphasis is placed on the adaptability of these networks to handle audio data, particularly through the manipulation of input sizes and structures, such as Mel-frequency cepstral coefficients and short-time Fourier transform spectrograms.

The chapter “Effectiveness Evaluations of Optical Color Fuzzy Computing” describes the special AI technique for increasing the efficiency of fuzzy information processing. The proposed by the authors approach consists of representing input fuzzy information as color information quanta with the ability to carry out logical operations with them based on the transformation of light radiation. It is shown that the proposed approach provides obvious advantages of increasing the speed of logical calculations due to direct processing (without digitalization) of large fuzzy input data.

The chapters of the monograph have been structured to provide an easy-to-follow introduction to the topics that are addressed, including the most relevant references, so that anyone interested in this field can get started in the area.

This book may be useful for researchers, policymakers, and students who are interested in creating strategies for AI research, development and implementation, and developing advanced AI tools and systems.

Let us express our deep appreciation to all authors for their contributions as well as to reviewers for their timely and interesting comments and suggestions. We certainly look forward to working with all contributors again shortly.

14 February, 2024

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About the Editors



Yuriy Kondratenko is a Doctor of Science, Professor, Honour Inventor of Ukraine (2008), Corr. Academician of the Royal Academy of Doctors (Barcelona, Spain), Corr. Academician of the Royal Academy of Economic and Finance Sciences (Spain), Head of the Department of Intelligent Information Systems at Petro Mohyla Black Sea National University (PMBSNU), Ukraine, Leading Researcher of the Institute of Artificial Intelligence Problems of MES and NAS of Ukraine, Fulbright Scholar. He has received a Ph.D. (1983) and Dr.Sc. (1994) at Odessa National Polytechnic University, and several international grants and scholarships for conducting research at P.R. of China, Germany, and the USA. He is Guest Editor of 3 Special Issue of River Publishers Journal of Mobile Multimedia and an Editor of several River Publishers monographs, including *Advances in Intelligent Robotics and Collaborative Automation* (2015), *Control Systems: Theory and Applications* (2018), *Advanced Control Systems: Theory and Applications* (2021), and *Recent Developments in Automatic Control Systems* (2022). Research interests include artificial intelligence, robotics, automation, sensors and control systems, intelligent decision support systems, and fuzzy logic.



Anatolii Shevchenko graduated from the Faculty of Physics at Donetsk State University with a major in Radio Physics and Electronics. In 1985, he defended his Ph.D. thesis and in 1990 he received the academic degree of Doctor of Technical Sciences. In 1997, he was awarded the title of professor, and in 1998 the honorary title of Honored Scientist and Technician of Ukraine. In 2006, was elected as a Corresponding Member of the National Academy of Sciences of Ukraine in the field of Computer Systems. In 2015, he was appointed as the Director of the Institute of Artificial Intelligence of the Ministry of Education and Science of Ukraine and the National Academy of Sciences of Ukraine in Kyiv. Together with the Department of Informatics of the National Academy of Sciences of Ukraine, he initiated an international scientific journal called “Artificial Intelligence” and was appointed as its chief editor. His research interests encompass various aspects of artificial intelligence, modeling human intelligence, simulating elements of human consciousness, breakthrough technologies in the field of artificial intelligence, and multidisciplinary aspects of artificial intelligence.

CHAPTER

1

Analysis of the Prospect Domains in AI Implementation: Nationals, NATO and Ukraine AI Strategies

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Abstract

This chapter is devoted to the implementation aspects of artificial intelligence (AI) based on the analysis of 50 national strategies for AI development in developed countries. The different forms of national AI presentations and prospect domains for AI applications are discussed. Special attention is paid to NATO and Ukraine activities in AI development and implementation at the current stage and in the future. The chapter focuses on the modern advantages in AI development and challenges in AI implementation including moral-ethical issues and dangers for human civilization. Some character examples of AI

implementation in positive and negative aspects are considered as the basis for creating national and world policies in the regulation of AI development and implementation.

Keywords: Artificial intelligence, strategies, development, implementation, advances, challenges, regulation policy.

1.1 Introduction

Artificial intelligence (AI) plays a decisive role in the modern stage of innovative development of technologically developed countries of the world. Methods and means of artificial intelligence are widely used in various areas of human activity [1, 2], such as medicine, manufacturing, agriculture, the country's defense, state administration, the space industry, and others.

Successful examples of the use of artificial intelligence in various countries of the world [3] confirm the possibility of a significant increase in economic indicators due to the creation of opportunities for a more effective solution for complex technical, economic, social, and humanitarian tasks.

AI has enormous potential and is the engine of global progressive development. This technology can help tackle challenges such as combating climate change, fighting against terrorism, discovering and developing new methods of diagnosis and treatment of oncological and cardiovascular diseases, optimization of automated industrial processes, increasing efficiency in education, and others.

Many publications are devoted to AI development and implementation in different fields, to describing successful cases, AI advances and AI influence on crucial decisions and shaping new perspectives on the future [4–7]. Today's key goal is to ensure efficient and transparent research in human-centered AI systems and an effective governance framework for AI implementation processes.

The efforts of researchers, governors, and policymakers must be directed to the adaptation of AI's potential to improve the lives of people and create a corresponding atmosphere and innovative conditions for AI development and implementation for a happy future of the people. The scientific community needs to constantly analyze and understand not only advances but also the challenges and dangers of wide AI implementation as well as develop and standardize approaches for AI research to take into account potential threats arising from unethical or uncontrolled behaviors of designers and users [3, 8].

The aim and focus of this chapter is the analysis of (a) the strategic plans in developing perspective AI technologies, (b) the main priority domains in AI implementation in the different regions of the world, and (c) the potential dangers and important ethical issues concerning AI development and implementation.

The remainder of the chapter is presented in the following way. Section 1.2 discusses the different forms and peculiarities of the national AI strategies for the main developed countries in the world. The NATO perspectives and directions in AI development and implementation are considered in Section 1.3. The conception, main prospect domains and plans for creating and implementing AI in Ukraine is discussed in Section 1.4. Section 1.5 is devoted to the analysis of the advantages, challenges, and dangers of AI implementation for people, countries, ecology, and others. The current state of creating regulatory policy in the AI field is considered in Section 1.6. Finally, Section 1.7 concludes the study and suggests potential directions for forthcoming research.

1.2 Priorities in AI Implementation Based on National Strategies

Investment in AI development and implementation is growing year by year in all regions of the world. According to experts, the implementation of AI is predicted by 2030 to increase the gross domestic product (GDP) of China, in particular, by 26%, in North America by 14%, and in Europe by around 10% [2, 3].

The rank of AI implementation in the different domains of human activity will play a significant role in the scientific-economical competition between countries, companies, and regions on the global world level and their leadership. Understanding this concept, the governments of different countries try to underline the importance of AI development and implementation by creating national AI strategies with a focus on the priorities in research, creation, and application of AI systems, taking into account their national peculiarities, national interests, and current state of science, education and the countries' economy as a whole.

A list of 50 developed countries, which represent 90% of the global GDP, was published by Holon IQ and included countries that officially presented their national strategies for AI development and implementation [9, 10]. Practically, the countries from all continents are presented in this list. It is very important to underline that national AI strategies in different countries have different forms, all national strategies were created without general unification and standardization approaches and correspondingly all 50 national AI strategies

can be divided into several groups depending on the forms of AI strategy presentation. Some of them are in the form of an AI roadmap, plan, program, initiative, white paper, executive order, etc. Table 1.1 presents information about the form of the national AI strategies in different countries and groups of countries.

Table 1.1: The form of national AI strategies in different groups of countries.

Form of the national AI strategy	Country
AI roadmap	Australia, the Netherlands, the Philippines
AI national programme	Finland, Singapore, Saudi Arabia
AI plan	Argentina, China, Poland, United States of America
AI strategy	Belgium, Brazil, Canada, Czech Republic, Denmark, Estonia, France, Germany, Hungary, India, Indonesia, Japan, Kenya, Lithuania, Luxemburg, Malta, Mexico, Norway, Qatar, South Korea, Spain, Tunisia and others
AI white paper	Italy
AI mission	Austria
National AI initiative	Portugal, South Africa
AI national approach	Spain
AI policy	Chile, Colombia
Presidential AI initiative	Pakistan
AI report	New Zealand, United Kingdom
AI framework	Malaysia
Recommendation for AI strategy	Sweden
Executive order on AI	Russia

Canada and Japan were the first and second countries in the world, respectively, that created and introduced their national strategies for AI development and implementation [3, 9, 10]. Each national AI strategy reflects the main domains and priorities in AI development and implementation, taking into account the unique economic and geographical characteristics of each country, the interconnection between industrial and agricultural sectors,

the correlation between science and education, and expected and desired transformations in corresponding areas of human activity.

Let us analyze the priority domains and priority goals for AI development and implementation based on the national AI strategies of several countries from different continents (Asia, Africa, North America, South America, Europe, and Australia).

Among the priority domains of AI implementation [3, 9, 10] are: health, infrastructure and natural resources (Australia); research and innovation, society, ethics and labor market, qualification and training, AI governance, security and law, AI in the public sector, infrastructure for industrial leadership positions, AI in the economy (Austria); research and talent development (Canada); human capital, fiber optic networks, computing infrastructure, ethics, standards, security, and regulation (Chile); R&D, industrialization, talent development, education and skills acquisition, standard setting and regulations, ethical norms, and security (China); financial inclusion, cybersecurity, land tilting, the election process, single digital identity, and overall public service delivery (Kenya); AI in the public delivery (Kenya); AI in the public sector and business based on regulation and data access, infrastructure and information-communication technologies; realization of the ethical principles, protection of data and security (Norway); education based on special training programs and AI graduate schools, health, public safety, and defense based on funding major projects, infrastructure based on AI semiconductors for autonomous vehicles (South Korea); the education domain for training more skilled AI professionals; the science domain for creating significant results in applied and fundamental AI research based on ethical, safe, reliable, and transparent AI developments (Sweden); transport, health, space, renewable energy, water, technology, education, environment and traffic (United Arab Emirates).

Among the main goals for AI development and implementation are [1, 2, 9, 10]: (a) policy support on ethics, regulation, skills, and competencies; provide AI cartography; co-animate Belgian AI community; collect EU funding and connect EU ecosystems; training in AI; implementation AI technologies to the industries; new products and services based on AI technologies (Belgium); (b) concentrate research on developing responsible and trusted AI, promote digital transformation for SME (small and medium-sized enterprises), enhance economic development, ensure equitable distribution of AI benefits (Czech Republic); (c) to make digital transformation of business and providing the necessary digital skills to people (Denmark); (d) advancing the AI implementation in the public and private sector, developing AI R&D, education and a legal environment for the AI introduction (Estonia); (e) enhance the skills for searching the quality jobs, invest in research and domains that can

provide the maximization of economic growth and social impact, and wide introduction of Indian-made AI developments to other developing countries (India); (f) increasing number of young researchers in AI fields and unifying data formats and standards for different industrial sectors (Japan); (g) crime prediction in the public sector, improving services for citizens and internal government processes (Lithuania); (h) building up AI talent, integrating ethics in AI frameworks, R&D investment, and balancing the role of man and machine (the Netherlands); (i) creating job places and an AI ecosystem for equitable and sustainable development (Tunisia); investing in AI research, unleashing AI resources, setting AI governance standards, building the AI workforce, and protecting the American AI advantages (United States of America).

As we can see, many priority goals and priority domains (transport, education, health, and others) are common for the national AI strategies of the corresponding groups of countries and, at the same time, many countries demonstrate specific and unique goals and priority domains for AI development and implementation.

Experts estimated [11] that by 2030 the contribution of AI to the global economy will be \$15.7 trillion (US dollars).

1.3 NATO's Priorities and Perspectives in AI Implementation

It is necessary to underline that AI's solutions have become a significant integral part of national security strengthening and an important component of warfare operations [2], especially at the last stage of quick development of various intelligent technologies and multidisciplinary research.

AI can offer a wide spectrum of military applications for providing strategic and tactical advantages. In particular, the war in Ukraine has become the first high-tech war in human history, in which both sides of the conflict began utilizing the capabilities of computational artificial intelligence. Ukrainian forces, during the Russian invasion of Ukraine, implemented modern AI technologies for battlefield intelligence, counterpropaganda, and communication interception across various channels [12] and others.

The UK pays a lot of attention to using AI for the modernization of its defense weapons [3]. The integration of AI is the basis for the implementation of an upgrading strategy for the UK defense program, which was unveiled in June 2022. According to this strategy, a centralized defense AI center for research, development, and implementation was established and a part of military capital

funds is planned for direct financial support of civilian AI projects with dual assignment.

Germany, for deployment and activation of scientific research and technological investigations based on the AI development and implementation, has dedicated euros 500 million (June 2022).

The US Department of Defense has asked (for the research and development of advanced AI-connected technologies) for a sum of US \$874 million as part of the 2022 US military budget.

Such examples of the organizational and financial activity and support of USA, Germany and UK demonstrate that NATO member states have recognized the significant potential of AI to transform their defense strategies, streamline operations, and enhance military capabilities [1, 2]. Striving to maintain a competitive advantage on the world stage, NATO countries prioritize AI research and implementation to increase interoperability and ensure a safer and more sustainable future. NATO, in July 2022, announced a euros 1 billion venture investment dedicated to technology investments, including AI [3].

Some publications consider the key priorities of AI research and implementation in NATO countries [1, 2, 3, 13, 14], and analyze the challenges and opportunities presented by this modern disruptive technology. Topics such as strategic planning, force optimization, information advantage, and ethical aspects are also discussed, highlighting how NATO members can effectively use AI to strengthen their defenses and contribute to international security. When considering the current landscape of AI in the military domain, an important focus is also on cooperation and interaction between NATO allies to achieve common goals and protect against potential threats.

To coordinate efforts in the field of AI technologies, the NATO Data and AI Review Board (DARB) was created. DARB began its work on AI standardization in February 2023 with the implementation of an initiative to develop a comprehensive and accessible certification standard for artificial intelligence. This standard aims to ensure that the industries and institutions of the Alliance meet international legal standards, as well as the principles and values of NATO [15].

The NATO Science and Technology Organization published “Science & Technology Trends 2023–2043” across the Physical, Biological, and Information Domains with the priorities of AI development and implementation for the years 2023–2043 [16].

Among the disruptive technologies, the authors of the overview in [16] consider big data, information and communication technologies, artificial

intelligence, robotics and autonomous systems, space, hypersonics, energy and propulsions, electronics, and electromagnetics. Quantum, bio, and human enhancement technologies are included in the group of emergent technologies.

At the same time, the most disruptive and emergent technologies are interconnected between each other based on convergence, inter-dependencies and synergies, and special attention in [16] is paid to data-AI-autonomy, data-quantum, space-hypersonics-materials, space-quantum, data-AI-biotechnologies, data-AI-materials, and energy-materials AI. As another example, NATO's Quantum Technologies Strategy talks about the need to take into account the consequences of the development of data and artificial intelligence for quantum technologies [17]. It is also necessary to underline that special research should be directed at solving complex problems associated with human-AI teaming and psycho-socio-technical issues.

NATO specialists use the AI definition, which was published by the Air Force Research Laboratory (AFRL) in [18], in particular:

“AI refers to the ability of machines to perform tasks that normally require human intelligence – for example, recognizing patterns, learning from experience, drawing conclusions, making predictions, or taking action – whether digitally or as the smart software behind autonomous physical systems”.

AI is seen by NATO analysts as a technology to improve operational awareness by processing and integrating data from various sensors, platforms, and intelligence sources in real time. AI tools can help a more complete understanding and prediction of potential risks, adversary intentions, and the impact of various strategic decisions as well as detecting anomalies or suspicious activity, informing decision-makers on potential dangers, and laying the groundwork for a faster and more targeted response.

AI can also be used to model the behavior of adversaries, giving NATO countries a better understanding of their actions and reactions in various scenarios.

The authors in [16] discuss some of the more exciting and potentially disruptive AI applications concerning artificial social intelligence, automating disinformation and cognitive warfare strategies, producing and identifying “deep fakes,” supplementing air or air-weapons control, aiding in high-resolution image recognition, creating images from text descriptions, navigating human terrain, and providing universal (low usage) language translation.

On the other hand, AI technologies are an organic ecosystem for analyzing current NATO capabilities inside the NATO Defense Planning Process (NDPP) [1, 2, 13] and more effective identification of shortcomings.

NDPP [1, 2, 13] may be considered a key mechanism that manages the development of NATO's military capabilities, ensuring the Alliance's readiness and ability to respond to new security challenges. In this regard, processing and evaluating data from various sources with the help of AI can provide a comprehensive overview of the Alliance's strengths and weaknesses, indicating areas that require improvement or investment. This can help NATO countries make informed decisions about the development and prioritization of force capabilities.

In addition, the identified gaps are the basis for specifying or forming new requirements for the minimum capabilities of forces (minimal capability requirements).

An effective tool that can help analysts in this process is the large language models (LLM) of AI. As an example, their ability to generate relevant proposals is illustrated in Figures 1.1 and 1.2, where the response of GPT-4 regarding the lethality of the soldier is given and the distribution of the corresponding fire lines according to the representation of GPT-4 is illustrated.

As everyone can see, the conclusions provided by GPT-4 are quite relevant and can inspire the relevant thoughts of experts regarding the formalization of requirements for the lethal capabilities of a unit or a platoon of soldiers.

This is quite important because now, the lack of analytical resources does not allow to advance the NDPP process to the company and platoon level of soldiers, limiting it to the battalion level.


Effective allocation of resources and optimization of military forces are vital for NATO countries to maintain their strategic advantage. AI-based systems can help streamline these processes, ensuring the efficient and effective use of assets across various areas and branches of military command.

In particular, the use of AI can reduce the cognitive burden of commanders with the help of personal LLM assistants [19]. On the tactical level, an application of large language models such as GPT-4 can significantly enhance the efficiency of various tasks performed by soldiers. For instance, LLMs can automate reporting and documentation, generating situational reports and filling out standard forms and documents, which greatly reduces time spent on bureaucratic processes. They support decision-making by analyzing large volumes of data, including combat reports, to provide recommendations and

Figure 1.1: A fragment of the GPT-4 proposals (answer) for the lethality of a soldier: SW – expert question.

SW

What are requirements to the letality distance of fire of small arms in squad level?




The lethality distance requirements for small arms at the squad level may vary depending on the military organization, mission objectives, and specific operational environment. However, some general guidelines can be applied to ensure that squads have effective engagement capabilities across various distances:

1. Close Range (0-100 meters): Soldiers must be proficient in engaging targets at close range using personal weapons, such as assault rifles or submachine guns. These weapons are typically chambered in intermediate calibers (e.g., 5.56x45mm NATO, 7.62x39mm) and offer a good balance of controllability, accuracy, and stopping power for close-range engagements.

2. Medium Range (100-300 meters): Effective engagement at medium range often relies on the use of assault rifles or designated marksman rifles (DMRs). These weapons provide greater accuracy and range than close-range personal weapons and are often equipped with optics to facilitate better target acquisition and engagement.

Figure 1.2: A generalized result of the recommended GPT-4 distribution distances of fire damage from small arms.

	<div>Close Range</div> <div>< 100 m</div>	<div>Medium Range</div> <div>7.62x39 5.56x45</div> <div>100–300 m</div>	<div>Long Range</div> <div>7.62x51 0.338</div> <div>300–800 m</div>	<div>Suppressive Fire</div> <div>< 1000 m</div>	<div>Anti-material Anti-Vehicle Fire</div> <div>0.5 BMG 12.7x108 14.5x114</div> <div>< 1500 m</div>
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support commanders in decision-making. LLMs are also useful in creating training materials and instructions and conducting virtual training sessions.

In terms of medical support, they can provide first-aid instructions, interpret symptoms, and offer treatment recommendations. Their ability to translate languages and texts facilitates communication with local populations or international partners without a language barrier. LLMs are also instrumental in planning and logistics, analyzing and optimizing logistical routes, task planning, and resource allocation. They can be used for image recognition and intelligent data analysis, identifying important objects such as enemy equipment or changes in the landscape.

LLMs offer psychological support, including stress management and counseling. They are capable of performing accurate ballistic calculations and providing up-to-date weather information. Additionally, LLMs can be used to create augmented reality (AR) applications for visualization and mission planning.

As information superiority and strong cyber defense capabilities are critical in an increasingly interconnected world, a priority for AI development is to help NATO countries achieve these goals by strengthening their intelligence, surveillance, and reconnaissance capabilities, as well as strengthening their cyber defenses. AI-based systems can analyze massive amounts of data to detect cyber threats and intrusions, respond in real time, and even predict and prevent future attacks. Additionally, AI can support information operations, such as disinformation campaigns and psychological operations, to counter an adversary's narratives and impact on target audiences.

With the increasing dependence of NATO countries on AI for military purposes, they must inevitably face the ethical aspects and ensure the responsible use of AI. The development and deployment of AI-based weapons systems raises questions about accountability, transparency, and potential unintended consequences. NATO countries cooperate to establish common ethical standards and principles governing the use of AI in defense and invest in scientific research to minimize bias, improve explanatory power, and ensure the technology's compliance with international humanitarian law and principles of human rights.

Finally, AI offers NATO countries enormous potential for revolutionary changes in military strategies and capabilities. By prioritizing strategic planning, force optimization, information dominance, and ethical aspects, NATO will be able to realize the full potential of AI and strengthen collective security. Collaboration and cooperation among NATO allies to confront complex challenges and threats will be crucial along the way.

Among 10 countries in the world (100%) with the highest level of AI development and implementation according to STEAM analysis for 2018–2021 are 6 countries that are NATO members [16], in particular, United States of America (41%), United Kingdom (11%), Germany (10%), France (5%), Canada (5%) and Italy (4%).

Among the 10 leading institutions in the world [16] in the AI field according to a STEAM analysis for 2018–2021 are 7 institutions from the NATO-member countries [16], in particular, Max Planck Society, Harvard University, University of Cambridge, Stanford University, University of Oxford, Massachusetts Institute of Technology and University of Michigan.

NATO has perspective relations with Ukraine and constantly supports Ukraine in this wartime during the Russian invasion of this independent country. In May 2023, the Minister of Digital Transformation of Ukraine, Mykhailo Fedorov, during a meeting in Brussels with Deputy Secretary General of the Alliance David van Wiel, announced [20] that NATO scientists will help Ukrainian developers in the field of military innovations.

1.4 Conception and Strategy of AI Development in Ukraine

Ukraine holds an active position in the global market for AI technologies. Ukraine is among the top three countries in Eastern Europe for the number of operating AI companies.

The conception for AI development and implementation in Ukraine [21] was created based on the initiative of the Ministry of Digital Transformation of Ukraine and approved by the Cabinet of Ministers of Ukraine in December 2020. This conception describes the main purpose, principles, and tasks of the development of artificial intelligence technologies in Ukraine as one of the priority directions in the field of scientific and technological research.

Implementation of the conception is foreseen for the period until 2030. The priority domains for AI implementation according to the conception for AI development and implementation in Ukraine are: (a) increasing contribution of Ukraine and occupying a significant segment of the world market of AI technologies and leading positions in international rankings; (b) active participation in the implementation of international initiatives on AI development, regulation and standardization; (c) implementation of AI technologies in the field of education, economy, public administration, cyber security, defense and other areas to ensure the long-term competitiveness

of Ukraine on the international market; (d) providing access to information (databases, electronic registers, etc.), its use during the development of AI technologies for the production of goods and the provision of services; (e) promoting the dissemination of research results in the field of AI and improving their quality; (f) increasing the level of professional training of specialists to ensure the field of AI technologies has qualified personnel; (g) protection of the information space from unauthorized intervention, ensuring the safe functioning of information and telecommunication systems; (h) increasing the level of public safety through the use of AI technologies during the development of resocialization measures for convicted persons and the risk of reoffending; (i) bringing the legislation in the field of using AI technologies into compliance with international legal acts.

The main priority areas for Ukraine in which the tasks of the state policy for AI development and implementation are [21]: education and professional training, science, economy, cyber security, information security, defense, public administration, legal regulation and ethics, and justice.

The Institute of Problems of Artificial Intelligence of the National Academy of Sciences and the Ministry of Education and Science of Ukraine [22] became the initiator and main organization for the implementation of the project on the creation of the Strategy for the Development of Artificial Intelligence in Ukraine, which was carried out in 2020 and 2021 with the involvement of leading specialists and scientists in the field of artificial intelligence from all over Ukraine.

During the work on the project, various proposals of the project participants were born and optimized, the introduced concepts and definitions were polished, critical remarks and comments were made regarding the structure of the document and the content of individual sections, the conclusions of the experienced experts involved in the examination of the project, who were not the authors of the project, were processed.

The main sections of the final version of the project Strategy for the Development of Artificial Intelligence in Ukraine are the following:

- (1) Paradigm of artificial intelligence.
- (2) Basic concepts and directions of research in the field of artificial intelligence.
- (3) The purpose and objectives of the National Strategy for the Development of Artificial Intelligence in Ukraine.
- (4) The state of development of artificial intelligence in Ukraine.
- (5) World's standards of artificial intelligence.
- (6) System of management and regulation of artificial intelligence in Ukraine.

- (7) Scientific, personnel, and material support of the national ecosystem of artificial intelligence.
- (8) Artificial intelligence in priority areas of development of Ukraine.
- (9) Assessment of changes in the labor market in Ukraine under the influence of the development of artificial intelligence.
- (10) Final provisions of the Strategy for the Development of Artificial Intelligence in Ukraine in 2026–2030.

Public discussion around the project “Strategy for Artificial Intelligence Development in Ukraine” [22, 23] commenced towards the end of 2021.

Besides the abovementioned priority domains described in the AI conception, the project of the AI strategy includes such priority areas as medicine, agriculture, industry and energy, transport and infrastructure, ecology, and environmental protection.

At the current time, Ukraine actively implements advanced AI technologies in the different domains, for example: (a) for creating AI-based autonomous drones and robots [24, 25, 26, 27, 28, 29, 30]: (1) Highland Systems, a company founded by Ukrainians, presented a prototype of the radar-invisible electric unmanned submarine Kronos [25], the drone can move silently at speeds of up to 50 km/h and launch torpedoes; (2) more than 200 Ukrainian companies are involved in the production of UAVs [26]; (3) on 24 October 2023, the ground kamikaze robot Ratel S, created by Ukrainian developers Brave1, successfully passed field tests and was put into mass production [27]. The Ukrainian Defense Forces will use the Ratel S as a mobile warhead carrying anti-tank mines or a combat module. An operator from a safe location can blow up an enemy tank or dugout. The maximum speed of the drone reaches 24 kilometers, and the range of use is 6 kilometers. Ratel S can work up to 2 hours without recharging; (b) Railway Company “Ukrzaliznytsia” [31] has begun to use ChatGPT to analyze passenger appeals. During the day, the app receives an average of 1300 travel ratings from passengers. About 300 of them are text reviews about the railway. Artificial intelligence will distribute passenger appeals on 21 topics, from service quality to delays. Currently, ChatGPT correctly determines the category of the request in 90% of cases; (c) The Ministry of Digitization is developing a virtual assistant in “Diya” [32], the task of which is to quickly find answers to users’ questions. In addition, AI will help the State Statistics Service to process and analyze data; (d) Some benefits of AI implementation are in military technologies [32] as AI helps to record the movement of enemy equipment and personnel, to shoot down missiles, to target UAVs more effectively, etc.; (e) Ukraine uses AI technologies (face recognition) to search for missing citizens during the full-scale Russian war [33]; (f) the National Agency for the Prevention of Corruption has decided that artificial intelligence will help verify the declarations of officials [34]. All submitted declarations will

undergo a risk assessment. Those declarations that will have the lowest risk rating indicator and can be checked automatically will be able to be checked by artificial intelligence – an automated check mechanism.

The “Strategy for Artificial Intelligence Development in Ukraine” pays special attention to such a “breakthrough” direction of AI research as designing AI systems based on the concept of consciousness and conscience (Figure 1.3) [1, 2, 3, 35, 36, 37].

Figure 1.3: Components of the new generation computer system based on embedded AI

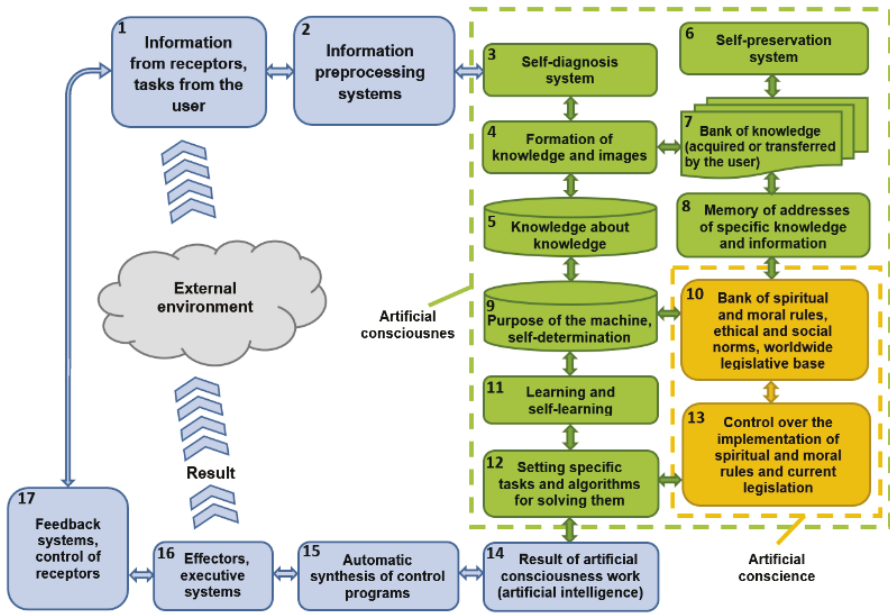


Figure 1.3 presents the main components of the integrated AI system, which is the basis for further research on AI in a personal context [38], for getting and preliminary processing sensor information, formation of patterns, and interaction with different memory units for real-time control of system functioning based on existing laws, rules and moral-ethical norms of the human-centered society [1, 2, 3, 24, 35, 38].

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- Y. Kondratenko , A. Shevchenko , Y. Zhukov , V. Slyusar , M. Klymenko , G. Kondratenko , O. Striuk , 'Analysis of the Priorities and Perspectives in Artificial Intelligence Implementation', 13th International IEEE Conference "Dependable Systems, Services and Technologies" (DESSERT'2023), Greece, Athens, October 13-15, 2023.
- Y. Kondratenko , G. Kondratenko , A. Shevchenko , V. Slyusar , Y. Zhukov , M. Vakulenko , 'Towards Implementing the Strategy of Artificial Intelligence Development: Ukraine Peculiarities', CEUR Workshop Proceedings, vol. 3513, 2023, pp. 106-117, <https://ceur-ws.org/Vol-3513/paper09.pdf>.
- Y. Kondratenko , A. Shevchenko , Y. Zhukov , G. Kondratenko , O. Striuk , 'Tendencies and Challenges of Artificial Intelligence Development and Implementation', Proceedings of the 12th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS'2023, Vol. 1, 2023, pp. 221–226, IDAACS 2023, Dortmund, Germany, 7-9 September 2023.
- P. Lee , C. Golberg , I. Kohane , 'The AI revolution in medicine: GPT-4 and beyond', Pearson Education Inc., 2023.
- Y. P. Kondratenko , N. Y. Kondratenko , 'Reduced library of the soft computing analytic models for arithmetic operations with asymmetrical fuzzy numbers', in: Soft Computing: Developments, Methods and Applications, A. Casey (Ed), NOVA Science Publishers, Hauppauge, New York, 2016, pp. 1-38.
- V. Slyusar , et al. , 'Improvement of the object recognition model on aerophotos using deep conventional neural network', East. Eur. J. Enterp. Technol., Vol. 5, No. 2 (113), pp. 6-21, 2021.
- D. Chumachenko , et al. , 'Machine Learning Methods in Predicting Patients with Suspected Myocardial Infarction Based on Short-Time HRV Data', Sensors, vol. 22, no. 18, 7033, 2022.
- A. Hanna , E. Bender , 'AI Hurts Consumers and Workers and Isn't Intelligent', TechPolicy Press, August 4, 2023.
- '50 National AI Strategies - The 2020 AI Strategy Landscape', <https://bit.ly/3DBYraQ>.
- 'The Global AI Strategy Landscape', <https://bit.ly/3LFvGY9>.
- T. Kohli , 'AI's contribution to the global economy will bypass that of China and India by 2030, to reach \$15.7 trillion', World Economic Forum, September 17, 2019, <https://www.weforum.org/agenda/2019/09/artificial-intelligence-meetsbiotechnology/>.
- 'Ukrainian developers use artificial intelligence for more accurate drone bombardment', 2022, <https://bit.ly/3f1bZh3>.
- V. Slyusar , N. Hamaliy , 'New model of NATO defense planning process, NDPP', Coordination problems of military-technical and defensive industrial policy in Ukraine. Weapons and military equipment development perspectives, V International Scientific and Practical Conference, Abstracts of reports, Kyiv, 11-12 October 2017, pp. 38-39.
- Z. Stanley-Lockman , E. H. Christis , 'An Artificial Intelligence Strategy for NATO', NATO, October 2021.
- 'NATO starts work on Artificial Intelligence certification standard', 07 February 2023, https://www.nato.int/cps/en/natohq/news_211498.htm.
- D.F. Reding , et al. , 'Science & Technology Trends 2023-2043', vol. 1-2, NATO Science and Technology Organization, Brussels, Belgium, March 2023.
- 'Summary of NATO's Quantum Technologies Strategy', 16 January 2024, https://www.nato.int/cps/en/natohq/official_texts_221777.htm.
- 'AFRL Artificial Intelligence – Air Force Research Laboratory', 2022, <https://afresearchlab.com/technology/artificial-intelligence/> (visited on 12/30/2023).
- V. Slyusar , 'Reducing the Cognitive Burden of a Soldier with the Help of a Personal AI and LLM Assistant', Human Systems Integration Team of Experts (HSI ToE) Virtual Winter Symposium, 12 January 2024, DOI: 10.13140/RG.2.2.10264.57605/1.
- M. Klymkovetsky , 'NATO scientists will help Ukrainian developers in the field of military innovations', 26 May 2023, <https://hromadske.ua/posts/naukovci-nato-dopomagatimut-ukrayinskim-rozrobnikam-u-sferi-vijskovih-innovacij-mincifri>
- 'On the Approval of the Concept of Artificial Intelligence Development in Ukraine', bit.ly/44GrVKh

Shevchenko, A. I., et al., 'Regarding the Draft Strategy Development of Artificial Intelligence in Ukraine (2022 – 2030)', Artificial Intelligence (Shtuchnyi Intel'ekt), No. 1, pp. 8-157, 2022.

Shevchenko, A.I., et al. 'Strategy for Artificial Intelligence Development in Ukraine', Monograph, IAIP, Kyiv, 2023, DOI:10.15407/development_strategy_2023.

Y. Kondratenko, I. Atamanyuk, I. Sidenko, G. Kondratenko, S. Sichevskiy, 'Machine Learning Techniques for Increasing Efficiency of the Robot's Sensor and Control Information Processing', Sensors, vol. 22, no. 3, 1062, January 2022.

'Engineers from Ukraine presented a radar-invisible electric unmanned submarine Kronos', BuildingTECH, 23 February 2023.

J. Hudson, K. Khudov, 'The war in Ukraine is spurring a revolution in drone warfare using AI', The Washington Post, 26 July, 2023, <https://www.washingtonpost.com/world/2023/07/26/drones-ai-ukraine-war-innovation/>

'Ukrainian kamikaze robot Ratel S launched into mass production. 24 October 2023, <https://news.pn/ru/RussiaInvadedUkraine/299190>

R. Duro, Y. Kondratenko (eds), Advances in Intelligent Robotics and Collaborative Automation, River Publishers, Aalborg, 2015.

Y. P. Kondratenko, L. P. Klymenko, V. Y. Kondratenko, G. V. Kondratenko, E. A. Shvets, 'Slip displacement sensors for intelligent robots: Solutions and models', Proceedings of the 2013 IEEE 7th International Conference on Intelligent Data Acquisition and Advanced Computing Systems, IDAACS 2013, 2, art. no. 6663050, pp. 861-866, 2013, doi:10.1109/IDAACS.2013.6663050

V. M. Kuntsevich, V. F. Gubarev, Y. P. Kondratenko, D. V. Lebedev, and V. P. Lysenko (Eds.), 'Control Systems: Theory and Applications', River Publishers, Girsrup, Delft, 2018.

'Ukrzaliznytsia: Processing passenger requests using ChatGPT', <https://www.facebook.com/Ukrzaliznytsia/posts/pfbid033VCGWzXrCDvkcP221opg79sPsGG8BLDQivk87qHfSrW1h667u2TCRQPKHn28sNil>

'Fedorov stated that Ukraine has started work on a strategy for regulating artificial intelligence', 3 August 2023, <https://news.pn/ru/public/295074>

'Dmytro Lubinets: artificial intelligence is used to search for missing people', 16 November 2023, https://ombudsman.gov.ua/news_details/dmitro-lubinec-shtuchnij-intelekt-vikorisovuyut-dlya-poshuku-zniklih-bezvisti-lyudej

V. Kolomiyets, 'Artificial intelligence will help to check the declarations of officials', Hromadske, 22 December 2023, <https://hromadske.ua/posts/shtuchnij-intelekt-dopomozhe-pereviryati-deklaraciyi-chinovnikiv-nazk>

A. I. Shevchenko, M. S. Klymenko, 'Developing a Model of Artificial Conscience', in: 15th IEEE International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT'2020, vol. 1, 23-26 Sept. 2020, Lviv-Zbarazh, pp. 51–54, 2020.

E. Hildt, 'Artificial Intelligence: Does Consciousness Matter?', Front. Psychology 10, 2019.

R. Manzotti, A. Chella, 'Good Old-Fashioned Artificial Consciousness and the Intermediate Level Fallacy', Frontiers in Robotics and AI 5, 2018.

A. I. Shevchenko, 'Natural Human Intelligence - The Object of Research for Artificial Intelligence Creation', International Scientific and Technical Conference on Computer Sciences and Information Technologies, 2019, 1, pp. XXVI–XXIX, 8929799, CSIT 2019, Lviv, 17-20 September 2019.

L. Medeiros, D. Psaltis, T. R. Lauer, F. Özel, 'The Image of the M87 Black Hole Reconstructed with PRIMO', The Astrophysical Journal Letters, 947:L7 (6pp), 10 April 2023, <https://iopscience.iop.org/article/10.3847/2041-8213/acc32d/pdf>

O. Striuk, Y. Kondratenko, 'Optimization Strategy for Generative Adversarial Networks Design', International Journal of Computing, vol. 22(3), pp. 292–301, 2023. DOI:10.47839/ijc.22.3.3223

O. Striuk, Y. Kondratenko, 'Implementation of Generative Adversarial Networks in Mobile Applications for Image Data Enhancement', Journal of Mobile Multimedia, 19(3), pp. 823–838, 2023.

O. Striuk, Y. Kondratenko, 'Generative Adversarial Neural Networks and Deep Learning: Successful Cases and Advanced Approaches', International Journal of Computing, Vol. 20, Issue 3, pp. 339-349, 2021.

P. Scharre, 'AI's inhuman advantage', Texas National Security Reviv, 10 April 2023, <https://warontherocks.com/2023/04/ais-inhuman-advantage/>

'French Open 2023: Grand Slam using AI to protect players from online abuse', Bbc, 28 May 2023, <https://www.bbc.com/sport/tennis/65706479>

'Japan is introducing technology to recognize drivers' emotions using AI to improve road safety', <https://news.pn/uk/public/294347>

A. Taylor , 'Albania to speed up EU accession using ChatGPT', EURACTIV, 12 December 2023, <https://www.euractiv.com/section/politics/news/albania-to-speed-up-eu-accession-using-chatgpt/>

R. Browne , 'An AI just negotiated a contract for the first time ever — and no human was involved', Cnbc, 12 November 2023, <https://www.cnn.com/2023/11/07/ai-negotiates-legal-contract-without-humans-involved-for-first-time.html>

D. Trotta , 'California turns to AI to help spot wildfires', Reuters, 11 August 2023, <https://www.reuters.com/world/us/california-turns-ai-help-spot-wildfires-2023-08-11/>

'UK cybersecurity center says 'deepfakes' and other AI tools pose a threat to the next election', Ap, 14 November 2023, <https://apnews.com/article/uk-cyber-threats-ai-elections-b6482d3127ae524551e15887b3fdb01b>

P. Glynn , 'Sony World Photography Award 2023: Winner refuses award after revealing AI creation', Bbc, 18 April 2023, <https://www.bbc.com/news/entertainment-arts-65296763>

A. Crawford , T. Smith , 'Illegal trade in AI child sex abuse images exposed', Bbc, 28 June 2023, <https://www.bbc.com/news/uk-65932372>

'In South Korea, an industrial robot mistakenly killed a man', <https://news.pn/uk/public/299999>

M. Sellman , 'ChatGPT falsely accuses law professor of sex assault', The Times, 6 April 2023, <https://www.thetimes.co.uk/article/chatgpt-falsely-accuses-law-professor-of-sex-assault-fmvfhptpp?fbclid=IwAR2lxhwr5-ezAgr8wCICZiCj2yN6uwST4x7yDbKOvI2RP5Qf9XN44Nrn6Uc>

D. Baschuk , 'Tech, AI Driving Job Changes for Nearly a Quarter of All Workers', Bloomberg, 30 April 2023, <https://www.bloomberg.com/news/articles/2023-04-30/tech-ai-driving-job-changes-for-nearly-a-quarter-of-all-workers?srnd=premium-europe&leadSource=uverify%20wall>

J. Henley , 'German tabloid Bild cuts 200 jobs and says some roles will be replaced by AI', The Guardian, 20 June 2023, <https://www.theguardian.com/world/2023/jun/20/german-tabloid-bild-to-replace-range-of-editorial-jobs-with-ai>

P. Gmyrek , J. Berg , D. Bescond , 'Generative AI and jobs: A global analysis of potential effects on job quantity and quality', International Labor Organization, ILO Working Paper 96, August 2023, https://www.ilo.org/wcmsp5/groups/public/---dgreports/---inst/documents/publication/wcms_890761.pdf

S. Russell , 'AI weapons: Russia's war in Ukraine shows why the world must enact a ban', Nature, v. 614, pp. 620-623, 23 February 2023.

Z. Kleinman , C. Vallance , 'AI 'godfather' Geoffrey Hinton warns of dangers as he quits Google', Bbc, 2 May 2023, <https://www.bbc.com/news/world-us-canada-65452940>

'Pause Giant AI Experiments: An Open Letter', Future of Life Institute, 22 March 2023, <https://futureoflife.org/open-letter/pause-giant-ai-experiments/>

'Lethal Autonomous Weapons Pledge . An Open Letter', Future of Life Institute, 6 June 2023, <https://futureoflife.org/open-letter/lethal-autonomous-weapons-pledge/>

'Ukraine has signed an international declaration dedicated to the safety of the use of AI', 2 November 2023, <https://thedigital.gov.ua/news/ukraina-pidpisala-mizhnarodnu-deklaratsiyu-prisvyachenu-bezpetsi-vikoristannya-shi>

'The Bletchley Declaration by Countries Attending the AI Safety Summit', 1-2 November 2023, <https://www.gov.uk/government/publications/ai-safety-summit-2023-the-bletchley-declaration/the-bletchley-declaration-by-countries-attending-the-ai-safety-summit-1-2-november-2023>

'Fact Sheet: President Biden Issues Executive Order on Safe, Secure, and Trustworthy Artificial Intelligence', White House, 30 October 2023, <https://www.whitehouse.gov/briefing-room/statements-releases/2023/10/30/fact-sheet-president-biden-issues-executive-order-on-safe-secure-and-trustworthy-artificial-intelligence/>

L. O'Carroll , 'EU agrees 'historic' deal with world's first laws to regulate AI', The Gardian, 8 December 2023, <https://www.theguardian.com/world/2023/dec/08/eu-agrees-historic-deal-with-worlds-first-laws-to-regulate-ai>

Ye. Gubina , 'The European Union has taken an important step towards the regulation of artificial intelligence', Meza, 15 June 2023. <https://mezha.media/2023/06/15/yevrosoiuz-zrobyv-vazhlyvyi-krok/>

M. Eisenstein , 'Seven technologies to watch in 2024', Nature, Vol 625, pp. 844-848, 25 January 2024.

Interrelation and Inter-influence of Artificial Intelligence and Higher Education Systems

A. Toma , S. Senkaiahliyan , P. R. Lawler , B. Rubin , B. Wang , 'To safely deploy generative AI in health care, models must be open source', Nature, Vol 624, 7 December 2023, pp. 36-38.

Y. Kondratenko , A. Shevchenko , Y. Zhukov , G. Kondratenko , O. Striuk , 'Tendencies and Challenges of Artificial Intelligence Development and Implementation', Proceedings of the 12th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS'2023, Vol. 1, 2023, pp. 221–226, IDAACS 2023, Dortmund, Germany, 7-9 September 2023.

Y. Kondratenko , A. Shevchenko , Y. Zhukov , V. Slyusar , M. Klymenko , G. Kondratenko , O. Striuk , 'Analysis of the Priorities and Perspectives in Artificial Intelligence Implementation', 13th International IEEE Conference "Dependable Systems, Services and Technologies" (DESSERT'2023), Greece, Athens, October 13-15, 2023.

Y. Kondratenko , G. Kondratenko , A. Shevchenko , V. Slyusar , Y. Zhukov , M. Vakulenko , 'Towards Implementing the Strategy of Artificial Intelligence Development: Ukraine Peculiarities', CEUR Workshop Proceedings, vol. 3513, 2023, pp. 106-117, <https://ceur-ws.org/Vol-3513/paper09.pdf>.

P. Lee , C. Golberg , I. Kohane , 'The AI revolution in medicine: GPT-4 and beyond', Pearson Education Inc., 2023.

D. Bulavin , 'What to do so that artificial intelligence does not take away your job, and how it will affect education in Ukraine', July 3, 2023, <https://hromadske.ua/posts/sho-robiti-abi-shtuchnij-intelekt-ne-zabrav-u-vas-robotu-i-yak-vin-vpli-ne-na-osvitu-v-ukrayini>

T. Biloborodova , I. Skarga-Bandurova , 'Human-AI Collaboration in Decision Making: An Initial Reliability Study and Methodology', 2023 IEEE 12th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), Dortmund, Germany, 2023, pp. 1151-1155, doi:10.1109/IDAACS58523.2023.10348928.

D. Leitão , P. Saleiro , M. A. T. Figueiredo , P. Bizarro , 'HumanAI Collaboration in Decision-Making: Beyond Learning to Defer', arXiv:2206.13202, <https://arxiv.org/abs/2206.13202>

Y. P. Kondratenko , N. Y. Kondratenko , 'Reduced library of the soft computing analytic models for arithmetic operations with asymmetrical fuzzy numbers', in: Soft Computing: Developments, Methods and Applications, A. Casey (Ed), NOVA Science Publishers, Hauppauge, New York, 2016, pp. 1-38.

Y. Kondratenko , N. Kondratenko , 'Real-Time Fuzzy Data Processing Based on a Computational Library of Analytic Models', Data, Volume 3, Issue 4, 59, pp.1-19, 2018, doi:10.3390/data3040059.

O. Kozlov , G. Kondratenko , Z. Gomolka , Y. Kondratenko , 'Synthesis and Optimization of Green Fuzzy Controllers for the Reactors of the Specialized Pyrolysis Plants', in: V. Kharchenko , et al. (eds), Green IT Engineering: Social, Business and Industrial Applications, Studies in Systems, Decision and Control, vol. 171, Springer, Cham, pp. 373-396, 2019, DOI: https://doi.org/10.1007/978-3-030-00253-4_16

Z. Gomolka , E. Dudek-Dyduch , Y. Kondratenko , 'From homogeneous network to neural nets with fractional derivative mechanism', International Conference on Artificial Intelligence and Soft Computing, ICAISC-2017, Rutkowski, L. et al. (Eds), Part I, Zakopane, Poland, 11-15 June 2017, LNAI 10245, Springer, Cham, pp. 52-63, 2017. DOI https://doi.org/10.1007/978-3-319-59063-9_5

M. Gault , 'Eric Schmidt Thinks AI Is as Powerful as Nukes', 2022, <https://bit.ly/3f1T3ie>.

'From Einstein to AI: how 100 years have shaped science', Editorials, Nature, Vol. 624, 21/28 December 2023, p. 474.

M. Ghassemi , A. Birhane , M. Bilal , S. Kankaria , C. Malone , E. Mollick , F. Tustumi , 'ChatGPT one year on who is using it, how and why?', Nature, Vol. 624, pp. 39-41, 7 December 2023.

M. Hutson , 'Will Superintelligent AI Sneak Up on Us? Study Suggests Not', Nature, Vol. 625, p. 223, 11 January 2024.

D. Castelvechi , 'DeepMind AI Outdoes Human Mathematicians on Unsolved Problem', Nature, Vol 625, pp. 12-13, 4 January 2024.

S. Hai-Jew , 'Generative AI in teaching and learning', 5 December 2023, DOI 10.4018/979-8-3693-0074-9, <https://www.scopus.com/record/display.uri?eid=2-s2.0-85182286246&origin=recordpage>

L. Wesemann , 'The promise and perils of AI in academia', University of Melbourne, Australia, <https://www.youtube.com/watch?v=i8lmyaB7sH4>

'ChatGPT caught NYC schools off guard. Now, we're determined to embrace its potential', 2023, <https://ny.chalkbeat.org/2023/5/18/23727942/chatgpt-nyc-schools-david-banks>

'Seoul Education Office to Introduce Robots for 1:1 English Learning', KBS, 29 November 2023, world.kbs.co.kr/service/news_view.htm?lang=e&Seq_Code=182095

M. Klymkovetskyi , 'The Ministry of Digitization and Google are launching a free course on artificial intelligence for Ukrainians', 3 May 2023, <https://hromadske.ua/posts/mincifri-i-google-zapuskayut-dlya-ukrayinciv-bezplatnij-kurs-pro-shtuchnij-intelekt>

D. Bulavin , 'The Ministry of Education and Science has launched a test based on artificial intelligence, which can help students determine their future profession', July 29, 2023, <https://hromadske.ua/posts/mon-zapustilo-test-na-0-snovi-shtuchnogo-intelektu-yakij-mozhe-dopomogti-uchnyam-viznachiti-majbutnyu-profesiyu>

A. Joshi , M. Vinay , P. Bhaskar , 'Impact of coronavirus pandemic on the Indian education sector: perspectives of teachers on online teaching and assessments', Interactive Technology and Smart Education, Volume 18, Issue 2, pp. 205-226, 2021, DOI 10.1108/ITSE-06-2020-0087

A. I. Shevchenko , M. S. Klymenko , 'Developing a Model of Artificial Conscience', 15th IEEE International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT'2020, Vol. 1, 23-26 September 2020, Lviv-Zbarazh, pp. 51-54, 2020.

'Top 7 Ways Artificial Intelligence Is Used in Education', 2021, <https://bit.ly/3DyW5Vp>.

D. Castelvechi , 'How will AI change mathematics?', Nature, vol. 615, pp. 15-16, 2 March 2023,.

O. Striuk , Y. Kondratenko , 'Generative Adversarial Neural Networks and Deep Learning: Successful Cases and Advanced Approaches', International Journal of Computing, Vol. 20, Issue 3, pp. 339-349, 2021.

R. Duro and Y. Kondratenko (Eds)., 'Advances in Intelligent Robotics and Collaborative Automation', River Publishers, Aalborg, 2015.

V. M. Kuntsevich , V. F. Gubarev , Y. P. Kondratenko , D. V. Lebedev , and V. P. Lysenko (Eds)., 'Control Systems: Theory and Applications', River Publishers, Girsrup, Delft, 2018.

I. Atamanyuk et al., 'Computational method of the cardiovascular diseases classification based on a generalized nonlinear canonical decomposition of random sequences', Scientific Reports, Vol. 13, 59, 2023, <https://doi.org/10.1038/s41598-022-27318-0>

M. Tetyana , Y. Kondratenko , I. Sidenko , G. Kondratenko , 'Computer Vision Mobile System for Education Using Augmented Reality Technology', Journal of Mobile Multimedia, vol. 17, no. 4, pp. 555-576, 2021.

Y. Kondratenko , I. Atamanyuk , I. Sidenko , G. Kondratenko , S. Sichevskiy , 'Machine Learning Techniques for Increasing Efficiency of the Robot's Sensor and Control Information Processing', Sensors, vol. 22, no. 3, 1062, Jan. 2022, <https://doi.org/10.3390/s22031062>

A.N. Tkachenko , et al., 'Evolutionary adaptation of control processes in robots operating in non-stationary environments', Mechanism and Machine Theory, vol. 18, No. 4, Print. Great Britain, pp. 275-278, 1983, DOI: 10.1016/0094-114X(83)90118-0

C. Basgier , S. Sharma , 'Should scientists delegate their writing to ChatGPT?', Nature, Vol 624, p. 523, 21 /28 December 2023.

S. Canali , F. Barone-Adesi , 'Can AI deliver advice that misjudgment-free for science policy?', Nature, vol. 624, p. 252, 14 December 2023.

R. Sharma , 'How Gemini Nano is Redefining Mobile Capabilities', 23 January, 2024, <https://markovate.com/blog/gemini-nano/>.

'StableLM Zephyr 3B GGUF', 27 January, 2024, <https://huggingface.co/brittlewis12/stablelm-zephyr-3b-GGUF>.

S. Chauhan , 'Rabbit Unveils Innovative Virtual Assistant R1 at CES 2024', 10 January 2024, <https://bnnbreaking.com/tech/rabbit-unveils-innovative-virtual-assistant-r1-at-ces-2024/>.

'Free AI Teaching Assistant and AI Tutor Powered by ChatGPT', Campus Technology, 30 November 2023. <https://campustechnology.com/articles/2023/11/30/free-ai-teaching-assistant-and-ai-tutor-powered-by-chatgpt.aspx?admgarea=News>

'AI in Digital Learning: Benefits, Applications and Challenges', Digital Learning Institute, 29 September 2023.

V. Paradkar , 'The Next Leap in AI: OpenAI's Journey Towards GPT-5', 12 January 2024, <https://medium.com/@virajsparadkar/the-next-leap-in-ai-openais-journeytowards-gpt-5-844f0a8d1d2d>

'GPT-5 Is Coming In 2024? Sam Altman Announces Updates at Y Combinator W24', <https://www.youtube.com/watch?v=qfPyVuxf4o0>

G. Kondratenko , et al. , 'Fuzzy Decision Making System for Model- Oriented Academia/Industry Cooperation: University Preferences', in: Berger-Vachon, C. , et al. (eds.), Complex Systems: Solutions and Challenges in Economics, Management and Engineering, Studies in Systems, Decision and Control, vol. 125, Springer, Berlin, Heidelberg, pp. 109-124, 2018.

Y. Kondratenko , et al., 'University Curricula Modification Based on Advancements in Information and Communication Technologies', CEUR Workshop Proceedings, 1614, pp.184–199, 2016.

Y.P. Kondratenko , et al. , 'Knowledge-Based Decision Support System with Reconfiguration of Fuzzy Rule Base for Model-Oriented Academic-Industry Interaction', in: Gil-Lafuente, A.M. , et al. (eds.), Applied Mathematics and Computational Intelligence, FIM 2015, Advances in Intelligent Systems and Computing, vol. 730, Springer, Cham, pp. 101-112, 2018.

'Governor Hochul Unveils Fifth Proposal of 2024 State of the State: Empire AI Consortium to Make New York the National Leader in AI Research and Innovation', January 8, 2024, Albany, NY, <https://www.governor.ny.gov/news/governor-hochul-unveils-fifth-proposal-2024-state-state-empire-ai-consortium-make-new-york>

A. Taylor , 'Albania to speed up EU accession using ChatGPT', EURACTIV, 12 December 2023, <https://www.euractiv.com/section/politics/news/albania-to-speed-up-eu-accession-using-chatgpt/>

'Arizona State University Partners with OpenAI to Explore Gen AI Potential in Education', Campus Technology, 18 January 2024, <https://campustechnology.com/Articles/2024/01/18/Arizona-State-University-Partners-with-OpenAI-to-Explore-Gen-AI-Potential-in-Education.aspx>

'Cambridge academics join £31 million consortium to develop trustworthy and secure AI', Cambridge University, 14 June 2023, <https://www.cam.ac.uk/research/news/cambridge-academics-join-ps31-million-consortium-to-develop-trustworthy-and-secure-ai>

'Responsible AI Institute Launches Inaugural Consortium; Operationalizes AI Safety Across Industries', InsideBIGDATA, 1 July 2023, <https://insidebigdata.com/2023/07/01/responsible-ai-institute-launches-inaugural-consortium-operationalizes-ai-safety-across-industries/>

'Auburn University leading SEC consortium to advance innovation in AI teaching, learning', Auburn University, 7 August 2023, https://ocm.auburn.edu/newsroom/news_articles/2023/08/071326-auburn-leading-sec-ai-teaching-consortium.php

'Norwegian Artificial Intelligence Research Consortium, NORA. <https://www.nora.ai/>

'New AI in Math program is funded by the U.S. Department of Education', Concord Consortium, January 4, 2024, <https://concord.org/blog/tag/artificial-intelligence/>

A. Helregel , 'NCSA Helps Found Trillion Parameter Consortium', NCSA, 27 November 2023. <https://www.ncsa.illinois.edu/ncsa-helps-found-trillion-parameter-consortium/>

O. Shurbin , et al. , 'Computerized system for cooperation model's selection based on intelligent fuzzy technique', CEUR Workshop Proceedings 2516, pp. 206-217, 2019.

M. Solesvik , et al., 'Architecture for Collaborative Digital Simulation for the Polar Regions', in: V. Kharchenko , et al. (eds), Green IT Engineering: Social, Business and Industrial Applications, Studies in Systems, Decision and Control, vol 171, Springer, Cham, pp. 517–531, 2019, DOI: https://doi.org/10.1007/978-3-030-00253-4_22

V. Shebanin , et al., 'Development of the Mathematical Model of the Informational Resource of a Distance Learning System', in: O. Chertov , et al. (eds.), Recent Developments in Data Science and Intelligent Analysis of Information, Proceedings of the XVIII International Conference on Data Science and Intelligent Analysis of Information, June 4–7, 2018, Kyiv, Ukraine. ICDSIAI 2018, Advances in Intelligent Systems and Computing, vol. 836, Springer International Publishing, pp. 199–205, 2019, DOI: [10.1007/978-3-319-97885-7_20](https://doi.org/10.1007/978-3-319-97885-7_20)

Y. Kondratenko , G. Kondratenko , I. Sidenko , 'Intelligent Decision Support System for Selecting the University-Industry Cooperation Model Using Modified Antecedent-Consequent Method', in: J. Medina et al. (eds), *Information Processing and Management of Uncertainty in Knowledge-Based Systems: Theory and Foundations*, 17th International Conference, IPMU 2018, Cadiz, Spain, June 11–15, 2018, Proceedings, Part II, CCIS 854, Springer International Publishing AG, pp. 596–607, 2018, https://doi.org/10.1007/978-3-319-91476-3_49

M. Solesvik , et al., 'Joint Digital Simulation Platforms for Safety and Preparedness', in: Luo Y. (eds), *Cooperative Design, Visualization, and Engineering*, CDVE 2018, Lecture Notes in Computer Science, vol. 11151, Springer, Cham, pp. 118–125, 2018, DOI: https://doi.org/10.1007/978-3-030-00560-3_16

V. Shebanin , et al. , 'Application of Fuzzy Predicates and Quantifiers by Matrix Presentation in Informational Resources Modeling', *Perspective Technologies and Methods in MEMS Design: Proceedings of the International Conference MEMSTECH-2016*. Lviv-Poljana, Ukraine, April 20–24, pp. 146–149, 2016, DOI:10.1109/MEMSTECH.2016.7507536

WestEd, <https://www.wested.org/>

'An MOU signing ceremony was held by Thailand A .I. University Consortium', Thailand A.I. University Consortium, 3 December 2020, <https://th-ai.org/>

'AI Africa Consortium', <https://aiafrica.ac.za/>

T. H. Trinh , et al., 'Solving olympiad geometry without human demonstrations', *Nature*, vol. 625, pp. 476–482, 2024, <https://doi.org/10.1038/s41586-023-06747-5>.

Multivariate Information Systems and Polymetric Sensors: AI Implementation Perspective in Shipping and Shipbuilding

H. Lee , J. Romero. *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001 https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf

P. Forster et al. *The Earth's Energy Budget, Climate Feedbacks and Climate Sensitivity*. Published online by Cambridge University Press: 29 June 2023, pp. 923-1054, doi: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/AE57C97E588FF3060C7C7E47DD4F3C6E/stamped-9781009157889c7_923-1054.pdf/the-earths-energy-budget-climate-feedbacks-and-climate-sensitivity.pdf

K. Cios et al. *Data Mining: Knowledge discovery approach*. Springer Science+Business Media, 2007, XV, 606 p.

I. Witten et al. *Data Mining: Practical Machine Learning Tools and Techniques*, Third Edition: Morgan Kaufman Series in Data Management Systems. Morgan Kaufman, 3 edit., 2011, 664 p.

I. Devici Kocakoc , M. Pulat . *Evolution and Optimization in Machine Learning: A Bibliometric Analysis and Strategy Overview*. Authorea. September 26, 2023. DOI: 10.22541/au.169574593/30757767/v1.

EU AI Act: First regulation on artificial intelligence. European Parliament, August 2023. DOI: https://www.europarl.europa.eu/pdfs/news/expert/2023/6/story/20230601STO93804/20230601STO93804_en.pdf. Last accessed 2024/01/31.

C. Stokel-Walker , R. Van Noorden , The promise and peril of generative AI, *Nature* 614, February 9, 2023, pp. 214–216.

X. Xu , Y. Lu et al. *Industry 4.0 and Industry 5.0—inception, conception, and perception*, J. Manuf. Syst., 61(October) (2021) 530-535. <https://doi.org/10.1016/j.jmsy.2021.10.006>.

K. Demir et al , *The next industrial revolution: industry 5.0 and discussions on industry 4.0*, Ind. 4.0 MIS Perspect., January 2019, pp. 247–260.

A. George et al. *The Evolution of Smart Factories: How Industry 5.0 is Revolutionizing Manufacturing*. PUIRP Publications, 2023, pp. 33-53, doi: https://www.researchgate.net/publication/374921635_The_Evolution_of_Smart_Factories_How_Industry_50_is_Revolutionizing_Manufacturing

Artificial Intelligence. *Markets and Markets: Semiconductor & Electronics*. doi: https://www.marketsandmarkets.com/Industry/semiconductor_and_electronics

Artificial Intelligence. Markets and Markets: Information & Communication. doi: https://www.marketsandmarkets.com/Industry/information_and_communications_technology

Artificial Intelligence. Markets and Markets: Automotive & Transportation. doi: https://www.marketsandmarkets.com/Industry/automotive_and_transportation

Artificial Intelligence. Markets and Markets: Aerospace & Defense. doi: https://www.marketsandmarkets.com/Industry/aerospace_and_defence

Artificial Intelligence . Markets and Markets: Energy & Power. doi: https://www.marketsandmarkets.com/Industry/energy_and_power

Emergence of AI based business models . Mega Trends: Artificial Intelligence, Whitepaper M&M, 2023. doi: <https://www.facebook.com/fimbapesaro24/>

Shipbuilding: Global Analysis, Insights and Forecast, 2023-2030: Fortune Business Insights. doi: <https://www.fortunebusinessinsights.com/>

K. Hossine et al. Metrology for 2020s. Middlesex, UK: National Physical Laboratory, 2012, 28 p.

A. Hasan et al. Emerging Technologies in Digital Manufacturing and Smart Factories.? In Advances in Logistics, Operations, and Management Science, Book Series, IGI Global Publisher, January 2024, 313 p.

A. García-Domínguez . Mobile Applications, Cloud and Bigdata on Ships and Shore Stations for Increased Safety on Marine Traffic; a Smart Ship Project. University of Tennessee, December 2023, UTC from IEEE Xplore, pp. 1532-1537.

M. Myvizhi et al. Sustainable Supply Chain Management in the Age of Machine Intelligence: Addressing Challenges, Capitalizing on Opportunities, and Shaping the Future Landscape. SMIJ 2023, Vol. 3. <https://doi.org/10.61185/SMIJ.2023.33103>

P. Centobelli , R. Cerchione et al. Sailing through a digital and resilient shipbuilding supply chain: An empirical investigation. Journal of Business Research, 2023, 13 p. <https://doi.org/10.1016/j.jbusres.2023.113686>

A. Qazi , J. Quigley et al. Cost-Effectiveness and Manageability Based Prioritisation of Supply Chain Risk Mitigation Strategies. In: Supply Chain Risk Management. Springer, Singapore, 2018, pp. 23-42. https://doi.org/10.1007/978-981-10-4106-8_2

A. K. Gupta , Framework for the selection of sustainable suppliers using integrated compensatory fuzzy AHP-TOPSIS multi-criteria approach. In: IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Kuala Lumpur, Malaysia, 2022, pp. 0772–0775. <https://doi.org/10.1109/IEEM55944.2022.9989663>.

D. Hapishko , I. Sidenko , G. Kondratenko , Y. Zhukov , Y. Kondratenko , Modification of Fuzzy TOPSIS Based on Various Proximity Coefficients Metrics and Shapes of Fuzzy Sets. In: Antoniou, G. et al. Information and Communication Technologies in Education, Research, and Industrial Applications. ICTERI 2023. Communications 72 Multivariate Information Systems and Polymetric Sensors in Computer and Information Science, vol 1980. Springer, Cham, 2023, pp. 98-113. doi: https://doi.org/10.1007/978-3-031-48325-7_8

Y. Kondratenko , S. Sidorenko , Ship Navigation in Narrowness Passes and Channels in Uncertain Conditions: Intelligent Decision Support. In: P. Shi et al. (Eds.), Complex Systems: Spanning Control and Computational Cybernetics: Foundations, volume 414 of Studies in Systems, Decision, and Control, vol. 414, Springer, Cham, 2022, pp. 475-493. https://doi.org/10.1007/978-3-030-99776-2_24

V. Timchenko et al., Decision Support System for the Safety of Ship Navigation Based on Optical Color Logic Gates. CEUR Workshop Proceedings, Vol. 3347, 2022, pp. 42–52. 4th International Scientific Conference "Information Technology and Implementation," IT&I'2022, Virtual, Online, 30 Nov - 2 Dec 2022, 186836

A. Cozar et al. , 2014. Plastic Debris in the Open Ocean. University of Hawaii, Honolulu. PNAS. July 15, 2014, vol. 111, no. 28, pp. 10239–10244.

J. Boucher et al. Primary Microplastics in the Oceans: A Global Evaluation of Sources. IUCN, Gland, Switzerland, 2017, 43 p.

M. Eriksen et al. Plastic pollution in the world's oceans. PLOS ONE (Public Library of Science) 9 (12), e111913, 2014, pp. 1–15.

E. Howell et al. On North Pacific circulation and associated marine debris concentration. Mar. Pollut. Bull. (65), 2012, pp. 16–22.

N. Bellou et al. Global assessment of innovative solutions to tackle marine litter. Nature Sustainability, Vol 516, 4 June 2021, pp. 516–524. doi: <https://doi.org/10.1038/s41893-021-00726-2>

E. Murphy et al. A decision framework for estimating the cost of marine plastic pollution interventions. *Conservation Biology*, 2021, pp. 1–11. <https://doi.org/10.1111/cobi.13827>

S. Taffel . Communicative Capitalism, Technological Solutionism, and the Ocean Cleanup. In: *Plastic Legacies. Pollution, Persistence, and Politics*, AU Press, Athabasca University, 2021, pp. 181-202. doi: <https://doi.org/10.15215/aupress/9781771993272.01>

I. Napper et al. Marine Litter: Are There Solutions to This Global Environmental Problem? In: *Plastic Legacies. Pollution, Persistence, and Politics*, AU Press, Athabasca University, 2021, pp. 25-40. doi: <https://doi.org/10.15215/aupress/9781771993272.01>

A. van Giezen et al. Spoilt - Ocean Cleanup: Alternative logistics chains to accommodate plastic waste recycling: An economic evaluation. *Transportation Research Interdisciplinary Perspectives*, 5, 2020, pp. 1–12.

Yu. Zhukov et al. OPUSS Project: First Results and Roadmap of Development. XII International Conference on Innovations in Shipbuilding and Ocean Technologies. National University of Shipbuilding, Mykolaiv, 30 Sept-01, Oct 2021, pp. 593-598.

J. Hopewell et al. Plastics recycling: challenges and opportunities. *Philos. Trans. R. Soc. London. Ser. B: Biol. Sci.* V. 364 (1526), 2009, pp. 2115–2126.

Recycled carpeting: another way to support plastic recycling , 2010. [Online] at: <https://www.plasticsmakeitpossible.com/plastics-recycling/howto-recycle/at-home/recycle-your-carpeting/>, Accessed date: 31.01.2024.

The project of a special-purpose vessel for the collection and processing of plastic garbage polluting the waters of oceans, seas and lakes. PL421955 (A1), B63B35/32, published 13.08.2018.

Energy-saving apparatus for collecting and sorting large marine debris using a catamaran and a method for collecting and sorting large marine debris. WO2014038732 (A1), B09B3/00; B63B1/10; B63B35/32; E02B15/04, published 13.03.2014.

Device for collecting plastic waste from the water surface. WO2019073107 (A1), IPC V63V 35/32, Ye02V 15/00, publ. 18.04.2019.

Energy-saving apparatus for collecting and sorting large marine debris using a catamaran and a method for collecting and sorting large marine debris, PCT WO 2014191100 (A2), B63B 35/32, E02B 15/04, published 04.12.2014.

Catamaran vessel for plastic waste collection Scheme solution. Australian Patent Document AU2015100062 (A4), IPC B63B35/28; B63B35/32, publ. 26.02.2015.

Multifunctional vessel for collecting plastic waste . China Patent Document CN103921901 (A), IPC B63B35/32; E02B15/10, publ. 16.07.2014.

A mobile vessel for collecting micro-plastic waste and a way to collect micro-plastic waste . China Patent Document CN108725706 (A), IPC B63B35/32; E02B15/10; H02J7/35, publ. 02.11.2018.

Full surface two-hull vessel for collection of floating plastic particles . China Patent Document CN109591970 (A), IPC B63B1/10; B63B35/32; E02B15/10, publ. 09.04.2019.

Vessel for garbage collection . Japanese Patent Document JPS6343892 (A), IPC V63V 35/00, issue 24.02.1988.

Ship for recycling plastic waste . Korean Patent Document KR20150119993 (A), IPC B09B3/00; B63B35/32; B63J3/04; E02B15/10, issue 27.10.2015.

Y. Zhukov et al. System of vessels and/or floating structures for utilizing plastic waste polluting the world's oceans waters. PCT, WO2022260643 (A1), B63B25/04; B63B25/08; B63B35/32; E02B15/10, published — 2022-12-15.

Y. Zhukov et al. System of vessels and/or floating structures for utilizing plastic waste polluting the world's oceans waters. PCT, WO2022260644 (A1), B63B25/04; B63B25/08; B63B35/32; E02B15/10, published — 2022-12-15.

Y. Zhukov et al. Vessel or floating structure for utilizing plastic waste polluting the world's oceans waters. PCT, WO2022260645 (A1), B63B25/04; B63B25/08; B63B35/32; E02B15/10, published — 2022-12-15.

M. Höyhtyä , J. Huusko et al. Connectivity for Autonomous Ships: Architecture, Use Cases, and Research Challenges. 8th International Conference on ICT Convergence, Jeju Island, Korea, October 2017. DOI: 10.1109/ICTC.2017.8191000.

M. Bakker et al. A model predictive control approach towards the energy efficiency of submerged dredging. *Ocean Engineering*, 287, [115770], 2023, 15 p. <https://doi.org/10.1016/j.oceaneng.2023.115770>.

Autonomous dredging requires over 60% less energy than conventional dredging . C-Job Naval Architects BV Web Site. <https://c-job.com/wp-content/uploads/2019/11/C-Job-AUMD-research-paper.pdf>. Lastseen 31.01.2024.

Uncrewed Surface Vessel . DEMCON Unmanned Systems. Online: <https://demcon-unmanned.nl/cases/>. Lastseen 31.01.2024.

Global Level Gauge Market by Type (Tank Level Gauges, Fuel Level Gauges, Water Level Gauges, Mechanical Level Gauges), by Technology (Magnetic, Reflexive, Transparent, Others), by End-user Industry Oil and Gas, Chemical, Water Treatment, Marine, Others): Global Opportunity Analysis and Industry Forecast, 2021-2031. 250 p. – Available at URL: <https://www.alliedmarketresearch.com/level-gauge-market>. Lastseen 31.01.2024.

Y. Kondratenko , et al., Slip displacement sensors for intelligent robots: Solutions and models, in: Proceedings of the 2013 IEEE 7th International Conference on Intelligent Data Acquisition and Advanced Computing Systems, IDAACS 2013, vol. 2, art. no. 6663050, 2013, pp. 861-866. doi: 10.1109/IDAACS.2013.6663050.

A. Topalov , G. Kondratenko , O. Gerasin , O. Kozlov , O. Zivenko , Information system for automatic planning of liquid ballast distribution, Proceedings of the 2nd International Workshop on Information Communication Technologies & Embedded Systems (ICTES 2020), Mykolaiv, Ukraine, CEUR Workshop Proceedings, Vol. 2762, 2020, pp. 191-200. <http://ceur-ws.org/Vol-2762/paper13.pdf>

Y. Zhukov et al. Polymetric sensing of intelligent robots, 2013 IEEE 7th International Conference on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS), 2013, pp. 880-884, DOI: <https://doi.org/10.1109/IDAACS.2013.6663053>.

Yu. Zhukov et al. Intelligent Polymetric Systems Industrial Applications / Proceedings of the 2nd International Workshop on Information-Communication Technologies & Embedded Systems (ICTES 2020) Mykolaiv, Ukraine, 2020, pp. 122-137. <http://ceur-ws.org/Vol-2762/paper8.pdf>.

O. Zivenko et al. Level measurement principles & sensors. II Materialy IX mezinárodní vedecko-praktická conference "Věda a technologie: krok do budoucnosti - 2013". - Díl. 28. Technické vdý. Prague, 2013, pp. 85-90.

Zivenko O. LPG accounting specificity during its storage and transportation // Measuring Equipment and Metrology, Issue No3 (80), 2019, pp. 21-27. <https://doi.org/10.23939/istcmtm2019.03.021>.

Y. Kondratenko et al., Machine Learning Techniques for Increasing Efficiency of the Robot's Sensor and Control Information Processing, Sensors 2022, 22(3), 1062. doi: 10.3390/s22031062.

R. Boute et al. AI in Logistics and Supply Chain Management. In Global Logistics and Supply Chain Strategies for the 2020s: Vital Skills for the Next Generation, Springer, 2022, pp. 49–65.

K. Czachorowski , M. Solesvik , Y. Kondratenko , 'The Application of Blockchain Technology in the Maritime Industry,' Studies in Systems, Decision and Control, vol 171, Springer, Cham, 2019, pp. 561-577. DOI: https://doi.org/10.1007/978-3-030-00253-4_24.

There is Still Plenty of Room at the Bottom: Feynman's Vision of Quantum Computing 65 Years Later

R. Duro and Y. Kondratenko (Eds.), Advances in Intelligent Robotics and Collaborative Automation, River Publishers, Aalborg, Denmark, 2015.

R. Feynman , "There's plenty of room at the bottom", Engineering and Science, 1960. Vol. 23, No. 5, pp. 22-36.

R. Feynman , R. Leighton , and M. Sands , The Feynman Lectures on Physics, Addison Wesley, Boston, Massachusetts, 2005.

V. M. Kuntsevich , V. F. Gubarev , Y. P. Kondratenko , D. V. Lebedev , and V. P. Lysenko (Eds.), Control Systems: Theory and Applications, River Publishers, Gistrup, Denmark, and Delft, Netherlands, 2018.

M. A. Nielsen and I. L. Chuang , Quantum Computation and Quantum Information, Cambridge University Press, Cambridge, U.K., 2011.

K. S. Thorne and R. D. Blandford , Modern Classical Physics: Optics, Fluids, Plasmas, Elasticity, Relativity, and Statistical Physics, Princeton University Press, Princeton, New Jersey,

2021.

V. Timchenko , Yu. Kondratenko , O. Kozlov , and V. Kreinovich , "Fuzzy color computing based on optical logical architecture", *Lecture Notes in Networks and Systems*, 2023, Vol. 758, pp. 491-498.

V. Timchenko , Yu. Kondratenko , and V. Kreinovich , "Decision support system for the safety of ship navigation based on optical color logic gates", *CEUR Workshop Proceedings*, 2022, Vol. 3347, pp. 42-52.

V. Timchenko , Yu. Kondratenko , and V. Kreinovich , "The architecture of optical logical coloroid with fuzzy computing", *CEUR Workshop Proceedings*, 2023, Vol. 3373, pp. 638-648.

V. Timchenko , Yu. Kondratenko , and V. Kreinovich , "Implementation of optical logic gates based on color filters", *Lecture Notes on Data Engineering and Communications Technologies*, 2023, 181, pp. 126-136.

V. Timchenko , Yu. Kondratenko , and V. Kreinovich , "Interval-valued and set-valued extensions of discrete fuzzy logics, Belnap logic, and color optical computing", *Springer Lecture Notes in Computer Science*, 2023, Vol. 14069, pp. 297-303.

V. Timchenko , Yu. Kondratenko , and V. Kreinovich , "Why color optical computing?", *Springer Studies in Computational Intelligence*, 2023, Vol. 1097, pp. 227-233.

Decision Support System for Maintenance Planning of Vortex Electrostatic Precipitators Based on IoT and AI Techniques

D. Renfrew , V. Vasilaki , E. Katsou , 'Indicator based multi-criteria decision support systems for wastewater treatment plants,' *Science of The Total Environment*, Vol. 915, 169903, 2024. <https://doi.org/10.1016/j.scitotenv.2024.169903>

Q. Ma , H. Li , 'A decision support system for supplier quality evaluation based on MCDM-aggregation and machine learning,' *Expert Systems with Applications*, Vol. 242, 122746, 2024. <https://doi.org/10.1016/j.eswa.2023.122746>

H. Hu , et al., 'Development of the health decision support system (HDSS) in Canada and its implications in China,' *2016 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD)*, Changsha, China, pp. 1391-1395, 2016. doi:10.1109/FSKD.2016.7603381.

I. M. Jiskani , et al., 'An integrated fuzzy decision support system for analyzing challenges and pathways to promote green and climate smart mining,' *Expert Systems with Applications*, Vol. 188, 116062, 2022. <https://doi.org/10.1016/j.eswa.2021.116062>

M. Solesvik , Y. Kondratenko , G. Kondratenko , I. Sidenko , V. Kharchenko , A. Boyarchuk , 'Fuzzy decision support systems in marine practice,' in: *Fuzzy Systems (FUZZ-IEEE)*, 2017 IEEE International Conference on Fuzzy Systems, pp. 1-6, 2017. DOI:10.1109/FUZZ-IEEE.2017.8015471

L. Jiang , et al., 'A framework of emergency clinical decision support system based on MDA and resource model,' *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, Hsinchu, Taiwan, pp. 451-456, 2014. doi:10.1109/CSCWD.2014.6846887.

Y. P. Kondratenko , S. B. Encheva , E. V. Sidenko , 'Synthesis of intelligent decision support systems for transport logistics,' in: *Proceedings of the 6th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems*, Prague, Czech Republic, pp. 642-646, 2011. DOI:10.1109/IDAACS.2011.6072847.

Y. Kondratenko , A. Shevchenko , Y. Zhukov , G. Kondratenko , O. Striuk , 'Tendencies and Challenges of Artificial Intelligence Development and Implementation,' in: *Proceedings of the 12th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS'2023*, Vol. 1, 2023, pp. 221-226, IDAACS 2023, Dortmund, Germany, 7-9 September 2023. DOI: 10.1109/IDAACS58523.2023.10348800

F. Camastra , et al., 'A Fuzzy Decision Support System for the Environmental Risk Assessment of Genetically Modified Organisms,' in: *Bassis, S. , Esposito, A. , Morabito, F. (Eds.) Recent Advances of Neural Network Models and Applications. Smart Innovation, Systems and Technologies*, vol 26. Springer, Cham, pp. 241-249, 2014. @@@@https://doi.org/10.1007/978-3-319-04129-2_24

E. B. Tirkolaee , N. S. Aydin , 'Integrated design of sustainable supply chain and transportation network using a fuzzy bi-level decision support system for perishable products,' *Expert Systems with Applications*, Vol. 195, 116628, 2022. <https://doi.org/10.1016/j.eswa.2022.116628>

O. Malanchuk , et al., 'A Neural Network Model-based Decision Support System for Time Management in Pediatric Diabetes Care Projects,' in: 2023 IEEE 18th International Conference on Computer Science and Information Technologies (CSIT), Lviv, Ukraine, pp. 1-4, 2023. doi:10.1109/CSIT61576.2023.10324014.

A. Rikalovic , et al., 'Intelligent Decision Support System for Industrial Site Classification: A GIS-Based Hierarchical Neuro-Fuzzy Approach,' in: *IEEE Systems Journal*, vol. 12, no. 3, pp. 2970-2981, 2018. doi:10.1109/JSYST.2017.2697043.

S., Muthukaruppan, M. J. Er , 'A hybrid particle swarm optimization based fuzzy expert system for the diagnosis of coronary artery disease,' *Expert Systems with Applications*, 39(14), pp. 11657-11665, 2012. <https://doi.org/10.1016/j.eswa.2012.04.036>

O.V. Kozlov , 'Optimal Selection of Membership Functions Types for Fuzzy Control and Decision Making Systems,' in: *Proceedings of the 2nd International Workshop on Intelligent Information Technologies & Systems of Information Security with CEUR-WS*, Khmelnytskyi, Ukraine, IntellTSIS 2021, CEUR-WS, Vol-2853, pp. 238-247, 2021. <https://ceur-ws.org/Vol-2853/paper22.pdf>

Y. P. Kondratenko , A. V. Kozlov , 'Parametric optimization of fuzzy control systems based on hybrid particle swarm algorithms with elite strategy,' *Journal of Automation and Information Sciences*, Vol. 51, Issue 12, New York: Begel House Inc., pp. 25-45, 2019. DOI:10.1615/JAutomatInfScien.v51.i12.40

P. Chatterjee , et al., 'IoT-based decision support system for intelligent healthcare – applied to cardiovascular diseases,' in: 2017 7th International Conference on Communication Systems and Network Technologies (CSNT), Nagpur, India, pp. 362-366, 2017. doi:10.1109/CSNT.2017.8418567.

Y. Kondratenko , O. Gerasin , O. Kozlov , A. Topalov , B. Kilimanov , 'Inspection mobile robot's control system with remote IoT-based data transmission,' *Journal of Mobile Multimedia. Special issue "Mobile Communication and Computing for Internet of Things and Industrial Automation"*, Vol. 17, Is. 4, pp. 499-522, 2021. DOI:<https://doi.org/10.13052/jmm1550-4646.1742>

Y. P. Kondratenko , O. V. Korobko , O. V. Kozlov , 'Frequency Tuning Algorithm for Loudspeaker Driven Thermoacoustic Refrigerator Optimization,' *Lecture Notes in Business Information Processing: Modeling and Simulation in Engineering, Economics and Management*. – K. J. Engemann , A. M. Gil-Lafuente , J. M. Merigo (Eds.), Vol. 115, Berlin, Heidelberg: Springer-Verlag, pp. 270-279, 2012. https://doi.org/10.1007/978-3-642-30433-0_27

V. M. Kuntsevich , V. F. Gubarev , Y. P. Kondratenko , D. V. Lebedev , V. P. Lysenko (Eds.), 'Control Systems: Theory and Applications', River Publishers, Gistrup, Delft, 2018. https://www.riverpublishers.com/book_details.php?book_id=668

R. Duro , Y. Kondratenko (Eds.), 'Advances in intelligent robotics and collaborative automation,' River Publishers, Aalborg, 2015. doi:<https://doi.org/10.13052/rp-9788793237049>

Y. Tian , et al., 'Development and experimental investigation of the narrow-gap coated electrostatic precipitator with a shield pre-charger for indoor air cleaning,' *Separation and Purification Technology*, Vol. 309, 123114, 2023. <https://doi.org/10.1016/j.seppur.2023.123114>

H. Shen , H. Jia , Y. Kang , 'Electrical Characteristics and Electrohydrodynamic Flows in Electrostatic Precipitator of Six Shaped Discharge Electrodes,' *Journal of Applied Fluid Mechanics*, Vol. 13, No. 6, pp. 1707-1718, 2020. DOI:10.36884/jafm.13.06.31085

T. Song-Zhen , et al. , 'Parametric optimization of H-type finned tube with longitudinal vortex generators by response surface model and genetic algorithm,' *Applied Energy*, Elsevier, vol. 239(C), pp. 908-918, 2019. DOI: 10.1016/j.apenergy.2019.01.122

N. Grass , A. Zintl , E. Hoffmann , 'Enhanced Performance for Electrostatic Precipitators by Means of Conventional and Fuzzy Logic Control,' in: 2008 IEEE Industry Applications Society Annual Meeting, Edmonton, AB, Canada, pp. 1-4, 2008 doi:10.1109/08IAS.2008.100.

R. M. Knight , et al. 'Development and optimisation of full-scale prototype electrostatic precipitators in a laboratory for particulate matter mitigation in poultryfacilities,' *Biosystems Engineering*, Vol. 230, pp. 71-82, 2023. <https://doi.org/10.1016/j.biosystemseng.2023.03.019>

N. Grass , A. Zintl , E. Hoffmann , 'Electrostatic Precipitator Control Systems,' in: *IEEE Industry Applications Magazine*, vol. 16, no. 4, pp. 28-33, 2010, doi:10.1109/MIAS.2010.936967.

O. Kozlov , G. Kondratenko , Z. Gomolka , Y. Kondratenko , 'Synthesis and Optimization of Green Fuzzy Controllers for the Reactors of the Specialized Pyrolysis Plants,' Kharchenko V. ,

Kondratenko Y. , Kacprzyk J. (eds) Green IT Engineering: Social, Business and Industrial Applications, Studies in Systems, Decision and Control, Vol 171, Springer, Cham, pp. 373-396, 2019. https://doi.org/10.1007/978-3-030-00253-4_16

Y. P. Kondratenko , O. V. Kozlov , 'Mathematical Model of Ecoprogenesis Reactor with Fuzzy Parametrical Identification,' Recent Developments and New Direction in Soft-Computing Foundations and Applications, Studies in Fuzziness and Soft Computing, Lotfi A. Zadeh et al. (Eds.), Berlin, Heidelberg: Springer-Verlag, Vol. 342, pp. 439-451, 2016. https://doi.org/10.1007/978-3-319-32229-2_30

Leveraging Pre-trained Neural Networks for Image Classification in Audio Signal Analysis for Mobile Applications of Home Automation

Y. Kondratenko , A. Shevchenko , Y. Zhukov , G. Kondratenko , O. Striuk , 'Tendencies and Challenges of Artificial Intelligence Development and Implementation', Proceedings of the 12th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS'2023, Vol. 1, 2023, pp. 221-226, IDAACS 2023, Dortmund, Germany, 7-9 September 2023.

A. Sheremet , Y. Kondratenko , I. Sidenko , G. Kondratenko , 'Diagnosis of Lung Disease Based on Medical Images Using Artificial Neural Networks', 2021 IEEE 3rd Ukraine Conference on Electrical and Computer Engineering, UKRCON 2021 - Proceedings, pp. 561-566, 2021.

Y. Kondratenko , I. Sidenko , G. Kondratenko , V. Petrovych , M. Taranov , I. Sova , 'Artificial Neural Networks for Recognition of Brain Tumors on MRI Images', in: A. Bollin , et al. (eds), Information and Communication Technologies in Education, Research, and Industrial Applications. ICTERI 2020. Communications in Computer and Information Science, vol. 1308, Springer, Cham, pp. 119-140, 2021. DOI:https://doi.org/10.1007/978-3-030-77592-6_6

J. Deng , W. Dong , R. Socher , et al., 'Imagenet: A large-scale hierarchical image database', 2009 IEEE conference on computer vision and pattern recognition, IEEE, pp. 248-255, 20 June 2009, DOI:10.1109/CVPR.2009.5206848.

V. Slyusar , et al., 'Improvement of the object recognition model on aerophotos using deep convolutional neural network', Eastern-European Journal of Enterprise Technologies, vol. 5, No. 2(113), pp. 6-21, 2021, DOI:10.15587/1729-4061.2021.243094.

A. Guzhov , F. Raue , J. Hees , A. Dengel , 'AudioCLIP: Extending CLIP to Image, Text and Audio', 24 June 2021, <https://arxiv.org/abs/2106.13043v1>.

Y. Gong , Y.-A. Chung , J. Glass , 'AST: Audio Spectrogram Transformer', 8 July 2021, <https://arxiv.org/pdf/2104.01778.pdf>.

G. Gwardys , D. M. Grzywczak , 'Deep image features in music information retrieval', IJET, vol. 60, no. 4, pp. 321-326, 2014, DOI:10.2478/eletel-2014-0042.

G. Tzanetakis , P. Cook , 'Musical genre classification of audio signals', IEEE Transactions on Audio and Speech Processing, vol. 10(5), pp. 293-302, 2002, DOI:10.1109/TSA.2002.800560.

'GTZAN Dataset - Music Genre Classification', URL:<https://www.kaggle.com/datasets/andradaolteanu/gtzan-dataset-music-genre-classification>.

K. Palanisamy , D. Singhania , A. Yao , 'Rethinking CNN models for audio classification', 2020, <https://arxiv.org/abs/2007.11154>.

A. Guzhov , F. Raue , J. Hees , A. Dengel , 'ESResNet: Environmental sound classification based on visual domain models', ICPR, pp. 4933-4940, 2021, DOI:10.1109/ICPR48806.2021.9413035.

R. Muller , F. Ritz , S. Illium , C. Linnhoff-Popien , 'Acoustic anomaly detection for machine sounds based on image transfer learning', 2020, URL:<https://arxiv.org/pdf/2006.03429.pdf>.

A. A. Lisov , A. Z. Kulganatov , S. A. Panishev , 'Using convolutional neural networks for acoustic based emergency vehicle detection', Modern Transportation Systems and Technologies, vol. 9(1), pp. 95-107, 2023, DOI:10.17816/transsyst20239195-107

A. Dosovitskiy , L. Beyer , A. Kolesnikov , D. Weissenborn , X. Zhai , T. Unterthiner , M. Dehghani , M. Minderer , G. Heigold , S. Gelly , J. Uszkoreit , N. Houlsby , 'An image is worth 16x16 words: Transformers for image recognition at scale', ICLR, 2021, <https://arxiv.org/abs/2010.11929>

V.-T. Tran , W.-H. Tsai , 'Acoustic-Based Emergency Vehicle Detection Using Convolutional Neural Networks', IEEE Access, Volume 8, 2020, 10.1109/ACCESS.2020.2988986.

V. Slyusar , et al., 'Improving a neural network model for semantic segmentation of images of monitored objects in aerial photographs', Eastern-European Journal of Enterprise Technologies, vol. 6/2 (114), pp. 86-95, 2021, DOI:10.15587/1729-4061.2021.248390.

Effectiveness Evaluations of Optical Color Fuzzy Computing

Y. J. Jung , et al., 'Reconfigurable all-optical logic AND, NAND, OR, NOR, XOR and XNOR gates implemented by photonic crystal nonlinear cavities', 2009 Conference on Lasers & Electro Optics & The Pacific Rim Conference', Shanghai, China, pp. 1–2, 2009, doi:10.1109/CLEOPR.2009.5292059.

S. Ma , Z. Chen , N. K. Dutta , 'All-optical logic gates based on two-photon absorption in semiconductor optical amplifiers', Optics Communications, Vol. 282 (23), pp. 4508–4512, 2009. <https://doi.org/10.1016/j.optcom.2009.08.039>

V. Jandieri , R. Khomeriki , et al., 'Functional all-optical logic gates for true time-domain signal processing in nonlinear photonic crystal waveguides', Optics Express, Vol. 28(12), pp. 18317–18331, 2020, <https://doi.org/10.1364/OE.395015>

X. Wang , et al., 'High-performance spiral all-optical logic gate based on topological edge states of valley photonic crystal', arXiv:2209.08358, 2022. <https://doi.org/10.48550/arXiv.2209.08358>

L. Caballero , et al., 'Photonic crystal integrated logic gates and circuits', Optics Express, Vol. 30(2), pp. 1976–1993, 2022, <https://doi.org/10.1364/OE.444714>

Z. Zhu , J. Yuan , L. Jiang , 'Multifunctional and multichannels all-optical logic gates based on the in-plane coherent control of localized surface plasmons', Optics letters, Vol. 45(23), pp. 6362–6365, 2020, <https://doi.org/10.1364/OL.402085>

K. Moritaka , T. Kawano , 'Spectroscopic analysis of the model color filters used for computation of CIELAB-based optical logic gates', ICIC Express Letters, Part B: Applications, vol. 5(6), pp. 1715–1720, 2014.

Z. Lin , M. Hong , 'Femtosecond Laser Precision Engineering: From Micron, Submicron, to Nanoscale', Ultrafast Science, Vol. 2021, Article ID: 9783514, 2021, DOI:10.34133/2021/9783514

C. Cole , 'Optical and electrical programmable computing energy use comparison', Optics Express, Vol. 29, Issue 9, pp. 13153–13170, 2021.

J. Hong , et al., 'Bokor, Experimental test of Landauer's principle in single-bit operations on nanomagnetic memory bits', Sci. Adv. 2, e1501492, 2016.

J. D. Meindl , J. A. Davis , 'The Fundamental Limit on Binary Switching Energy for Terascale Integration (TSI)', IEEE Journal of Solid-State Circuits, Vol. 35, No. 10, pp. 1515-1516, October 2000, doi:10.1109/4.871332.

V. Nikul , A. Drozd , J. Drozd , V. Ozeransky , 'Efficiency of the computation bitwise pipelining in FPGA based components of safety-related systems', Technology and design in electronic equipment, no. 4, pp. 3–13, 2018, <http://jnas.nbuv.gov.ua/article/UJRN-0000933499>

P. L. McMahon , 'The physics of optical computing', arXiv:2308.00088v1, [physics.optics], 31 July 2023.

M. Matuszewski , A. Prystupik , A. Opala , 'The role of all-optical neural networks', arXiv:2306.06632v2, [cs.ET], 13 June 2023.

L. Zadeh , 'The role of fuzzy logic in modelling, identification and control', Modelling, Identification and Control, Vol. 15 (3), pp. 191–203, 1994, <https://doi.org/10.4173/mic.1994.3.9>

V. Kreinovich (ed.), 'Uncertainty Modeling', Springer Verlag, Cham, Switzerland, 2017.

R. Duro , Y. Kondratenko (Eds.), 'Advances in intelligent robotics and collaborative automation', River Publishers, Aalborg, 2015.

A. I. Shevchenko , 'Natural Human Intelligence - The Object of Research for Artificial Intelligence Creation', International Scientific and Technical Conference on Computer Sciences and Information Technologies, 1, pp. XXVI–XXIX, 8929799, 2019, CSIT 2019, Lviv, 17–20 September 2019.

Y. P. Kondratenko , O. V. Kozlov , O. V. Korobko , 'Two Modifications of the Automatic Rule Base Synthesis for Fuzzy Control and Decision Making Systems', in: J. Medina et al. (eds),

Information Processing and Management of Uncertainty in Knowledge-Based Systems: Theory and Foundations, 17th International Conference, IPMU 2018, Cadiz, Spain, June 11–15, 2018, Proceedings, Part II, CCIS 854, Springer International Publishing AG, pp. 570–582, 2018, https://doi.org/10.1007/978-3-319-91476-3_47

B. Werners , B., et al., 'Alternative Fuzzy Approaches for Efficiently Solving the Capacitated Vehicle Routing Problem in Conditions of Uncertain Demands', in: C. Berger-Vachon , et al. (eds), *Complex Systems: Solutions and Challenges in Economics, Management and Engineering, Studies in Systems, Decision and Control*, Vol. 125, Berlin, Heidelberg: Springer International Publishing, pp. 521–543, 2018, https://doi.org/10.1007/978-3-319-69989-9_31

Y. Kondratenko , S. Sidorenko , 'Ship Navigation in Narrowness Passes and Channels in Uncertain Conditions: Intelligent Decision Support', in: P. Shi , J. Stefanovski , J. Kacprzyk (eds), *Complex Systems: Spanning Control and Computational Cybernetics: Foundations. Studies in Systems, Decision and Control*, vol. 414, Springer, Cham, pp. 475 – 493, 2022, https://doi.org/10.1007/978-3-030-99776-2_24

V. Timchenko , Yu. Kondratenko , V. Kreinovich , 'Why Color Optical Computing?', *Studies in Computational Intelligence*, 1097, pp. 227–233, 2023, https://doi.org/10.1007/978-3-031-29447-1_20

V. Timchenko , Yu. Kondratenko , V. Kreinovich , 'Interval-Valued and SetValued Extensions of Discrete Fuzzy Logics, Belnap Logic, and Color Optical Computing', *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 14069 LNCS, pp. 297–303, 2023.

V. Timchenko , Yu. Kondratenko , V. Kreinovich , 'Decision support system forthesafetyofshipnavigationbasedonopticalcolorlogicgates', *CEUR Workshop Proceedings*, 3347, pp. 42–52, 2022.

V. Timchenko , Yu. Kondratenko , O. Kozlov , V. Kreinovich , 'Fuzzy color computing based on optical logical architecture', *Lecture Notes in Networks and Systems*, 758 LNNS, pp. 491–498, 2023.

V. Timchenko , Yu. Kondratenko , V. Kreinovich , 'The Architecture of Optical Logical Coloroid with Fuzzy Computing', *CEUR Workshop Proceedings*, 3373, pp. 638–648, 2023.

V. Timchenko , Yu. Kondratenko , V. Kreinovich , 'Implementation of Optical Logic Gates Based on Color Filters', *Lecture Notes on Data Engineering and Communications Technologies*, 181, pp. 126–136, 2023.

N. Sulaiman , Z. A. Obaid , M. H. Marhaban , M. N. Hamidon , 'FPGA-Based Fuzzy Logic: Design and Applications – a Review', *IACSIT International Journal of Engineering and Technology*, Vol. 1, No. 5, pp. 491–503, December 2009.

Y. Kondratenko , E. Gordienko , 'Implementation of the neural networks for adaptive control system on FPGA', *Annals of DAAAM for 2012 & Proceeding of the 23th Int. DAAAM Symp. "Intelligent Manufacturing and Automation"*, Vol. 23, No.1, B. Katalinic (Ed.), Published by DAAAM International, Vienna, Austria, EU, pp. 0389–0392, 2012.

V. Opanasenko , A. Palahin , S. Zavyalov , 'The FPGA-based problemoriented on-board processor', *Proceedings of the 2019 10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS 2019*, 1, pp. 152–157, 8924360, 2019.

'Cortex-M4 instructions', ARM Developer, <https://developer.arm.com/documentation/ddi0439/b/CHDDIGAC>.

J. Yiu , 'System-on-Chip Design with Arm Cortex-M Processor', eBook, ISBN 978-1-911531-19-7, <https://www.arm.com/resources/ebook/system-on-chip-design>

A. Fog , 'Instruction tables: Lists of instruction latencies, throughputs and micro-operation breakdowns for Intel, AMD and VIA CPUs', 2023, https://www.agner.org/optimize/instruction_tables.pdf.

M. Gritsenko , 'Physics of Liquid Crystals, Taras Shevchenko ChNPU', Chernigiv, 2015, erpub.chnpu.edu.ua:8080/jspui/handle/123456789/7138