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Monograph

Information Processing in Control and Decision-Making Systems. Problems and solutions

Information control systems

Intelligent systems and data analysis

Modeling and software engineering

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Odesa Polytechnic National University

INFORMATION PROCESSING IN CONTROL AND DECISION-MAKING SYSTEMS. PROBLEMS AND SOLUTIONS.

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Рецензенти:
Prof. Ye Zhengmao, Southern University (United States);
Prof. Algirdas Pakštas, British Computer Society (United Kingdom);
Prof. Anatoly Kargin, Ukrainian State University of Railway Transport (Ukraine);
Prof. Malakhov Evgeniy, Odessa National University, I.I. Mechnikov (Ukraine)

Авторський колектив:
Axak N., Bobok I., Dong C., Khlamov S., Kirchu P., Kobozeva A., Kondratenko G., Kondratenko Y., Kostiuk S., Krasnobayev V., Kushnaryov M., Kutiepov V., Kovalchuk D., Kovalchuk D.,Kozlov O.,Lysenko O.,Martynenko A.,Ponomarenko S.,Potienko O., Prots'ko I., Rudnichenko M., Rykmas R., Shibaeva N., Shevchenko A., Shpinareva I., Sitnikov T., Skakodub O., Slyusar V., Sushyn I., Tachinina O., Tatarnykov A., Otradska T., Petrov I., Vakulenko M., Vychuzhanin O., Vychuzhanin V., Yanko A., Zheng Y., Zhukov Y.

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У монографії відображені результати наукових досліджень у галузі інформаційних, інтелектуальних систем та аналізу даних, моделювання та розробки програм. Матеріали монографії будуть корисними для аспірантів, магістрантів, викладачів вищих навчальних закладів, що спеціалізуються на галузі ІТ-технологій.

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INFORMATION PROCESSING IN CONTROL AND DECISION-MAKING SYSTEMS. PROBLEMS AND SOLUTIONS

CONTENTS

SECTION 10. INFORMATION SYSTEMS

PREFACE

The collective monograph presents the results of scientific research in the field of information systems and technologies, intelligent systems, data analysis, modeling and program development.

The monograph is compiled in the form of scientific articles-sections corresponding to thematic areas, which thoroughly reflect the results of research in the following areas: intelligent control technologies; control systems in robotic systems; information control systems; data security and cryptography; data mining technologies and big data; intellectual models and knowledge engineering technologies; mathematical and simulation modeling; intelligent systems and data analysis; multi-agent systems and distributed computing; control information system;information systems.

In the collective monograph, the authors pay attention to solving problems in the field of information systems and technologies using a fuzzy automatic control system for tracking mobile robotic platforms, an approach to determining the influence of the parameters of the spatial movement of a UAV on its characteristics. steganalytic method of declaring lsb attachments in digital video, sequences of digital images, the main directions of implementing the artificial intelligence strategy in Ukraine, intelligent monitoring of the technical condition of complex systems.

Considerable attention is paid to expanding neural network models with adaptive activation functions, the steganalytic method of declaring lsb-embeddings in digital video, the sequence of digital images, and intelligent monitoring of the technical condition of complex systems.

Through the research findings presented, readers will gain a useful body of knowledge needed to better understand problems and solutions in the field of information systems and technology.

The articles presented in the monograph correspond to the original author. Only the authors are responsible for the content of articles.

The materials of the monograph will be useful for graduate students, undergraduates, teachers of higher educational institutions specializing in the field of information systems and technologies.

Scientists consisting of 14 doctors of science, 14 candidates of science, and 12 applicants took part in the work on the collective monograph.

Section 1. Intelligent control of systems and technologies

UDC 004.8

MAIN DIRECTIONS FOR IMPLEMENTATION OF THE ARTIFICIAL INTELLIGENCE STRATEGY IN UKRAINE

Corr. Member of NAS of Ukraine, Dr.Sci. Shevchenko A.[1], Dr.Sci. Kondratenko Y.[1,2], Dr.Sci. Slyusar V.[1], Dr.Sci. Zhukov Y.[3], Ph.D. Kondratenko G.[2], Ph.D. Vakulenko M.[1]

[1]Institute of Artificial Intelligence Problems under the Ministry of Education and Science and National Academy of Sciences of Ukraine, Ukraine,
[2]Petro Mohyla Black Sea National University, Ukraine,
[3]C-Job Nikolayev, 17/6, Artyleriyska Str., Mykolaiv, 54006, Ukraine
ORCID: 0000-0002-0095-538X, 0000-0001-7736-883X, 0000-0002-2912-3149, 0000-0002-6391-4382, 0000-0002-8446-509, 0000-0003-0772-7950
[1] E-mail: rector_iai@ukr.net, ypk@ipai.net.ua, swadim@ukr.net, maxvakul@gmail.com
[2] E-mail: y_kondrat2002@yahoo.com, halyna.kondratenko@chmnu.edu.ua
[3]E-mail: y.zhukov@c-job.com.ua

Abstract. *This paper is devoted to the analysis of the specific focuses, directions, and peculiarities of the Strategy of Artificial Intelligence (AI) Development in Ukraine. The main paper's components are an analysis of the current state of the justification, development, and governmental approval of the National Strategy of AI in Ukraine; key elements and main priority areas of AI implementation according to IAIP-project "Strategy for AI Development in Ukraine"; proposals for AI development in short- and long-term perspectives and features of the AI implementation in Ukraine during the current wartime. Special attention is paid to such focuses in AI research and development as (a) the design of AI systems based on cognitive and conscience conceptions; (b) new solutions in intelligent robotic systems for ground, underwater and aerial applications; (c) AI perspectives in the marine industry; (d) prospective AI implementation in education; (e) linguistic competency of AI systems. The obtained, by the authors, results can be used for the development of strategic steps and plans in AI research and implementation on the governmental level of decision-making processes.*

Keywords: *Strategy, artificial intelligence, development, implementation, Ukraine, priorities, peculiarities, analysis, IAIP-project*

1. Introduction

Artificial intelligence (AI) plays a more and more important role in the different fields of human activity. Scientists and experts are expecting revolutionary results with AI development and implementation in medicine and healthcare, transportation, science, education, military and defense, manufacturing, agriculture, space exploration, and different services [1,2 3,

4, 5]. The new developments in the AI field are changing quickly and AI implementation areas are extending quickly. A new type of society is in the process of its establishment (Society 5.0), its chains of production, logistics, and social infrastructure will be based on artificial intelligence. The governments of developed countries understand the necessity of funding AI research for providing significant economic growth and for the leading position in the world's GDP competition. Many countries created their own Strategy for AI development and determined the priority areas for AI implementation, taking into account the features of their own economic situation, national interests, the indicators and possibilities in science, the level of the education system, and others. Among the countries with their own AI strategies are Canada, Japan, China, the United States, Brazil, Australia, Austria, Germany, and others. According to IQ-Holon publication [6] the governments of fifty countries from different continents have created and approved AI strategies in different forms and styles as plans, conceptions, roadmaps, extended and detailed strategies, executive orders, etc. Modern AI products have increasing implementation for solving different complex tasks with access for users based on fee or non-fee financial approaches. In particular, ChatGPT, GPT-4 and other AI platforms are very popular and very important with their huge potentials and possibilities [7, 8] for generating and correcting texts, consulting people in various spheres of human activities, reviewing and analyzing articles and reports, translating and calculating, transforming mathematical tasks, etc. At the same time, the powerful development and implementation of AI products led to many changes in the traditional styles of human life concerning changes in the labor market, in the set of personal and professional skills, in education processes (school and university curricula), and other changes. Many scientists, experts, policymakers, and entrepreneurs also widely discuss and focus on ethical issues in the AI design processes, the balance between the advantages and disadvantages of AI applications [9], and the dangers of AI implementation in powerful weapons, where AI will independently decide the fate of people. This paper aims to the analysis of the main focuses and features of the strategy for AI development in Ukraine. It is very important for consolidation and

concentration of the research efforts for implementing AI in priority areas. The rest of this paper is organized as follows. Section 2 presents the developed "Strategy for AI development in Ukraine" with an analysis of its key components, Ukraine's priorities in AI development, and specific features of AI implementation in the current wartime. In section 3, the authors discuss the approach to the design of AI systems based on conscience conception. New solutions in intelligent robotics for ground, underwater and aerial applications are considered in section 4. Sections 5 discuss the prospective AI implementations in the marine industry and section 6 – in education. Section 7 is devoted to the linguistic competency of AI systems. The paper ends with a conclusion in Section 8.

2. Strategy for AI development in Ukraine

Let us analyze the current state of the justification, development, and governmental approval of the "Strategy for Artificial Intelligence Development in Ukraine" based on the IAIP's project on AI Strategy [10, 11] that is created under the leadership of the Institute of Artificial Intelligence Problems of the Ministry of Education and Science and National Academy of Sciences of Ukraine.

2.1. National AI development strategy in Ukraine: current state

The AI field is developing and implementing very fast in Ukraine. There are more than 2,000 software development companies in Ukraine specializing in the AI industry. Ukraine has made a progressive step in the publishing open data direction, especially during the past few years. Concerning the Global Open Data Index, Ukraine places 31st position in the world. The National Academy of Sciences, the Ministry of Digital Transformation, the Ministry of Education and Sciences, the Ministry of Strategic Industries, and many other governmental organizations in Ukraine are involved in the process of creating a National Strategy for AI Development and Implementation in Ukraine. As a result, the Conception for AI Development and Implementation was created in Ukraine and on 2 December 2020 [12] was approved by the Cabinet of Ministers of Ukraine.

In 2020 also was started the process of creating a detailed Strategy for the development of AI in Ukraine. The Institute of Artificial Intelligence Problems (IAIP) under the National Academy of Sciences (NASU) and the

Ministry of Education and Science of Ukraine (MESU) became the leading organization in the IAIP-project "Creating Strategy for the Development of AI in Ukraine" [10, 11]. Many Ukrainian scientists, who have scientific and practical experience in the AI field (including authors), were united in one team for creating, discussing, and promoting the Ukrainian AI Strategy. The main steps for the development of the Ukrainian AI strategy were defined by the next tasks: a) analysis and comparative review of the published national strategies of AI development in different countries from different continents; b) formation of a generalized presentation of the analytical AI centers' activities; c) determination of promising directions for developing AI in Ukraine; d) generalization of the basic terminology definitions, organizational principles, and main focuses of further research of Ukrainian scientists in the AI field; e) identification of the priority domains for implementation of advanced AI in Ukraine; f) formation of a list of necessary legislative, organizational, and investment measures for the implementation of the identified directions for the development of AI in Ukraine. The IAIP-project was successfully executed but, unfortunately, the Russian aggression on Ukraine in February 2022 seriously influenced the global discussions and final approval of this AI Strategy as National AI Strategy at the governmental level. Let us focus on the key components of the developed AI Strategy and the main priorities in the implementation of AI in Ukraine according to IAIP-project "Strategy for Artificial Intelligence Development in Ukraine".

2.2. IAIP-project of strategy for AI development in Ukraine: key content components and main priorities in AI implementation

The key content components in ten sections of the developed "Strategy for AI development in Ukraine" consist of an introduction and paradigm; basic AI concepts, definitions, and research directions; aims and objectives of the Ukrainian strategy for AI development; regulatory framework and current state of AI development and implementation in Ukraine; priority areas in Ukrainian economy for AI applications; scientific support, staffing, and funding for the national AI ecosystem; and evaluating the effectiveness of the Strategy for AI development in Ukraine. This AI strategy was created based on the Ukrainian national characteristics and interests, the necessity to

extend AI research, and the implementation of the recent AI tool developments in different fields of the Ukrainian economy. During the process of the AI Strategy creation, IAIP sent letters of inquiry to over 300 different organizations, in particular, to the majority of ministries of Ukraine, scientific institutions, state and private institutions of higher education, and commercial organizations to determine the need to implement and use AI in their work. As a result, the next main priority areas for the implementation of AI in Ukraine were included in the Strategy for AI development in Ukraine" with detailed justifications and descriptions: AI in the National Security and Military-Industrial Complex of Ukraine; AI in Science and Education; AI in Medicine and Healthcare; AI in the Manufacturing Industry and Power Sector; AI in the Telecom Industry; AI in Transportation and Infrastructure; AI in Agriculture; AI in Ecology.

Besides, the priority areas for AI implementation in Ukraine according to [12] are economics, cybersecurity, information security, public administration, justice, legal regulation and ethics. The Strategy of AI Development in Ukraine (AIDU Strategy) [11] is designed for the period of 2023-2030, and its adoption process consists of two stages: (a) for 2023-2025; (b) for 2026-2030. To successfully implement the AIDU Strategy, the following immediate steps should be executed: Step 1. Approve and adopt the regulatory framework. Step 2. Create the supervisory board to monitor and accomplish the tasks declared in the AIDU Strategy. Step 3. Determine the roadmap of the AIDU Strategy; Step 4. Prioritize the objectives of the AIDU Strategy; Step 5. Accomplish the most prioritized and fundamental tasks; Step 6. Provide mechanisms for quarterly and annual control over the implementation of the AIDU Strategy (reporting, optional examination, etc.). Step 7. The final step is the reassessment of the AIDU Strategy, its analysis of compliance with the actualities of 2025, and, if necessary, its effective modification.

The AIDU Strategy should be supplemented with additional midterm (annual) deadlines, before which the aim and objectives of the relevant block must be completely accomplished. Each midterm period should be completed with an analytical report followed by an adjustment of the dynamic schedule. This component acts as a stimulus that will positively

affect the intensity of the AIDU Strategy implementation. To effectively implement the AIDU Strategy, it is necessary to take the following measures by 2025:

– Create a regulatory framework that provides for the protection of economic and scientific data, as well as its storage in Ukraine.

– Provide scientific and theoretical support for the execution of the AIDU Strategy.

– Attract financial resources for the development of AI in Ukraine.

– Provide support for fundamental and applied scientific AI research.

– Increase the number of qualified AI employees and raise new technology awareness.

– Improve the digital literacy of the Ukrainian people.

– Build a national database system.

The main mechanism for the Strategy of Artificial Intelligence Development in Ukraine implementation is the annual action plans developed by the Committee on the Development and Implementation of Artificial Intelligence and approved by the Cabinet of Ministers of Ukraine.

2.3. Peculiarities of the AI implementation during the current wartime

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 so-called computational artificial intelligence (AI). The implementation of AI in Ukraine during wartime is characterized by its widespread use across various domains. First and foremost, AI plays a crucial role in tactical combat actions and military operations, particularly in enhancing the effectiveness of mass deployment of unmanned aerial vehicles (UAVs) for surveillance and reconnaissance tasks, and the evaluation of artillery fire effectiveness. According to experts, the deployment of UAVs accounts for over 70% of targets destroyed during combat operations. Developers quickly transitioned from using classical convolutional neural networks to segmenting objects based on various U-Net and PSPNet structures [13, 14]. In relatively simple object classification tasks, transfer learning and zero-shot learning methods based on neural networks previously trained on the ImageNet dataset [15, 16] performed well. Later, in a short period, the

process of adapting known neural network technology, Object Detection (OD) [17], to field datasets gained popularity. This was used not only for automatic target detection but also for simultaneous classification under varying seasonal conditions. The most ambitious projects aim to implement object identification and target class recognition, for example, combat vehicles, tanks, logistical transport, etc. This can be extended to classify a specific type of object similarly. To solve all these mass deployment tasks, various versions of YOLO family neural networks were widely used [18]. Primarily, their operation takes place not onboard the UAVs but in the command post equipment. Importantly, object detection in images is combined with video tracking algorithms for real-time incoming video streams from onboard or stationary cameras of different spectral ranges in different domains. For example, Fig. 1 shows a fragment of video tracking based on YOLO5 Small of a high-speed motor boat. The neural network effectively tracks the boat and allows counting the number of people on board. Similar results of automatic detection and tracking of a drone by a neural network are shown in Fig. 2. This OD technology is also used for detecting unexploded ordnance on the seabed using underwater drones and assessing housing and infrastructure damage. An additional direction to enhance the capabilities of military information support was the application of intelligent chatbots in Telegram channels or based on separate mobile applications. These allow for alerts about the appearance of enemy machinery, means of air attacks, and so on. The chatbot boom has also covered areas such as psychological support for service members and legal assistance. Natural language processing (NLP) is generally a promising direction in the field of AI, especially considering the capabilities of the language model GPT-4 and its less powerful counterparts. With Ukraine receiving Western weapons samples, effective combat operation requires translations of NATO standards and corresponding technical documentation from various European languages into Ukrainian. In this regard, smartphone translators with built-in audio and optical text recognition feature from Google, as well as translation functions implemented in ChatGPT, have become handy. Furthermore, relying on local GPT-4 analogs such as LLaMA [19], Alpaca [20], etc., automatic analysis of combat reports from

units can be provided. This allows for the prompt provision of information about the current battlefield situation to commanders upon their requests, facilitating rapid response to critical threats and decision-making support.

Fig.1. YOLO5 Small for the detection and tracking of a moving motorboat and people

Apart from the application of large language models (LLM), NLP algorithms, and neural networks for video tracking and image processing, an important direction is neural network processing of time series. This allows for predicting meteorological data for high-precision artillery firing, expenditure and needs in various resources, the evolution of satellite navigation correction adjustments over time, etc. Implementing AI in war conditions has its challenges. One of these is the necessity to ensure data security and protection against cyber-attacks. Given the heightened risk of cyber threats, artificial intelligence should be viewed as a potent player in cybersecurity efforts. It is employed in algorithms designed to detect and neutralize threats, as well as to protect critical infrastructure. The role of AI also extends to the coordination of humanitarian aid. In the logistics sector, AI ensures the efficient distribution and optimal delivery of assistance to those who need it most. In the realm of information warfare, artificial intelligence plays a significant role in detecting and countering disinformation campaigns. It enables the analysis of large volumes of data to discern patterns and trends in disinformation. Machine learning methods have become the de facto standard approach when performing social media and mass media publication analysis for Open Source Intelligence interests. The predictive analytics capabilities of AI are also employed to forecast

enemy movements and the tactics of deploying weapons and military equipment.

a) b)

Fig. 2. Neural network tracking of UAVs in the evening (a, b)

This assists military planners in strategizing their actions and responding to potential threats. In addition, AI is utilized in the management and servicing of critical infrastructure during warfare. It aids in monitoring and predicting potential infrastructure failures, and coordinates repair and maintenance efforts. This information is based on the latest data available as of June 2023 and is continually supplemented with new evidence of the growing role of AI in all spheres of society amidst military operations.

3. Design of AI systems based on conscience conceptions

The novel authors' proposal in AI Strategy for Ukraine deals with the development, design and implementation of disruptive AI systems based on conscience conceptions. As its human cognate, artificial consciousness (AC) is a necessary attribute of an artificial personality with AI. Artificial consciousness manifests itself as an emergent global self-organized information phenomenon that evaluates and controls core processes of the system, exchanges data between system components to coordinate their behavior, provides for the social and personal perception of the environment, and conditions internal integration and external separation of the system [11]. It has been proposed that the AC modeling should include two sides of the same process: (i) the modeling of an attention schema as a mechanism of information selection and broadcasting; (ii)the modeling of the mechanism of information flow correlation. Successfully designing the AC is a complicated and multidisciplinary task but its solving will provide AI, which is friendly for humans. This approach suggests the synergetic

treatment of AC that may be represented by a strange attractor and correspondingly simulated. Similar ideas were put forward earlier. For example, W. Calvin [21] introduces the concept of a "global workspace" that results from neuron interactions and integrates information from different brain regions. A. Bailey [22] examines James' theory of the stream of consciousness which includes subjective feelings and emotions. The functional model of a new-generation computer system with AI is shown in Fig. 3 with modules [23] of artificial consciousness and artificial conscience. The first attempt to create AI based on the conscience conception was made by the firm Anthropic [24]. Anthropic claims that their Claude chatbot adheres to many rules, including the principles enshrined in the Universal Declaration of Human Rights. The firm Anthropic claims that its chatbots have a "conscience".

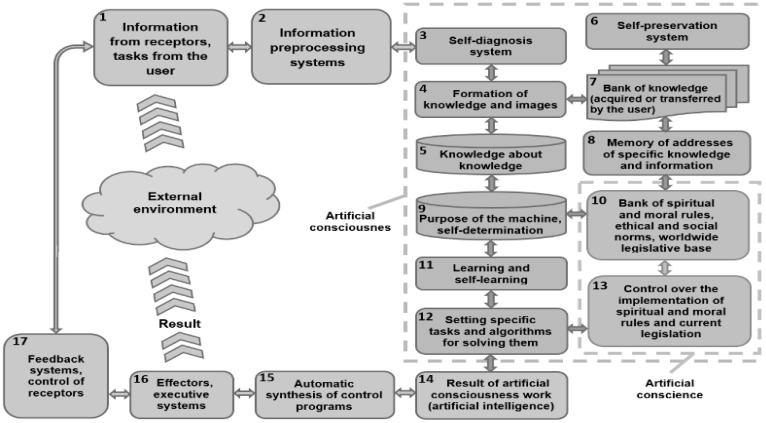

Fig.3. New-generation computer system with embedded artificial consciousness and conscience

Creating cognitive computers and robot knowledge analysis based on cognitive computing and modular neural networks [25, 26] is also a very promising research direction in AI design. Cognitive computers are intelligent processors advanced from data and information processing to autonomous knowledge learning and intelligence generation [25]. Many scientific publications are devoted to the research and design of cognitive computers. For example, the work [25] (based on deep analysis) presents a

retrospective and prospective review of the odyssey toward cognitive computers empowered by transdisciplinary basic research and engineering advances. For now, a wide range of fundamental theories and innovative technologies for cognitive computers is explored, and a set of underpinning intelligent mathematics is created. For example, the architectures of cognitive computers for Cognitive Computing and Autonomous Intelligence Generation are designed as a brain-inspired cognitive engine [25]. The development of new solutions and implementation of cognitive computers in autonomous AI have good perspectives in the near future.

4. New solutions and research directions in intelligent robotics

Ukrainian scientists and policymakers pay special attention to the development and implementation of robotic systems. In intelligent robotics, research is focused on the evolution of autonomous ground vehicles (UGVs), autonomous surface (USVs), underwater vehicles (AUVs), unmanned aerial vehicles (UAVs), and the integration of these systems. The development of all these directions is propelled by the implementation of advanced AI capabilities. Machine learning is utilized for navigation, obstacle avoidance, and decision-making. There is an emerging trend towards employing multi-robot systems featuring dynamic self-organization of swarms. In underwater robotics, equipping AUVs with advanced sensors and AI algorithms assists in pipeline inspection/protection and research of marine biology, underwater environments, and landscapes. Current developments aim to improve the autonomy of AUVs, allowing them to operate for extended periods and at considerable distances in challenging underwater conditions. Aerial robotic systems, especially drones or UAVs, are used for a wide range of applications, from delivery services to combat operations. Future research in this field focuses on swarm robotics, where a group of drones collaboratively performs complex tasks. Alongside this, there is a need to develop AI algorithms that facilitate drone navigation in complex urban conditions, particularly in the absence of satellite navigation signals. An important direction for future research is the development of integrated robotic systems capable of operating in terrestrial, underwater, and aerial environments. This could potentially involve the creation of amphibious robots or systems where terrestrial, underwater, and aerial

robots work in harmony. As robotic systems gain greater autonomy, accompanying ethical and legal issues must be addressed. Specifically, this concerns responsibility for the consequences in case of accidents, privacy issues related to surveillance drones, and ethical implications of autonomous weapon systems. Let us outline the future trajectories for the development of intelligent robotic systems (IRS). Direction 4.1. Powerful LLMs such as GPT-3.5 and GPT-4 developed by OpenAI [27] use machine learning to generate human-like text and have found diverse applications in IRS. Implementation of such LLMs can enable robots to understand commands given in natural language, generate human-like responses, and even engage in conversations, making them more useful and easier to use. Direction 4.2. By learning to understand a set of rules or guidelines laid out in natural language, a robot gains the ability to use these rules to make decisions in real-world situations. In this way, a prototype of an artificial conscience could be implemented, whose mechanism would allow for the avoidance of issues in communication with humans and other robots, making decisions that respect human rights and universal values. Using LLMs robots can be trained to read and understand instructions, allowing them to learn to perform new tasks without the need for explicit programming. A robot can use a GPT model for role-playing behavior, generating a series of potential actions and estimating probable outcomes of the activity, and then choosing the action most likely to achieve its goal. Direction 4.3. Additional possibilities will be provided by the development of local GPT analogs such as LLaMA, Alpaca, etc. These models can be embedded in the onboard equipment of a robot, increasing its independence from external communication networks. This direction is closely related to the development of neural networks designed for converting audio streams into text and text-to-speech. Although LLMs offer many potential advantages for the IRS, they also pose certain challenges. For example, GPT models may sometimes generate incorrect or nonsensical responses, their training requires large volumes of data and computational resources, and their use in autonomous systems raises significant concerns regarding safety, ethics, and legal regulation. These issues will require thorough investigation to ensure the beneficial use of such AI technologies without posing excessive risks.

Direction 4.4. Importantly, (a) future solutions for IRS will allow robots to learn from past experiences and adapt to new situations without human intervention; (b) improvements in sensor technology can enable robots to better understand and interact with their environment [2, 5] as robots will be able to detect and respond to changes in temperature, pressure, light, and other environmental factors. Quantum sensors (QS), which employ quantum physics to measure physical quantities with unprecedented accuracy, will significantly influence the future of IRS. QS could detect minute changes in environmental conditions, such as local fluctuations in temperature, pressure, or magnetic fields, and can provide high-precision measurements of acceleration and rotation, making them useful for robot navigation in situations where GPS is unavailable or unreliable, such as underwater or in space. QS might also enable the generation of new forms of imaging, such as ghost images, where the image is formed from light that has never interacted with the object. This technology could be implemented in robot vision systems, enabling them to see through obstacles or around corners. Furthermore, QS could play a role in secure quantum communication. This would allow robots to communicate with each other and with control systems in a way that is secure from eavesdropping. The collaborative robots concept (cobots) is expected to evolve, allowing smoother interaction between humans and robots. Robots will be able to anticipate human actions and respond accordingly. Distributed robotics, involving multiple robots working together to achieve a common goal, may see advancements leading to more complex swarm behaviors and increased task efficiency. Another subfield of robotics destined to make a place in society is soft robotics. This field involves the construction of robots using highly pliable materials, leading to the creation of more flexible and adaptable robots. Faster and more reliable communication between robots and their control systems will be facilitated by the transition to 6G - the future generation of wireless technologies.

Direction 4.5. A significant impact on the future of the IRS will be made by Augmented Reality (AR) technology [28]. It will provide a more intuitive way for humans to interact with robots, visualizing a robot's intentions, planned actions, or internal state. This will simplify the

understanding and prediction of a robot's behavior for humans. AR and Virtual Reality (VR) can also be used to create realistic training scenarios for robots, which is particularly beneficial in situations where real-world training would be dangerous, expensive, or impractical. Furthermore, AR could enable remote control of robots, allowing a human operator to use an AR headset to see the same view as the robot and control the robot's actions from a safe distance. AR will enhance robots' autonomy by helping them better understand and navigate their environment. It is important to note that the realization of the outlined future achievements in the IRS will depend on various factors, including scientific breakthroughs, actual advances in the development of respective technologies, societal perception, as well as legal and ethical approaches.

5. AI perspectives in the marine industry

Implementing AI technologies has a good perspective on the marine industry, which is very important for Ukraine as a marine country. For example: (a) the AI multi-software complexes are successfully used in design processes in shipbuilding and ship-repairing; (b) intelligent polymetric sensor systems are highly efficient as information components of the integrated ships' control systems [29]; etc. Particular attention should be paid to increasing the efficiency of ship safety monitoring systems based on AI [30, 31], which can: (a) provide the seafarer with reliable and visualized factual information concerning ship loading and wind-wave impact to increase the soundness of his decisions for safe and efficient routing in heavy sea conditions, in particular, to provide navigational safety at stormy seas; (b) control of the autonomous (crewless) marine vehicle for fulfilling its mission with correction of the planned path, speed, and course in the current sea environment. Early and current research on ship safety monitoring systems focused primarily on using sensors and other hardware devices to detect hazards such as collisions, fires, capsizes, and leaks. Such systems effectively recognize potential dangers and warn crew members and other stakeholders early. However, these systems' existing hardware/software limitations could influence their effectiveness. For example, these systems were often limited by the hardware devices' processing power, which can result in delays in data analysis and decision-

making. In any case, they still are DSS - Decision Support Systems [5, 31, 32], proposing to the ship Master only visualized forecasted options and limitations on routing choice (Fig. 4 and Fig. 5, where green zones mean safe parameters and red zones – dangerous parameters). The latest developments in Smart Sensors and AI-based systems for ship safety monitoring have shown promise in addressing these limitations. By leveraging intelligent digital sensors and AI technology instruments, these systems can provide real-time data analysis and predictive capabilities that can improve safety and reduce the risk of accidents. Direction 5.1. The AI-based ship safety monitoring systems involve AI algorithms and advanced digital sensors to detect and analyze potential hazards in real-time operations and optimize ship routing from human, technical, commercial, and ecological safety points of view. This AI approach would involve the integration of multiple digital and smart sensors, including liquid cargoes, green fuels and technological liquids state parameters sensors, dynamic parameters of control units, weather conditions monitoring, main engine and auxiliary systems parameters monitoring, and other devices, to provide real-time data on conditions onboard the ship into cloud databases. The data collected by these sensors would be analyzed using AI algorithms to identify potential hazards and provide early warning to crew members and other stakeholders. The AI algorithms ship used would be designed to learn over time, improving their ability to detect hazards and provide accurate predictions, and also recommendations to create the next ships' generations.

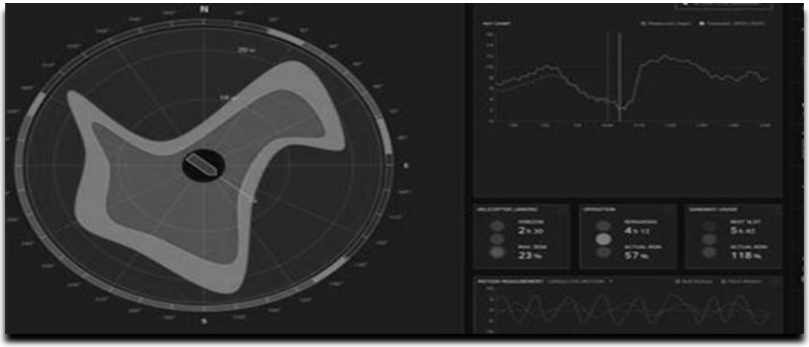

Fig. 4. Visualization of ship safety diagram: limitations by speed

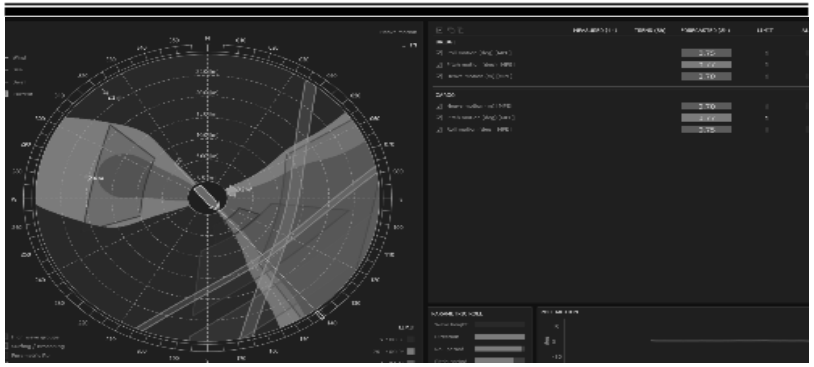

Fig. 5. Visualization of ship safety diagram: limitations by course

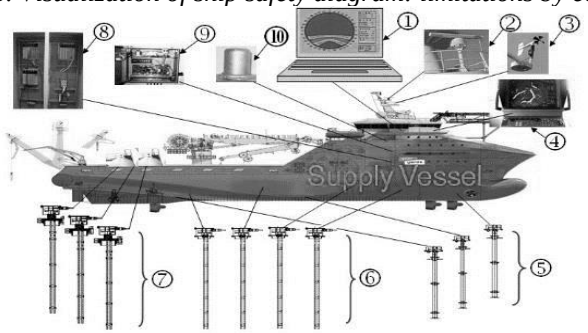

Fig. 6. Component structure of the Cyber-physical System "Supply Vessel"

The proposed AI approach's practical implementation would involve installing advanced sensors and AI algorithms onboard the ship. This approach would require the development of new intelligent hardware devices and software applications that can support real-time data analysis and predictive capabilities. For example [29], the generalized sensor-information components of the Cyber-physical System "Supply Vessel" are presented in Fig. 6. The main sensory sub-agencies of the Cyber-physical System (Fig. 6) are: operator workplace (1); a radar antenna (2); an onboard anemometer (3); the radar display and a keyboard (4); a set of sensors for ship draft monitoring (5); a set of polymetric sensors for fuel-oil, ballast water and other liquid cargo quantity and quality monitoring and control (6);a set of polymetric sensors for liquefied LPG or LNG cargo quantity and quality monitoring and control (7); switchboards of the subsystem or

actuating devices and operating mechanisms control (8); a basic electronic block of the subsystem for liquid, liquefied and loose cargo monitoring and control (9); specialized electronic block with sensors for real-time monitoring of parameters of ship dynamics (10).

Potential challenges in implementing this AI approach include the need for significant investment in research and development, as well as the need for specialized training for crew members and other stakeholders. However, the potential benefits of this approach, including improved safety and reduced risk of accidents, make it a worthwhile investment for ship owners and operators.

Direction 5.2. Digital Twins (DT) would be widely used in ship design, manufacturing, operation, maintenance, modernization, repair, and, finally, their utilization. The output of DT returns to the ship as actions, recommendations, and even control. The outcomes of DT are used to: Increase safety and reduce operational costs; Design new green and digitalized ships, equipment, etc.;Training of operators and predictive maintenance; Oversight and compliance monitoring, emergency response, etc. While there are challenges to implementing this AI approach, the potential benefits make it a worthwhile investment for the shipping industry. Further research and development in this area are needed to realize the potential of AI-based ship safety monitoring systems fully.

6. Advanced AI implementation in education

LLMs ChatGPT and GPT-4 have significant potential for their use in the educational field. The capabilities of GPT-4 increased after the introduction of access to the paid version of this language model to Internet resources and the provision of the possibility of using about 800 embedded plugins, the list of which is constantly expanding. Based on the gained practical experience of working with ChatGPT and GPT-4, it is possible to formulate a set of proposals or directions regarding potential areas of application of AI platforms built on LLMs in teaching, learning, and research processes.

Direction 6.1. GPT-4 can act as a personal tutor that provides information from different areas of knowledge and can explain concepts, helping students to better understand the learning material. AI-based platforms can create a more personalized and flexible learning environment

for distance learning students [33]. GPT-4 and similar technologies facilitate access to education for those living in remote areas or for individuals with special needs by converting text to speech for students with visual impairments or prov.

Direction 6.2. GPT-4 can be used 24/7 to dialogue with students, form answers to their questions, and even host seminars and discussions, allowing students to learn on their own schedule and at their own pace. AI can play the role of a personal assistant that helps navigate learning and provides advice on choosing a course, career path, or even personal development. AI should be seen as an effective means of providing emotional support to students to help them cope with stress and maintain mental health. In essence, such language models are a powerful tool for personalized learning, providing valuable experiences for the purposeful formation of knowledge, skills and abilities by adapting to the individual needs of each student. They can assess students' current level of understanding of the learning material and provide specialized content and exercises to help them improve. In fact, we are talking about the mass creation of neuro-curators (neuro-teachers) who will answer students' questions in Telegram bots and on websites, including with voice support. The GPT-4 usage service already provides access to 5 tutoring plugins, including: (a) Tutory (affordable tutoring and on-demand education), (b) Open Lecture (offers useful points in open course lectures for targeted learning), (c) Giga Tutor (personalized AI-based tutor, which stores personalized answers to questions), (d) edX (finds courses and content from leading universities to expand the user's knowledge at any level), (e) ABCmouse (offers fun and informative learning activities for children 2-8).

Direction 6.3. AI can help educators assess assignments, provide feedback to students, and identify areas where students are struggling and need additional support. AI also can provide teachers with resources for professional development, such as suggestions for improving teaching strategies or information that will allow them to stay abreast of the latest research in their field. Using GPT-4, teachers can automate some aspects of the learning process, reducing their workload. For example, GPT-4 is capable of automatically grading assignments or creating learning content

by generating learning materials such as: lecture summaries, self-test questions, interactive practice exercises, quizzes, lesson plans, examples and scenarios to illustrate complex topics and more. It is very useful to involve AI as an aid in the review process to identify potential problems in the manuscript, such as plagiarism or inconsistencies, to develop suggestions for improving the clarity and coherence of the writing.

Direction 6.4. Another area of AI implementation is the effective management of the resources of educational institutions, for example, the optimal distribution of the teaching load among teachers, the preparation of lesson schedules, the management of library resources, or the coordination of services for students. An urgent task is the formation of the necessary background for the future involvement of artificial intelligence technologies in the process of generating compromise solutions in typical situations of managerial activity. This approach will allow for generalizing the best management practices and updating conceptual approaches to their implementation.

Direction 6.5. LLMs are capable of working with different languages, allowing for the creation of multilingual learning resources and providing global access to education. AI can be a valuable tool for native and foreign language learning, providing instant feedback on grammar, pronunciation, and vocabulary. It can also facilitate the practice of speaking in a safe and non-judgmental environment, without judgment, providing real-time translation services that facilitate the learning and collaboration of students who speak different languages. In this context, it is worth noting the additional capabilities of GPT-4, which are provided, for example, by plugins Speak (a language tutor based on artificial intelligence that allows you to learn to speak anything in another language), Speechki (provides the conversion of texts into ready-made audio with a download link sound files, or to the page of the audio player).

Direction 6.6. A promising trend is the integration of LLMs with generative transformers capable of synthesizing two-dimensional and three-dimensional images, and videos. This opens a wide field for creativity and improvement of teaching and learning processes.

Direction 6.7. Using artificial intelligence as a teaching tool, teachers and faculty can train students to identify and analyze the limitations inherent in artificial intelligence, which will help develop critical thinking. As artificial intelligence becomes more common, it is important for students to understand how such systems work and the ethical considerations involved in their use. Therefore, AI should be used as a tool to teach relevant important skills.

Direction 6.8. AI can facilitate collaborative learning by coordinating group projects, creating an environment for discussion, and providing feedback on group dynamics. A very valuable asset is the ability of AI to generate dynamic simulations or scenarios that allow students to apply their knowledge in a virtual environment. This is especially useful in fields such as medicine, engineering, or any other discipline where real-world application of skills is key.

Direction 6.9. No less important direction is psychological assistance to students. AI should be seen as an effective means of providing emotional support to students to help them cope with stress and maintain mental health. This may include mindfulness exercises, stress management techniques, or even simply providing compassionate communication. An intelligent chatbot can help identify situations where a student is experiencing emotional difficulties and suggest appropriate resources or interventions. In this context, AI can play the role of a personal assistant that helps navigate learning and provides advice on choosing a course, career path, or even personal development.

Direction 6.10. LLMs are also a valuable tool to assist researchers by providing quick access to information, generating ideas for research and writing fragments of scientific reports, dissertations, or articles, summarizing large volumes of text, identifying key themes in the literature, and even suggesting areas for further research. AI can also help with data analysis and visualization and symbolic computation. In particular, the Wolfram plugin provides access to mathematical calculations, knowledge sampling, and real-time data through Wolfram Alpha and Wolfram Language services. Although the proposed directions have great potential, it is also important to constantly consider the ethical implications and potential

risks associated with the use of AI in education. These include issues related to privacy, bias, and the quality of AI-generated content. It is critical to have safeguards in place to address these issues and use AI as a tool in a way that supports rather than replaces teachers. Again, while AI platforms offer exciting opportunities, it is important to approach them critically, ensuring that the use of AI enhances, rather than detracts from, the human element of education and research. It should be noted that the GPT-4 plugin engine relies on external programs, and GPT-4 with the plugin enabled can send them sensitive information or parts of the dialogue, including the user's country, preferences, etc. In this context, it is more reliable to use local large language models that function on the closed platform of the Ministry of Education and Science, an educational institution. Examples of these are LLaMA 7B/13B, Alpaca, etc. It is significant that the effectiveness of neural networks will grow over time in accordance with the improvement of AI technologies, increasing the quality and quantity of output data, and computing capabilities. This will encourage the revision of the concepts of training and their constant adaptation. The policymakers in different countries pay attention to the implementation of the ChatGPT in education processes. For example, the Chancellor of the nation’s largest school system, New York City Public Schools, David C. Banks said on 18 May 2023 [34] that ChatGPT caught NYC schools off guard and now, they are determined to embrace its potential and in New York public schools, students will be taught how to use AI. Direction 6.11. No doubt, the efficiency of training students in the AI field at the university level may be significantly increased in the framework of specialized integrated education environments [35] such as multi-university (academic) consortia and academic-industry consortia.

7. Linguistic competency of AI systems

Linguistic competency is a recognized sign of human intelligence. It results from linguistic intelligence in Gardner’s theory of multiple intelligences [36]. Besides, verbal communication using natural language and language acquisition are included in the list of competencies characterizing human-level general intelligence [37]. Given this, the ability to express thoughts, ideas, and suggestions using human language, which

constitutes the linguistic competency of an artificial personality, is an important subtask in developing AI. In turn, “accurate report”, which is a standard behavioral index indicating consciousness in humans, is best realized through human language [38]. In a similar way, these ideas are applicable to AI, which imitates human intelligence and thinking. In this sense, the developed linguistic competency of an artificial personality able to report accurately on what is going on may be regarded as a criterion indicating the rise of artificial consciousness. The role and rise of linguistic competency follow from Potebnja’s theory of thought and language which emphasizes the importance of language in shaping human thought processes. According to Potebnja, language is not simply a tool for communication but is also a means of organizing and structuring our thoughts [39]. He argues that language is a form of thought and that the way we use language reflects our cognitive processes. Potebnja’s ideas have influenced the development of cognitive linguistics, which seeks to understand the relationship between language and thought [40]. In a similar way, these ideas are applicable to AI which imitates human intelligence and thinking. Human understanding of the text or a message is based on the meanings of the used words, which are presented in explanatory dictionaries. Intrinsically, the use of such vocabulary as a knowledge resource of AI simulates the human way to formulate thoughts. The meaning of each word can be decomposed into elementary senses and these can be deduced from the word definition or explanation available in the dictionary. This process can be described mathematically and correspondingly formalized to automatically build semantic fields [41], resulting in the technical possibility of developing a deep intelligent instrument able to assess and compare texts and disambiguate word senses. The linguistic module of artificial personality can acquire human-like linguistic competency in this way. Chomsky argues [42] that humans have an innate ability to acquire language, which is hard-wired into our brains. This idea has been influential in the development of NLP algorithms, which seek to replicate human language acquisition processes in machines and AI technologies. It is important that the AI mechanisms modeling human thought and language preserve the information contained in the processed

texts. If the original language uses a non-Latin alphabet, some natural language processes require its Romanization. To be able to restore the initial text, the Latinization process should be based on scholarly (strict) transliteration, which provides simple-correspondent (one-to-one) or isomorphic correspondence between initial and Romanized graphemes. The Latinization rules using a mediator language inevitably refer to corresponding sounds in that language. That is, they are based on practical transcription rather than transliteration and, therefore, fail to preserve contained semantics. For example, the use of the English-oriented Romanization system for Ukrainian results in word form distortion and the appearance of false identities: Гальченко – Галченко (Halchenko), Тронко – Тронько (Tronko), Воронко – Воронько (Voronko), Банкова – Банькова (Bankova), Паньківська – Панківська (Pankivska), Польова – Полова (Polova), Лялько – Ліалко (Lialko), Ліліана – Ліляна (Liliana), Маріан – Мар'ян (Marian), медіана – медяна (mediana), Возіанов – Возянов (Vozianov), Гундеріан – Гундерян (Hunderian), Клаузіус – Клаузюс (Klausius), Пії – Пій (Pii), Лар'їн – Ларін (Larin), Левитський – Левицький (Levytskyi), Тоцька – Тотська (Totska), Чернятський – Черняцький (Cherniatskyi), etc. To avoid these inconsistencies [43], it is expedient to introduce in AI systems the national transliteration standard DSTU 9112:2021.

Direction 7.1. Research direction, which concentrated on increasing the linguistic competency of AI systems for a correct understanding of the contents in communications between humans and intelligent robots and between different kinds of robots in multi-robotic systems, is perspective and important for future AI development and implementation.

8. Conclusion

The main peculiarities of the developed AIDU Strategy, priorities in AI implementation, and prospective research directions in the AI field are focused on and discussed in detail. The result of the "Strategy for Artificial Intelligence Development in Ukraine" [39] implementation should deal with the creation of breakthrough technologies in the field of computer science and artificial intelligence as well as the creation of conscious AI-powered computers that make decisions considering ethical, moral, and legal norms.

One promising way to realize the AIDU Strategy is the study of artificial consciousness based on a synergetic approach. At the next step, future research must deal with software and hardware development, testing and implementation of proposed new-generation intelligent systems with AI based on the conscience conception. Another important direction (7.1) is the development of linguistic technologies, particularly those providing semantic text analysis that manifest the emergence of linguistic competency of an artificial personality. Besides, the authors analyzed and underlined the most important fields for AI implementation in Ukraine, as well as, developed, formalized and justified priority practical-research directions for future successful AI results and achievements, in particular, (4.1) – (4.5) in intelligent robotics, (5.1) – (5.2) in the marine industry, (6.1) – (6.11) in the education sphere. Scientific efforts must be concentrated on intensive AI research in the abovementioned directions to increase the role of Ukraine in the world as a highly technological country, strong marine country and country with high-caliber standards in education. IAIP-project on the AIDU Strategy may be the base as well as can be modified, extended and transformed into the final edition of the National Strategy for AI Development in Ukraine.

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ОСНОВНІ НАПРЯМКИ РЕАЛІЗАЦІЇ СТРАТЕГІЇ ШТУЧНОГО ІНТЕЛЕКТУ В УКРАЇНІ

Член-кор. НАНУ, Dr.Sci. Шевченко А.[1], Dr.Sci. Кондратенко Ю.[1,2], Dr.Sci. Слюсар В.[1], Dr.Sci. Жуков Ю.[3], Ph.D. Кондратенко Г.[2], Ph.D. Вакуленко М.[1]

[1]Інститут проблем штучного інтелекту Міністерства освіти і науки та Національної Академії наук України, Україна,
E-mail: rector_iai@ukr.net, ypk@ipai.net.ua, swadim@ukr.net, maxvakul@gmail.com
[2]Чорноморський національний університет імені Петра Могили, Україна,
E-mail: y_kondrat2002@yahoo.com, halyna.kondratenko@chmnu.edu.ua
[3]C-Job Nikolayev, Україна,
E-mail:y.zhukov@c-job.com.ua

Анотація. *Даний розділ присвячена аналізу конкретних напрямків та особливостей Стратегії розвитку штучного інтелекту (ШІ) в Україні. Основними складовими роботи є аналіз поточного стану з обґрунтування, розробки та державного затвердження Національної стратегії ШІ в Україні; ключові елементи та основні пріоритетні напрямки впровадження ШІ згідно з ІПШІ-проектом «Стратегія розвитку ШІ в Україні»; пропозиції щодо розвитку ШІ в короткостроковій та довгостроковій перспективі та особливості впровадження ШІ в Україні в сучасний воєнний час. Особлива увага приділяється таким напрямкам досліджень ШІ, як (а) проектування систем ШІ на основі когнітивних концепцій і концепцій свідомості; (б) нові рішення в інтелектуальних робототехнічних системах для наземного, підводного та повітряного застосування; (в) перспективи штучного інтелекту в морській галузі; (г) перспективне впровадження ШІ в освіту; (д) лінгвістична компетентність систем ШІ. Отримані авторами результати можуть бути використані для розробки стратегічних кроків і планів у дослідженні ШІ та впровадженні процесів прийняття рішень на державному рівні.*

Ключові слова: *Стратегія, штучний інтелект, розробка, впровадження, Україна, пріоритети, особливості, аналіз, ІПШІ-проект*

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ТА ПРИЙНЯТТЯ РІШЕНЬ.
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НУ «ОМА», центр «Видавінформ»
65052, м. Одеса, Дідріхсона, 8, корп. 7
Свідоцтво ДК № 1292 від 20.03.2003
e-mail: publish@onma.edu.ua
Телефони: +38 (048) 793-24-50
+38 (048) 793-24-51