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**SITUATIONAL CENTERS AND DECISION-MAKING SYSTEMS.
INNOVATIVE TECHNOLOGIES OF NATIONAL SECURITY**

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Анотація. У статті розглядаються сучасні підходи до організації та функціонування ситуаційних центрів (СЦ). Особлива увага приділяється архітектурі та компонентам СЦ, технологіям збору та обробки даних, а також застосуванню машинного навчання та штучного інтелекту (ШІ) у системах підтримки прийняття рішень. Технології збору та обробки даних відіграють критичну роль у роботі ситуаційних центрів. У статті розглядаються сучасні підходи до збору даних, включаючи використання супутникових знімків та інших сенсорів. Машинне навчання та штучний інтелект є невід'ємною частиною систем підтримки прийняття рішень у ситуаційних центрах. Чат-боти та віртуальні помічники є важливими інструментами у ситуаційних центрах, забезпечуючи автоматизацію взаємодії з користувачами та підтримку прийняття рішень. Описуються приклади їх застосування для консультацій, моніторингу та оперативного реагування на інциденти. Розробка принципово нових підходів до створення систем II є однією з центральних тем статті. Розглядаються багатозв'язкові, багатовимірні, рецепторно-ефекторні нейроподібні мережі, що ростуть (ммрен-РС), як перспективна технологія, яка перевершує традиційні методи машинного навчання. У статті описуються унікальні можливості ммрен-РС, включаючи адаптивність, самоорганізацію та ефективність обробки інформації в реальному часі, обговорюються потенційні переваги від інтеграції та використання ммрен-РС у ситуаційних центрах. Наголошується на важливості цих переваг для урядових та військових СЦ, особливо в умовах військового протистояння. Аналізуються переваги та недоліки традиційних методів машинного навчання та ШІ порівняно з ммрен-РС. Автори статті вважають, що для остаточної перевірки ефективності та потенціалу ммрен-РС необхідно створення прототипу інтелектуальної системи, аналогічної до біологічного мозку. На закінчення автори підкреслюють, що ммрен-РС відкривають нові горизонти в галузі інтелектуальних систем, надаючи потужні інструменти для обробки, аналізу та класифікації інформації, представленої в багатовимірних вимірах.

Ключові слова: ситуаційні центри, системи ухвалення рішень, інформаційні технології, штучний інтелект, нейроподібні мережі, що ростуть.

Abstract. The article considers modern approaches to the organization and functioning of situational centers (SC). Particular attention is paid to the architecture and components of SC, data collection and processing technologies, as well as the use of machine learning and artificial intelligence (AI) in decision support systems. Data collection and processing technologies play a critical role in the operation of situational centers. The article considers modern approaches to data collection, including the use of satellite images and other sensors. Machine learning and AI are becoming an integral part of decision support systems in situational centers. Chatbots and virtual assistants are also becoming important tools in them, providing automation of interaction with users and decision support. Examples of their application for consultations, monitoring, and rapid response to incidents are described. The development of fundamentally new approaches to creating AI systems is one of the central topics of the article. Multi-connected, multidimensional, receptor-effector neural-like growing networks (mmren-GNs) are considered a promising technology superior to traditional machine learning methods. The article describes the unique capa-

bilities of mmren-GN, including adaptability, self-organization, and efficiency of real-time information processing, and discusses the potential benefits of integrating and using mmren-GN in situational centers. The advantages and disadvantages of traditional machine learning and AI methods are analyzed in comparison with mmren-GN. The importance of these benefits for government and military SCs, especially in military confrontation conditions, is emphasized. Advantages and disadvantages of traditional machine learning and AI methods compared to mmren-GN are analyzed. The authors of the article believe that for the final verification of the effectiveness and potential of mmren-GN, it is necessary to create a prototype of an intelligent system similar to a biological brain. In conclusion, the authors emphasize that mmren-GN opens new horizons in the field of intelligent systems, providing powerful tools for processing, analyzing, and classifying information presented in multidimensional dimensions.

Keywords: situational centers, decision-making systems, information technologies, artificial intelligence, neural-like growing networks.

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1. Introduction

In the modern world, the speed of decision-making is becoming a critical factor for the successful functioning of states.

Situation centers play a key role in ensuring the national security of any country. These high-tech complexes allow for the effective collection, analysis, and interpretation of information for quick and informed decision-making. Situation centers combine elements of information systems, control systems, and data visualization tools, creating a single platform for interaction between various structures and departments.

Particular attention should be paid to the use of situation centers for military purposes. In the context of military operations and threats to national security, the efficiency and accuracy of decision-making can determine the outcome of the conflict and minimize losses. Military situation centers integrate data from various sources — intelligence services, satellite imagery, unmanned aerial vehicles, and other surveillance equipment — creating a comprehensive picture of the operational situation.

Decision-making systems integrated into military situation centers are complex algorithms and models capable of processing large volumes of data in real time. They provide the command with relevant and reliable information necessary for developing strategies, planning operations, and responding to sudden threats. In conditions of uncertainty and dynamically changing situation, such systems become an integral management tool, increasing the sustainability and adaptability of military structures.

In this article, we will consider the principles of construction and operation of situational centers, as well as the methods and technologies underlying decision-making systems, with a special emphasis on their military application. We will discuss the issues of integration of various data sources, development of analytical models and algorithms, as well as aspects of cybersecurity and information protection in the military context. Also, we will provide examples of the application of situational centers in military operations and national security.

The aim of the paper is to provide the readers with a comprehensive understanding of the capabilities and prospects for using situational centers and decision-making systems in modern conditions, as well as to inspire the development and implementation of their own innovative solutions in this area that contribute to strengthening security and protecting the interests of the state.

2. Situation centers

A situation center (SC) is a complex of special software and hardware for personal and collective analytical work of a group of managers. It is designed for centralized control and management of the infrastructure of the object under control.

In systems of this class, in accordance with the achieved level of knowledge formalization, there is a possibility of automatic preparation of information about the area, subject, process under consideration, and the integration of this knowledge with the informal knowledge of a group of people (specialists, experts) who make a decision takes place [1].

Situation centers, as a concept, originated in the middle of the 20th century, when military and government agencies began to realize the need to create specialized premises for the coordination and management of operations.

With the development of technology and the increasing complexity of military operations, situation centers began to evolve. In the 50–60s, during the Cold War, situation centers began to use more advanced communications and computing machines for data processing. The advent of computers and their integration into command posts made it possible to significantly increase the volume and speed of information processing. During this period, situation rooms began to evolve into sophisticated technological systems capable of handling large amounts of data and providing more accurate and timely information for decision-making.

One of the most significant examples of this period is the creation of NORAD (North American Aerospace Defense Command) in 1957. This joint US-Canadian project was a centralized situation room located in underground bunkers on Cheyenne Mountain. The NORAD system was designed to monitor airspace and detect ballistic missiles in real time. Computers installed in the center could quickly analyze data coming from radars and satellites and transmit the information to military commanders for immediate decision-making. This was the first step towards automating processes in situation rooms and using computers to process huge amounts of data [2].

Situation rooms continued to evolve in the 70s and 80s with the advent of new technologies, such as satellite communications and more powerful computers. These innovations further increased the data collection and processing capabilities of the centers. Battle management systems became more integrated, combining different types of data, such as intelligence, weather, and troop movement, into a single picture. This greatly improved the quality and speed of decision-making at all levels of command.

In the 90s, with the development of the Internet and global data networks, situational awareness centers became even more efficient and integrated. The Internet allowed instant access to information from anywhere in the world, which greatly improved coordination between different units and agencies. Military operations, such as the Gulf War, demonstrated the effectiveness of new technologies. Situation centers began to use GPS systems to accurately determine the location of troops and targets, which significantly increased the accuracy and effectiveness of combat operations.

In the early 21st century, with the development of artificial intelligence and machine learning, situational awareness centers entered a new era. These technologies made it possible to automate many processes, such as analyzing big data and predicting possible scenarios. Modern situational awareness centers use advanced analytical tools to process information in real time, allowing commanders to quickly respond to changing situations. The use of virtual reality and augmented reality technologies allows for more intuitive operator interfaces and improved data visualization [3]. Today, situational awareness centers play an important role not only in military operations, but also in crisis management, disaster response, and security at major events. They continue to evolve, adopting the latest technologies to ensure reliable and effective coordination of actions in any situation. Modern situational awareness centers are high-tech complexes capable of processing huge amounts of data and providing commanders and operators with accurate and timely information for informed decision-making.

2.1. Situation center architecture and components

The architecture of situation centers is a set of hardware and software designed to collect, process, analyze, and visualize information necessary for decision-making in crisis situations. Depending on the specific goals and objectives, whether these are government services, business companies, or military organizations, the architecture of situation centers may vary. Let's consider the main components and aspects of the architecture of situation centers.

The centralized structure of the situation center assumes the presence of a main center, which concentrates all the key functions and capacities for data processing and decision-making. Such a structure ensures a high degree of control and coordination of actions. The main control center is a central room with the main equipment, servers, and data display systems. Field units are local branches or mobile units that transmit data to the main center for analysis and coordination.

The decentralized structure of the situation center assumes the distribution of functions and capacities between several centers or units that can work autonomously or in coordination with each other. This increases the flexibility and stability of the system. Regional centers located in different regions can function independently, and network communications provide communication and coordination between these centers for information exchange and collaboration.

The hardware infrastructure of the situation center includes various technical means necessary for collecting, processing, and displaying data. Servers and data warehouses are powerful servers for processing large volumes of data and storage systems for reliable storage of information. Communication systems provide communication between various elements of the situation center and external data sources. Display systems include large screens, video walls, and workstations with multi-monitor configurations for visualization of information and data.

The software infrastructure of the situation center consists of various software tools and systems that provide data collection, processing, analysis, and visualization. Data management systems are designed to collect and store data from various sources, including databases and data management systems (DMS). Analytical platforms include machine learning, artificial intelligence, and predictive analytics tools for data analysis. Visualization systems present data in the form of graphs, charts, maps, and other visual formats.

Security and data protection are critical aspects of the situation room architecture, especially in the context of government and military services. Cybersecurity includes measures to protect information systems from cyber attacks, such as firewalls, intrusion detection and prevention systems (IDS/IPS), and data encryption. Physical security ensures the safety of the situation room hardware and premises, including access control, video surveillance, and security systems. Procedures are developed and implemented to ensure data security and incident management.

Integration and interoperability of various systems and components are the key factors of effective functioning of the situation room. Interfaces and protocols define standards and protocols for the exchange of data between the various systems and components of the situation room. Integration systems use middleware and integration platforms to ensure compatibility and interoperability of various systems and applications [4].

Thus, the situation room architecture is a complex and multi-layered system that includes centralized and decentralized structures, hardware and software infrastructure, as well as security and integration measures. Each of these components plays a key role in ensuring effective collection, processing, and analysis of data required for making operational and strategic decisions in various conditions and contexts. Situation centers are complex technological complexes consisting of many interconnected components. The main goal of these centers is to ensure fast and accurate decision-making through the collection, analysis, and interpretation of data.

2.2. Basic elements of the situation center architecture

The command room (the heart of the situation center) is the central element in the management and coordination of various processes within the organization. This is where data is collected, analyzed, and decisions are made to ensure that the organization runs efficiently. This room is equipped with modern visualization systems, such as large displays and interactive panels. These devices display critical information in real time, allowing specialists to quickly respond to changes and make informed decisions. Large displays are multi-screen systems that can simultaneously display maps, graphs, and video streams. Interactive panels allow operators to interact with data, zoom in and out, make annotations, and easily switch between different sets of information [5].

A data processing center (DPC), or just data center, is the main storage and processing center for information in the organization. The DPC contains server rooms, data storage systems, and computing power that ensure the operation of analytical models and algorithms. Huge amounts of data from various sources are processed here. This data is used for analysis and forecasting which help the organization make informed decisions. The center also ensures data protection using modern encryption and backup methods, which guarantees their safety and availability even in the event of failures or attacks. The reliable infrastructure of the data center allows for maintaining high performance and uninterrupted operation of all information systems [6].

Communication systems are the most important link in the structure of any organization, ensuring reliable exchange of information between various departments and agencies. These systems include local and global networks, satellite communications, radio communications, and other means of communication. Thanks to these technologies, employees can quickly transfer data, conduct video conferences, and coordinate their actions in real time. Communication systems ensure high data transfer speeds and protect information from unauthorized access, which is especially important for effective management and decision-making in a rapidly changing environment.

Data visualization and analysis systems are fundamental elements in presenting information in a form convenient for analysis. These systems include software that processes data and turns it into visual graphs, charts, and maps.

Geographic information systems (GIS), database management systems (DBMS), and analytics platforms enable professionals to easily understand and interpret data, which leads to more accurate and faster decision-making. These tools help to identify trends, predict developments, and develop strategies based on factual information.

GIS are powerful tools for visualizing data on maps and other graphical interfaces, which help to visualize spatial relationships and trends. GIS integrate spatial data with attribute information, allowing users to analyze and interpret geographic data.

GIS provide tools for analyzing spatial data. These features allow users to identify patterns and relationships between features on a map.

GIS can integrate data from a variety of sources, including sensors, satellite images, databases, and other geospatial data. This provides a more complete and accurate representation of information. GIS are widely used in various fields, such as the environment, transportation, resource management, security, and defense. They help to solve planning, monitoring, and management problems by providing a visual representation of data in a geographic context [7].

Interactive panels are data visualization tools that allow users to interact with information and obtain operational reports. These dashboards provide visual representations of data in the form of charts, graphs, tables, and other visual elements. Interactive dashboards allow users to interact with data, change visualization parameters, and explore data in real time. This includes filtering, sorting, zooming, and drilling into data. Interactive dashboards allow you to create and generate operational reports that can be easily customized to meet specific user needs. This provides quick access to key information and supports the decision-making process.

Visualization and reporting systems, including GIS and interactive dashboards, provide powerful tools for analyzing and presenting data. GIS allows you to visualize data on maps and analyze spatial relationships, which helps you better understand geographic data. Interactive dashboards allow users to interact with information and receive real-time reports, and they help you make decisions quickly and effectively. When used together, these systems help to improve data analysis and management efficiency in a variety of areas.

2.3. Data collection and processing technologies in situation centers

In a modern situation room, data collection and processing technologies play a fundamental role in ensuring prompt and effective decision making.

2.3.1. Data collection

The basis for data collection in situation centers is the integration of various information sources and the use of advanced technologies for obtaining, processing, and analyzing data. Effective data collection provides the basis for decision-making, forecasting, and responding to crisis situations. Let's consider the main components and methods of data collection used in the SCs of government services, business companies, and the military.

SCs of government services use a wide range of data sources to obtain information necessary for their functioning. The main data sources include open sources, such as news, social networks, public reports, and publications. Government databases provide information from the information systems of various government agencies, including the Ministry of Internal Affairs, the Ministry of Emergency Situations, and the Ministry of Health. Sensors and detectors provide environmental monitoring and video surveillance. Humanitarian intelligence (HUMINT) includes information received from the population and the agent network.

In business, SCs also rely on a variety of data sources. Market research provides reports from analyst agencies, sales data, and consumer research. Internal data includes financial reports, CRM data, and production metrics. Competitive intelligence provides information about competitors obtained from open sources and specialized research. Social media is used to monitor brand mentions, products, and public opinion [8].

Military SCs use intelligence services to obtain information using both technical means and human resources. Satellite intelligence provides satellite images and data on enemy troop movements. Signal intelligence (SIGINT) intercepts and analyzes enemy electronic communications. Drones and unmanned systems collect data using unmanned aerial vehicles and ground systems. Humanitarian intelligence (HUMINT) collects information through agent networks and interaction with local populations.

Intelligence services in government situational awareness centers focus on preventing and responding to threats to public safety. This includes identifying terrorist groups, preventing crime, monitoring threats to public order, and ensuring preparedness for natural disasters. These services are critical in coordinating responses during emergencies, providing actionable information for real-time decision-making, coordinating resources, and maintaining communication between different agencies. They also help to maintain law and order by collecting information on criminal organisations and illegal activities, monitoring financial transactions to detect money laundering and using analytical tools to detect and disrupt illegal activities. Political and economic intelligence collects information needed to support public policy and economic development, including monitoring international political and economic developments and analysing their impact on national interests.

The main methods of work of intelligence services are media and social media monitoring, cyber intelligence, interagency cooperation and humanitarian intelligence (HUMINT). Analysis of data from public sources, such as news and social media, helps to identify and analyze trends and potential threats. Cyber intelligence includes protecting government information sys-

tems and networks from cyber attacks. Interagency cooperation allows for a more effective response to transnational threats and the use of joint resources. Humanitarian intelligence (HUMINT) includes collecting information through interaction with the population and the agent network, which is especially important for collecting data that is not available through technical means.

Intelligence services in business companies focus on collecting and analyzing information about competitors, researching their strategies, products, market positions, and financial indicators. Market analysis includes monitoring changes in consumer preferences, analyzing market niches, and predicting future trends. Risk management includes detecting and analyzing risks associated with business activities, such as political, economic, and cyber risks. Intellectual property protection is aimed at preventing the theft of corporate secrets and technologies. Decision support includes providing information for strategic planning and operational decisions.

The main methods of work of business intelligence services are open data analysis, social media monitoring, cyber intelligence, and network analysis. Open data analysis includes collecting information from public sources, such as news and company reports. Social networks are used to analyze public opinion and identify potential threats. Cyber intelligence includes monitoring network activity and developing measures to prevent cyber attacks. Network analysis helps to identify possible vulnerabilities and risks in supply chains and ensure the continuity of business processes.

Military services have a key importance in ensuring national security. They collect and analyze information about hostile forces, their intentions, and possible actions. Strategic planning includes the development of long-term military strategies and operational plans based on up-to-date intelligence information. Threat detection includes analysis of data on possible attacks, enemy troop movements, and new technologies. Operations support provides information for military operations in real time. Cybersecurity involves protecting military infrastructure and information from cyber attacks. The primary methods of military intelligence are satellite intelligence, signals intelligence (SIGINT), humanitarian intelligence, and cyber intelligence. Satellite intelligence uses satellite imagery and data to analyze troop movements and changes in enemy territory. Signal intelligence intercepts and analyzes enemy electronic communications. Humanitarian intelligence collects information through agent networks and interactions with local populations. Cyber intelligence involves monitoring cyberspace and developing offensive and defensive strategies in cyber warfare.

Let's take a closer look at the methods of collecting information by the intelligence services of military SCs. To collect data, intelligence services use both human and technical resources. Intelligence agents work in a variety of conditions, sometimes risking their own safety to collect data that may be of great importance. Intelligence services rely on a network of agents who provide information on various aspects, such as the political situation, economic status, potential threats, and more.

Human Intelligence (HUMINT) is a method of collecting and analyzing intelligence information obtained from human sources. In the context of information security, HUMINT is used to collect and analyze information about potential threats to information systems and infrastructure of an organization. Human intelligence is the process of collecting data from agents and informants working on the scene. This type of intelligence provides a deep understanding of the enemy's intentions and actions, providing information that cannot be obtained using technical means. Agents infiltrate enemy structures, establish contacts, and collect information directly from sources. They can be embedded in key organizations, work undercover, or collaborate with locals.

HUMINT provides unique information, such as enemy plans and intentions, internal conflicts, morale, etc. This type of intelligence is especially valuable in situations, where contextual

and qualitative information is important. Informants can provide data on future attacks, political maneuvers, and other critical aspects.

However, agents have a highly risky job, as they operate in dangerous conditions and are often under constant surveillance. In addition, HUMINT requires a significant investment of time and resources to train specialists and conduct operations, and it is also associated with the risk of specialist exposure or information leakage.

Interestingly, HUMINT is one of the oldest and most widely used methods of intelligence collection. It was used as far back as the times of ancient civilizations, when spies were sent to other countries to gather information about enemy's military plans. Today, HUMINT remains a flexible and powerful tool that allows for a deep understanding of human behavior and motivation, which is useful in developing strategies to counter various threats.

Technical Intelligence (TECHINT) is a specialized field of intelligence that collects, analyzes, and uses technical information to support decision-making in various fields, such as military operations, law enforcement, intelligence services, and industry. This form of intelligence encompasses a wide range of sources and methods to obtain data that may be critical to security, technology development, and strategic planning. Technical intelligence is primarily designed to counteract technological surprises. Knowledge of the characteristics and capabilities of enemy weapons enables countries to develop effective countermeasures.

TECHINT sources include scientific and technical literature, patents, trade journals, and specialized databases. Scientific and technical literature, such as articles in scientific journals, conference papers and books, provides information on the latest advances in science and technology. These publications may contain data on new technologies, methods, and research that can be useful for a variety of purposes, from developing new products to analyzing the potential of technologies. Patent documents contain detailed descriptions of new inventions and technologies, and their analysis helps to understand the direction of technological development and identify new trends and innovations. Publications in specialized journals and trade publications provide information on news and events in specific industries, which is useful for understanding market trends and competitive strategies. Databases containing technical documents, standards and specifications are an important source of information for TECHINT, allowing it to obtain accurate and up-to-date information on the technical aspects of various technologies and systems. To analyze and process large amounts of data, TECHINT uses advanced analytical tools, such as software and algorithms, to identify patterns and analyze trends. These tools may include machine learning, artificial intelligence, and big data to create models and forecasts. Specialized tools for analyzing and interpreting technical data, such as data visualization systems, simulations, and modeling, help to identify anomalies, assess risks, and support decision-making. The information collected through TECHINT can be used to develop new technologies, optimize, and modernize existing systems and processes, and support strategic decision-making. TECHINT identifies innovative ideas and solutions that can be implemented in new projects and helps to identify weaknesses and suggest ways to improve them. This information and analytics can be used to develop strategies and plans, helping to make informed decisions in a variety of contexts, from national security to corporate governance.

An example of the use of TECHINT can be seen in the work of the organization ThreatNG, which uses it to improve cybersecurity. TECHINT is used to identify technical vulnerabilities and weaknesses in an organization's infrastructure and systems, and to provide recommendations for remediation to prevent their exploitation. ThreatNG uses TECHINT to scan an organization's attack surface and discover potential vulnerabilities by analyzing technical data associated with those vulnerabilities and providing a detailed assessment of the organization's exposure to technical risks. TECHINT plays a key role in threat hunting and incident response, helping ThreatNG gather information about ongoing attacks, including IP addresses, malware

signatures, and command and control servers, to identify and contain attacks. TECHINT also monitors the Dark Net and other underground forums to identify potential threats and exploits.

Technical intelligence should be distinguished from intelligence obtained «by technical means».

Technical intelligence involves collecting data using specialized technical means. These tools can be very diverse and include radars, electronic devices, signal interception systems, and other high-tech tools. Technical reconnaissance allows for the collection of vast amounts of data over long distances and in challenging conditions, making it indispensable in the modern intelligence process. Radars can detect and track the movement of objects, such as aircraft, ships, and ground vehicles, providing data on their speed, direction, and other parameters. Electronic devices can intercept and analyze radio signals, identifying enemy communications and determining their location. Signal interception systems can capture various types of communications, including telephone conversations, text messages, and Internet traffic, allowing for the collection of information about the enemy's plans and intentions. Satellite systems play a vital role in the modern world, providing unique capabilities for surveillance and data collection on a global scale. These systems allow for the production of highly accurate images of the earth's surface and the provision of continuous surveillance of specific areas, which is especially important for military, intelligence, and scientific purposes. There are two key areas in this category: satellite imaging and geostationary satellites.

Satellite imaging is the process of obtaining high-precision images of the earth's surface using satellites equipped with cameras and other optical instruments. These images allow for detailed tracking of troop movements, detection of objects, and monitoring of landscape changes. Geostationary satellites occupy a special place among satellite systems. These satellites orbit at an altitude of about 35.786 kilometers above the equator and move synchronously with the rotation of the Earth. This allows them to remain above the same point on the planet's surface, providing continuous surveillance of a certain area. Unmanned aerial vehicles (UAVs) are becoming an integral part of modern military and intelligence operations. These devices provide unique capabilities for collecting data and performing combat missions, ensuring a prompt and effective response to various threats. The main types of UAVs include reconnaissance and attack UAVs.

Reconnaissance UAVs are designed to collect data in real time, providing monitoring of the operational situation, especially in hard-to-reach or dangerous areas. These aircraft are equipped with various sensors and cameras that enable them to obtain high-resolution images and videos, as well as other data, such as thermal and infrared images. Attack UAVs are multi-role aircraft that can perform combat missions in addition to data collection. These devices are equipped with weapons, such as missiles and bombs, making them valuable tools for quickly responding to threats. Ground sensors and detectors are one of the key elements in collecting data and providing situational awareness. These devices can be installed in various locations and are designed to detect and track objects and events in real time. Among the many types of ground sensors, optical, infrared, and acoustic sensors are among the most important and widely used. Optical and infrared sensors are used to detect and track objects in various visibility conditions. These devices can capture images and videos in the visible spectrum and in the infrared range, allowing data to be collected both during the day and at night, as well as in low-visibility conditions, such as fog or smoke. Acoustic sensors are designed to detect sounds, such as gunfire or vehicle movement, over long distances. These devices can record and analyze sound waves, allowing them to determine the location and nature of the sound source. Acoustic sensors can be used for a variety of applications, including perimeter security, combat monitoring, and detecting illegal activity.

Technical intelligence provides objective and quantitative data that can be analyzed and used to confirm or refute information obtained from other sources. Technical means allow data to

be obtained in real time and over long distances, which is especially important in active military operations or when monitoring remote regions.

Intelligence services provide a comprehensive and multifaceted approach to information collection. HUMINT and TECHINT complement each other, providing both qualitative and quantitative data, which allows for a complete picture of the operational situation. This information is the basis for making strategic decisions, planning operations and ensuring security at all levels.

All types of intelligence services collect, analyze, and interpret information to support decision-making. They use advanced technologies and methods for collecting and processing data. They play a critical role in risk management and security (national, public or corporate). At the same time, military intelligence services focus on national security and military operations, using more secret and specialized methods (satellite reconnaissance, SIGINT, HUMINT). Public services focus on public safety and law enforcement, relying more on interagency cooperation and public sources. Business intelligence focuses on commercial interests and competitive advantages, actively using open data analysis and market research.

2.3.2. Data processing

Data processing plays a key role in extracting valuable information from huge amounts of data. There are various methods and technologies that allow you to effectively process and analyze this data, turning it into useful information for decision-making. The main methods and technologies of data processing are described below.

Big Data. Using Big Data processing technologies allows you to work with huge amounts of information coming from various sources. This data can include text messages, images, videos, sensor data, and many other types of information. Big Data technologies allow you not only to store this data, but also to quickly process, analyze, and visualize it. Specialized tools and platforms, such as Hadoop and Spark, provide distributed data processing, which allows you to process it in parallel on several servers. This significantly speeds up the analysis process and allows you to extract valuable insights from huge amounts of data.

Machine learning and artificial intelligence (AI) are playing an increasingly important role in data analysis. AI and machine learning-based analytical models can predict events, identify hidden patterns, and automate decision-making. Machine learning uses algorithms that are trained on large data sets and are able to find complex patterns and correlations. This allows, for example, to predict user behavior, detect fraud, analyze medical images, and solve many other problems. AI is also used to create intelligent systems that can independently make decisions based on the analyzed data, which significantly speeds up and simplifies the information management process.

Integration and synergy. The integration of Big Data, machine learning, AI, and GIS technologies allows you to create powerful analytical platforms that can process and analyze data in real time. These platforms provide users with the ability to quickly access the information they need, analyze it, and make informed decisions. The synergy of these technologies allows not only to improve the quality of data analysis, but also to significantly speed up the processing process, which is critical in a rapidly changing environment.

Thus, data processing using modern technologies and methods allows for extracting valuable insights from huge amounts of information, automating the decision-making process, and improving the understanding of the operational situation. This contributes to more effective management and allows organizations to quickly adapt to changing conditions.

2.3.3. Data analysis and interpretation

Data analysis and interpretation play a critical role in making informed decisions. This process involves the use of various methods and technologies that help to transform raw data into useful information that facilitates strategic planning and operational management. It is important not only to collect and process data, but also to interpret it correctly in order to understand its meaning and possible consequences.

Decision support systems (DSS) are software packages that help analyze data and propose optimal courses of action. These systems use various algorithms and models to evaluate data and provide recommendations. DSS can include expert systems that imitate the decision-making process of experts in a particular field, as well as data analysis systems that use statistical methods and machine learning. The main goal of DSS is to help users make more informed decisions by providing them with relevant data and possible action scenarios. This is especially important in complex and rapidly changing conditions, where the accuracy and speed of decision-making are critical.

Predictive modeling involves creating models that help predict future events and suggest optimal courses of action. These models are based on historical data and are used to estimate the likelihood of various scenarios.

Model creation. Predictive models are created based on historical data and incorporate various mathematical and statistical techniques. These models can be used for time series forecasting, regression, classification, and other tasks.

Data analysis. Predictive modeling involves analyzing data to identify key factors that influence outcomes. This may include correlation analysis, factor analysis, and other techniques to understand the relationships between variables.

Event prediction. Predictive models are used to predict future events, such as changes in market conditions, customer behavior, resource requirements, etc. These predictions help organizations develop strategies and action plans.

Decision optimization. Predictive models can also be used to optimize decisions by suggesting the best courses of action based on predictions. This includes inventory optimization, manufacturing process planning, risk management, and other tasks.

Analytical and predictive models, including the use of machine learning and AI, as well as predictive modeling, provide powerful tools for analyzing data and predicting events. Machine learning and AI can reveal hidden patterns and automate data analysis, providing valuable insights for decision-making. Predictive modeling helps predict future events and optimize decisions, which allows organizations to develop effective strategies and improve their results. The combined use of these technologies helps organizations become more efficient and competitive in the modern world.

Interactive dashboards and data visualization are technologies that allow users to interact with information and get the necessary analytics in a convenient and visual form. These technologies include the use of touch screens, interactive graphs, charts, and maps that make it easier to understand and analyze data. Interactive dashboards allow users to quickly filter data, change visualization parameters, and get detailed information for each metric. Data visualization helps identify hidden patterns and trends, as well as present complex information in a simple and understandable way. This significantly improves the process of analyzing and interpreting data, allowing you to make more informed decisions and quickly respond to changes.

The integration of decision support systems, predictive modeling and interactive dashboards creates a powerful toolkit for analyzing and interpreting data. These technologies complement each other, providing a comprehensive approach to data analysis and decision-making. Decision support systems suggest optimal actions, predictive modeling evaluates possible development scenarios, and interactive dashboards allow you to clearly present and analyze data. The combined use of these technologies provides a deeper understanding of the situation and im-

proves the quality of decisions made. This allows organizations to be more flexible and adaptive, effectively respond to challenges and take advantage of the opportunities that data analysis provides.

2.4. Decision-making

Decision-making is a choice of parameters of transition to the desired state of a person (system), based on knowledge, based on the available information about the current state of the system, a set of models (life experience for a person, a system of models of processes occurring in the object for complex objects) [9]. That is, decision-making is a process of identifying alternatives and choosing among them, based on the values and preferences of the decision-maker. The decision-making process consists of several key stages that help to structure and systematize the process of selecting the optimal decision in different situations. These steps provide a systematic approach to analyzing the problem, generating and evaluating alternatives, and implementing the chosen solution.

2.4.1. Basic stages of decision-making

Problem Definition. The first stage involves identifying and clearly articulating the problem to be solved. At this stage, it is important to understand the context of the problem and to identify the objectives and constraints associated with the problem. This requires an in-depth analysis of the situation, identifying key factors and understanding exactly what needs to be accomplished. Defining the problem is the foundation for all subsequent stages and ensures that the right aspects are focused on.

Generation of alternatives. Once the problem has been defined, the next step is to develop possible alternatives or solutions. It is important to consider a wide range of possible options to ensure that there are multiple options to evaluate. This is the stage of creative thinking and finding different ways to solve the problem. Methods for generating alternatives may include brainstorming, analyzing previous solutions, exploring best practices and innovative approaches.

Evaluation of alternatives. Each proposed alternative is evaluated against a number of criteria, such as cost, benefits, risks, and potential consequences. The evaluation may include quantitative and qualitative analysis, as well as predicting possible outcomes. It is important to use as much data and information as possible to objectively evaluate each alternative. This step helps you understand the strengths and weaknesses of each alternative and determine which one is best suited to achieve your goals.

Selecting the best alternative. Based on the evaluation, the alternative that provides the greatest expected utility or the best balance between risks and benefits is selected. This choice should be based on a careful analysis of all available data and information. At this stage, it is important to consider all factors and make an informed decision that best meets the objectives and constraints established at the outset.

Decision Realization. Once the best alternative has been selected, a decision is made to implement it. This involves developing and executing a plan of action to achieve the goals established in the initial phase. Implementation requires clear organization, allocation of tasks and resources, and monitoring and control of the plan. It is also important to be ready to adapt the plan in case of unforeseen circumstances or changes in the situation [10].

The decision-making process consists of sequential steps, each of which plays an important role in achieving an optimal outcome. Defining the problem, generating and evaluating alternatives, selecting the best alternative and implementing the decision provide a systematic and logical approach to problem solving, contributing to the successful achievement of objectives and effective management of resources.

2.4.2. Classical decision-making theory

The underlying principle of classical decision theory is the assumption that individuals are rational. According to this principle, individuals act rationally in an effort to maximize their utility or satisfaction. In the context of decision-making, this means that individuals carefully evaluate all possible alternatives before making a choice. They analyze the potential outcomes of each option and choose the one they believe will provide the greatest benefit.

Rationality assumes that people are able to evaluate information objectively and logically, consider the probabilities of different outcomes, and evaluate their consequences. For example, in business, when making financial decisions, the decision-maker (DM) will analyze various investment opportunities, consider risks and potential profits, and choose the investment that, in their opinion, will bring the greatest expected feedback [11].

Let's consider the military sphere and imagine a DM who needs to choose a strategy for a military operation. In accordance with the principles of rationality, the DM will consider various strategic options, analyze their strengths and weaknesses, and assess possible risks and benefits. They will take into account information about the terrain, weather conditions, enemy troop strength and equipment, and the possible consequences of each option. For example, the DM may choose between a direct attack and a bypass maneuver. A direct attack may be riskier, but it can lead to quick success. A bypass maneuver, on the other hand, may be less risky but more time- and resource-consuming. Ultimately, the DM will choose the strategy they believe will lead to the greatest military success with minimal losses, following the rationality principles of classical decision theory.

In practice, however, this behavior may be difficult due to limited information, time, and cognitive resources. Nevertheless, the classical theory assumes that decision-makers strive for rational behavior and use the resources available to them to maximize their utility.

Expected utility theory. It is one of the key models in classical decision-making theory. This model was proposed in the middle of the 20th century and still remains an important tool for analyzing and understanding human behavior under uncertainty.

According to the expected utility theory, people make decisions based on an estimate of the expected utility of various alternatives.

Expected utility (EU) is calculated as the sum of probabilities (P) of possible outcomes multiplied by their utilities (U):

$$EU = \sum (P_i \times U_i),$$

where P_i is the probability of the i -th outcome and U_i is the utility of the i -th outcome. In other words, for each alternative an individual evaluates all possible outcomes, multiplies their utility by the probability of their occurrence, and adds up these products. The alternative with the highest expected utility is considered optimal and is selected for implementation.

For example, suppose a person decides whether to invest in stocks or bonds. They evaluate such possible outcomes as high stock returns, average bond returns, and possible losses in the event of a market crash, and assign certain probabilities and utilities to each of these possibilities. After that, they calculate the expected utility for each option: stocks (probability of high return) * (utility of high return) + (probability of loss) * (utility of loss); bonds (probability of medium return) * (utility of medium return). If the expected utility of stocks is higher, the person will choose to invest in stocks, and vice versa.

The expected utility theory also takes into account people's subjective preferences and evaluations. Utility is not always measured in money or material goods; it can reflect personal preferences, satisfaction, and other intangibles.

However, as with rationality, difficulties can arise in practice. People are not always able to accurately assess probabilities and utility, and their decisions may be subject to cognitive and

emotional distortions. Nevertheless, expected utility theory provides a useful model for understanding and predicting behavior under uncertainty.

The principles of rationality and utility maximization, as well as expected utility theory, are cornerstones of classical decision theory. They assume that people strive for rational behavior, carefully evaluate possible alternatives, and choose those that yield the greatest expected utility. Despite practical limitations and complexities, these models provide important tools for analyzing and understanding the decision-making process.

Application of the classical decision theory. Classical decision theory is used in a variety of fields and helps to structure the decision-making process, providing a rational approach to selecting the best alternatives.

Business planning. This theory is used to develop strategies for company development, analyze market opportunities and threats, identify target segments, and develop products. Managers use this theory to make decisions related to investment, marketing, and resource management.

Financial investing. Investors use classical theory to analyze and select investment opportunities, manage a portfolio of assets, and evaluate risks. The theory helps in making informed decisions to maximize returns and minimize risks.

Project management. In project management, classical theory helps in planning and managing projects, prioritizing tasks, allocating resources, and assessing risks. This ensures that project objectives are effectively achieved on time and within budget.

Personal planning. Classical theory is also applied in personal life to make decisions related to career, education, finances, and personal goals. It helps in structuring thoughts and evaluations to make informed choices.

Limitations of the classical decision theory. Despite its importance and wide application, classical decision theory has its limitations. It assumes ideal conditions of rationality and completeness of information, which rarely corresponds to real life.

Limited information. In practice, people are often faced with limited or incomplete information, which makes it difficult to objectively evaluate all possible alternatives. The lack of data can lead to erroneous decisions.

Cognitive biases. People are susceptible to various cognitive biases, such as confirmation bias (confirmation bias), recency bias (recency bias), and the fear of loss (loss aversion). These biases can distort information perception and affect the rationality of decisions.

Emotional factors. Emotions play an important role in the decision-making process and can strongly influence choices. Stress, fear, enthusiasm, and other emotional states can lead to irrational decisions.

Limited cognitive resources. People have limited cognitive resources to process and analyze information. In complex situations that require rapid evaluation of a large amount of data, they may not have time to thoroughly analyze all alternatives and make the best decision [12].

Classical decision theory provides fundamental principles and models for rational choice among alternatives. The basic steps of the process, including problem definition, generation of alternatives, evaluation, selection, and implementation, help to systematize the decision-making approach. However, it is important to keep in mind that in real life, the decision-making process may be more complex and subject to various distortions and constraints, which requires additional approaches and methods for more accurate and efficient decision-making.

2.4.3. Game theory

Game theory is a field of mathematics and economic science that studies interaction strategies between different decision-making agents. This discipline is used to analyze situations in which outcomes depend on the actions of several participants, each of whom seeks to maximize their own interests. Game theory allows people to model and predict the behavior of participants under conditions of competition and cooperation.

Games in game theory are formalized situations in which multiple participants, called players, make decisions that affect outcomes for all parties. Players are the participants in a game, each with their own goals and set of available actions. Strategies, in turn, are a set of actions or decisions that a player can choose at any point in the game. Strategies can be either simple, involving a choice between two options, or complex, requiring planning a series of actions over a long period of time.

Nash equilibrium. One of the fundamental concepts in game theory is the Nash equilibrium, introduced by mathematician John Nash. It describes a state of the game in which no player can improve their outcome by changing their strategy unilaterally, provided that the strategies of the other players remain unchanged. The Nash equilibrium can be achieved both in pure strategies, where players choose specific actions, and in mixed strategies, where players choose actions with a certain probability.

Game types. There are different types of games. In zero-sum games, one player's gains are equal to another player's losses, as in poker or chess. In non-zero-sum games, the total gain or loss may vary depending on the interaction of the players, as in business or politics. Dynamic games involve sequential decision-making, where players make moves in turn and current decisions may depend on previous actions. In static games, all players make their choices simultaneously and independently without knowing the actions of others [13].

Limitations. Game theory assumes that participants act rationally and have complete information about their own strategies and the strategies of others'. However, in reality, people may make decisions based on emotions, biases, and insufficient information. Also, game theory models can be simplistic and do not always adequately reflect the complexity of real-world situations, where the interaction between participants may be more complex and multi-layered.

Game theory has a wide range of applications in various fields, offering valuable tools for analyzing and optimizing interaction strategies between players. In economics and business, it helps to model market competition and determine optimal pricing strategies, as well as to analyze and design auctions. In politics and international relations, game theory is used to analyze the strategies of states in international conflicts and negotiations. In sociology and psychology, it helps to understand how and why people cooperate or act altruistically, and to analyze the behavior of groups and organizations. In ecology and common resource management, game theory is used to analyze the coordination of actions to avoid resource depletion and protect the environment. In computer science and cybersecurity, it helps to model attack and defense strategies and optimize resource allocation and traffic management in distributed systems. In financial markets, game theory is used to analyze investment strategies and the interactions between banks in the market.

Game theory is a powerful tool for analyzing interaction strategies between decision-makers. Basic concepts such as the Nash equilibrium help to understand how players choose their strategies in competitive and cooperative environments. Despite its limitations and assumptions, game theory has wide applications in a variety of fields, including economics, politics, and sociology, providing a valuable perspective for analyzing complex interactions.

2.4.4. Bayesian approach to decision-making

The Bayesian approach to decision-making is based on Bayes' theorem, which allows the probabilities of hypotheses to be updated with new data. The theorem is formulated as follows:

$$P(H | D) = \frac{P(D | H) * P(H)}{P(D)},$$

where $P(H|D)$ is the posterior probability of hypothesis H given the data D , $P(D|H)$ is the likelihood of the data D given the hypothesis H , $P(H)$ is a prior probability of hypothesis H , and $P(D)$ is the probability of the data D .

Thanks to Bayes' theorem, it is possible to adapt the probability of a hypothesis based on new observations, which is particularly useful under uncertainty and in the presence of incomplete information [14].

Bayesian updating. Bayesian updating is the process by which confidence in a hypothesis is updated as new data becomes available. In the context of decision-making, it allows strategies and actions to be adapted based on incoming information, making the approach more flexible and adaptive. For example, in medical diagnosis updating, it is the probability of disease based on new symptoms and test results, in financial forecasting, — adjusting investment strategies based on new market data.

Heuristics and cognitive distortions. Heuristics are simplified rules that people use to make decisions under conditions of uncertainty and limited information. These rules allow for quick decision-making but can lead to systematic errors or cognitive distortions. Cognitive distortions are deviations in thinking that occur due to the use of heuristics. Simplified rules or mental shortcuts help to make decisions quickly. For example, when buying a product, the “cheaper is better” rule is often used, which can lead to ignoring other important factors. The availability heuristic is the tendency to estimate the probability of an event based on how easily relevant examples come to mind. For example, following a news report about an airplane crash, people may overestimate the likelihood of airplane accidents. Representativeness heuristic is the tendency to judge the likelihood of an event based on its similarity to a prototype. For example, if a person looks and behaves like a scientist, we may erroneously assume that they have a degree, even though such people are a minority.

These examples demonstrate how theoretical approaches and practical methods can be integrated into complex and dynamic decision-making processes.

2.4.5. Decision-making technologies

Decision technologies include many tools and techniques to support informed and optimal decisions.

Big data analytics plays an important role in this field. Data mining techniques can be used to extract valuable information from huge amounts of data, which facilitates informed decisions. Predictive analytics uses statistical algorithms and machine learning techniques to predict future outcomes based on historical data, while real-time analytics provides immediate insights from streaming data, which is important for timely decision-making.

Decision Support Systems (DSS) represent another important technology. Executive Information Systems (EIS) provide senior managers with easy access to internal and external information needed for strategic decisions. Geographic Information Systems (GIS) analyze spatial and geographic data to support decision-making in such areas as urban planning and disaster management. Expert systems mimic human expertise, providing recommendations in specific domains.

Blockchain technology is also finding its way into decision-making. Smart contracts automate and protect decision-making processes through self-executing contracts with predefined conditions, and decentralized autonomous organizations (DAOs) use blockchain for decentralized decision-making and governance.

Modeling and simulation tools such as agent-based modeling and system dynamics allow simulating the interaction of autonomous agents and analyzing complex systems and their behavior over time. The Internet of Things (IoT) facilitates real-time decision-making by collecting and transmitting data from various sources using networked sensors, while Edge Computing processes data closer to the source, reducing latency, and increasing the speed of decision-making.

Natural Language Processing (NLP) helps to gauge public opinion and sentiment through sentiment analysis, while chatbots and virtual assistants provide decision support through conversational interfaces.

Robotic Process Automation (RPA) optimizes repetitive tasks and processes, improving efficiency and accuracy.

Cloud computing provides scalable, on-demand resources to process and analyze large amounts of data, and collaboration platforms enable real-time collaboration and data sharing to support collective decision-making. Together, these technologies significantly enhance the capabilities of situation centers, improving data processing, analysis, and decision-making across multiple domains.

One of the key decision-making technologies is artificial intelligence (AI) and machine learning (ML). AI algorithms help to improve decision-making by analyzing big data, identifying patterns, and making predictions. Machine learning models are trained on input data, allowing them to become more accurate and efficient over time, especially in predictive analytics and adaptive decision-making.

3. Machine learning and artificial intelligence

The application of machine learning and artificial intelligence has opened new horizons in various fields, including decision-making. These technologies provide powerful tools for analyzing data and automating processes, making them indispensable in today's world.

3.1. Machine learning

Machine learning includes various approaches and techniques for creating models that can predict outcomes based on data. One of these approaches is learning with a teacher.

3.1.1. Supervised learning

Supervised learning involves using labeled data to train the model. In this approach, the model receives input data and its corresponding correct answers (labels) and then learns to predict results for new, unseen data based on them. Let's take a closer look at some of the popular algorithms used in terms of this approach.

Logistic regression is used for binary classification problems where you need to predict the probability of an object belonging to one of two classes. For example, in medicine, logistic regression can help to predict whether a patient has a certain disease or not based on their symptoms and test results. The model learns from the labeled data, where each set of symptoms corresponds to one or another diagnosis, and then can make predictions for new patients.

Decision trees create models in the form of a tree structure, where each node represents a question about the value of an attribute (e.g., «What is the patient's temperature?») and each leaf represents a final prediction (e.g., «The patient has the flu»). This algorithm is particularly useful when a decision-making process needs to be explained, as the decision tree visualizes how the model arrives at its conclusion. In business, decision trees can be used to evaluate the creditworthiness of customers based on their financial history.

Random forests consist of multiple decision trees and use an ensemble method to improve the accuracy of predictions. Each tree in the forest is trained on a random subset of the data, and the final prediction is obtained by combining the predictions of all trees. This approach significantly improves the robustness of the model to errors and overtraining. For example, in agrotechnology, random forests can help predict crop yields based on weather, soil, and previous harvest data.

Neural networks mimic the workings of the human brain and can be used for complex tasks, such as image and speech recognition. They consist of many interconnected neurons that send signals to each other, adapting their weights based on input data. For example, neural networks can be used in automatic text translation systems, analyzing and translating sentences from

one language to another with a high degree of accuracy. In healthcare, they can help to diagnose diseases from medical images, detecting pathologies that may not be visible to the human eye.

3.1.2. Unsupervised learning

Unsupervised learning is used to analyze unlabeled data. Unlike supervised learning, where models are trained based on the input data and their corresponding correct answers, unsupervised learning focuses on identifying hidden structures or patterns in the data. This is particularly useful when the data has no explicit categories or when previously unknown patterns need to be discovered.

K-means clustering is one of the most popular methods of teacherless learning. This algorithm groups data into k clusters, where each cluster represents a set of data points that are similar in certain characteristics. The algorithm works iteratively, trying to minimize the intra-cluster distance between the data points and their centroids (the middle points of the cluster).

Hierarchical clustering creates a tree structure of clusters, where each level of the tree represents different levels of detail of the clusters. There are two main types of hierarchical clustering: agglomerative (bottom-up) and divisive (top-down). In agglomerative clustering, each object is first considered a separate cluster and the clusters are combined in pairs at each step. In divisive clustering, all objects start in one cluster, which is then divided into smaller clusters.

Dimensionality reduction algorithms are used to reduce the number of variables in data while preserving important information. This helps to simplify data analysis and visualization, especially when the data contains many variables.

Principal Component Analysis (PCA) method reduces the dimensionality of the data by transforming the original variables into a set of new variables (principal components) that maximize the explanation of the variation in the data.

T-SNE (t-distributed Stochastic Neighbor Embedding) method is used to visualize high-dimensional data in two- or three-dimensional space, preserving relationships between data points.

For example, in medical research, PCA can be used to analyze genomic data to identify the underlying components that explain variation in patients' genetic data. This helps in identifying genes associated with certain diseases [15].

3.1.3. Examples of machine learning applications

3.1.3.1. Learning with a teacher

In medicine, a system that helps doctors diagnose diseases based on medical data utilizes all the mentioned above machine learning algorithms. Logistic regression can be used for initial screening, determining the likelihood of having a certain disease based on a patient's underlying symptoms and medical history. Decision trees can help physicians understand which specific factors most strongly influence diagnosis, allowing for more informed decision-making. Random forests can combine data from different sources and create more accurate predictions, minimizing the risk of error. Neural networks can analyze medical images, detecting abnormalities that might have been missed in a routine examination.

In terms of military situation centers, a system that helps military situation center specialists make decisions based on a variety of real-time data can use machine learning algorithms for a variety of purposes. Logistic regression can be used to assess the likelihood of various threats, such as attacks or infiltration into protected areas. By analyzing data on enemy force movements, meteorological conditions and other factors, the system can provide operational staff with information on likely scenarios.

Decision trees can help commanders understand which factors affect the success or failure of a military operation most significantly. For example, factors, such as the availability of a par-

ticular type of weaponry to the enemy, logistical support, or terrain conditions, can be critical to planning operations. Random forests can be used to combine data from many different sources, such as intelligence information, satellite imagery, battlefield reports, and weather forecasts. This will create more accurate forecasts and recommendations, minimizing the risk of error and improving the quality of decisions.

Neural networks can analyze visual data, such as satellite or aerial imagery, to detect hidden objects or anomalies that would be missed by conventional analysis. Such systems can also process troop and equipment movement data, identifying patterns that indicate potential threats or offensive opportunities.

The use of machine learning in military situation centers can significantly improve decision-making by providing more accurate and timely information to commanders.

3.1.3.2. Learning without a teacher

• Commerce and medicine

In commerce, K-means clustering is used to segment customers into groups with similar buying habits. A company can use the data to develop targeted marketing strategies for each customer group, which increases advertising effectiveness and improves customer satisfaction.

As for bioinformatics, hierarchical clustering technique is used to group genes with similar expressions in genetic data. This allows scientists to identify gene groups that work together and better understand biological processes.

Talking about medical research, principal component analysis is used to analyze genomic data to identify the main components that explain variation in patients' genetic data. This helps in identifying genes associated with certain diseases.

• Military situation centers

Social Network Analysis is used to identify and analyze social structures through interactions and relationships between nodes. In military situation centers, it helps in identifying key figures and groups in social networks, which is important for strategy development and decision-making.

Time series analysis is used to analyze and predict changes in the operational environment, such as identifying patterns in the movement of enemy forces or predicting logistical requirements.

DBSCAN (Density-Based Spatial Clustering of Applications with Noise) method is used to identify and analyze geographically distributed data, such as the location of military installations or activities. It helps in identifying hidden patterns and anomalies, which helps in better planning of operations and resource allocation.

3.2. Artificial intelligence

Modern situation centers play an important role in crisis management, security, strategic planning, and decision-making. Artificial intelligence is being integrated into SOs to improve the efficiency, speed, and accuracy of data analysis and decision-making. Let's review the current state and key applications of AI in situation centers.

3.2.1. Current state of AI in situation centers

The current state of AI in situation centers is a complex and dynamic system in which different technologies and approaches are combined to create effective management and analysis tools. AI is actively used to process large amounts of data that come from multiple sources, such as sensors, surveillance cameras, social media, and other information channels. This data can be structured or unstructured, which requires advanced analytics techniques to extract useful information.

Automated data analysis is one of the key applications of AI in situation centers. AI algorithms can process and analyze vast amounts of data in real time, revealing hidden trends, anomalies and patterns that may be missed during manual analysis. This is especially important in crisis situations, where time is crucial. With AI, potential threats can be quickly identified, and the necessary steps can be taken to neutralize them.

Analyzing data from social media and other sources allows AI to identify trends, assess public opinion and predict possible social or political changes. This helps to develop information influence strategies and manage public sentiment.

Prediction and predictive models are another important application area of AI in situation centers. Using historical data and machine learning techniques, AI can build models that predict future events and scenarios. For example, in the case of natural disasters, such as floods or earthquakes, AI can predict their possible consequences and help to develop evacuation and rescue plans. In addition, AI is actively used to improve the quality and speed of decision-making. Modern situation centers often employ decision support systems (DSS) that integrate AI algorithms to analyze data and provide recommendations. These systems can use various analytical models to assess risks, predict consequences, and select optimal strategies. This provides decision-makers with informed and relevant data to develop effective action plans.

Modeling and simulation of complex systems are also among the key tasks of AI in situation centers. AI is used to create accurate models to simulate different scenarios and assess the possible consequences of different actions. This helps in selecting optimal strategies and making better-informed decisions.

Forecasting and predicting events also play an important role. Using machine learning techniques and time series analysis, AI can predict natural disasters, economic crises, or troop movements. This enables early response to threats and preventive measures, which significantly increases security and stability.

Optimizing resource planning and logistics is another area where AI shows its effectiveness. AI-based algorithms help minimize costs and increase the efficiency of operations, which is especially important when resources are limited and there is a need to react quickly to changing conditions.

Cybersecurity is an increasingly important application of AI. AI-based systems can detect and prevent cyberattacks by identifying anomalies in network traffic and recognizing new types of threats. This enables automated action to protect information systems and prevent potential damage.

Another application of AI in situation centers is the processing and analysis of visual data. AI algorithms can analyze images and video from surveillance cameras to identify suspicious objects or activities. This is especially important for security at large events or high-density locations. AI can also be used to automatically recognize faces and license plates of vehicles, which helps in investigations and crime prevention.

Pattern recognition and video analytics is another important application area of AI. Computer vision systems are used to analyze images and videos, including facial, object, and anomalous behavior recognition. This is particularly useful for security and monitoring real-time situations.

Robotics and autonomous systems are also finding their way into situation centers. Autonomous drones and ground robots equipped with AI perform reconnaissance, rescue, and other tasks in complex and dangerous environments, improving safety and efficiency of operations.

The integration of AI into situation centers also includes the use of deep learning and neural networks for data analysis and decision-making. Deep neural networks can be trained on large amounts of data to perform complex tasks, such as classification, object recognition, and event prediction. These technologies enable more accurate and robust models that can adapt to changing conditions and provide relevant data in real time.

3.2.2. Application of AI in military situation centers

The application of artificial intelligence in military SOs is of great importance and is driven by several key factors. In today's world, where conflicts are becoming increasingly complex and multi-layered, AI plays an important role in ensuring speed, accuracy, and efficiency in decision-making.

First, AI greatly improves the processing and analysis of big data. Military SOs collect information from various sources, such as satellite imagery, drone data, intelligence reports, and social media. The volume of this data can be overwhelming and manual processing takes too much time. AI can automatically analyze this data in real time, identifying key patterns and anomalies, which speeds up decision-making and improves accuracy.

Second, AI facilitates modeling and simulation of various scenarios. Military operations often require rapid response to changing conditions. With AI, accurate combat models and simulations of possible scenarios can be created, which helps commanders predict developments and make optimal decisions. This is especially important in uncertain and rapidly changing environments.

The third important aspect is prediction and forecasting. AI can analyze historical data and current events to predict possible threats and risks. For example, analyzing data on troop movements, weather conditions, and economic situations can help to predict the likelihood of conflicts or terrorist attacks. This allows early action to be taken to prevent threats and ensure security.

In addition, AI plays a key role in cybersecurity. Modern warfare often involves cyberattacks aimed at disabling the enemy's communication and information systems. AI systems can detect and prevent such attacks by analyzing network traffic and identifying anomalies. This helps to protect critical infrastructure and ensure continuity of operations.

Optimizing logistics and planning is also an important application area of AI. Military operations require efficient management of resources, such as fuel, ammunition, and food. AI algorithms can optimize supply routes, forecast requirements, and minimize costs. This is especially important when resources are limited and there is a need to react quickly to changes in the environment.

AI is also used to analyze data from social media and other open sources. It can identify public sentiment, predict social unrest, and assess the impact of information campaigns. In modern conflicts, information and public opinion play an important role, and the ability to analyze this data provides a significant advantage.

Finally, the use of autonomous systems and robotics greatly enhances the safety and effectiveness of military operations. Drones and robots equipped with AI can perform reconnaissance missions, engage in combat, and conduct rescue operations in dangerous environments, reducing risks to human personnel.

Thus, the application of machine learning and artificial intelligence not only improves decision-making, but also allows for achieving high results in various fields, making the world more efficient and safer.

3.2.3. Chatbots and virtual assistants

The need for chatbots and virtual assistants like ChatGPT in military situation centers is important and justified by several key factors.

Firstly, chatbots and virtual assistants can significantly improve agility and speed of decision-making. In a rapidly changing environment where time is of the essence, the ability to quickly receive and process information becomes critical. Virtual assistants like ChatGPT can provide prompt answers to questions, process requests in real time, and help military professionals quickly find the information they need. This allows SC commanders and operators to make informed decisions faster and more efficiently.

Secondly, such technologies can significantly improve information communication and coordination between different units and commands. Chatbots can integrate with various information systems and databases, providing a single interface to access necessary information. This facilitates data sharing, reduces errors, and improves coordination between different levels of command and task forces.

In addition, chatbots and virtual assistants can automate routine and repetitive tasks, freeing up time and resources for more complex and critical operations. For example, such systems can automate intelligence collection and processing, provide regular reports and updates, and follow standard procedures and protocols. This allows military professionals to focus on analyzing information and making strategic decisions, improving overall SO productivity and efficiency.

Virtual assistants like ChatGPT can also greatly enhance the education and training process. They can provide instant answers to questions, explain complex concepts and procedures, and run simulations of various scenarios for training. This can improve the training and readiness of staff to perform their tasks in a real-world environment.

What is more, such technologies can be useful for analyzing public opinion and information influence. They are able to analyze data from social networks and other sources, identify key trends and sentiments. These allow people to promptly respond to information challenges and form effective communication strategies. In the context of modern information wars and hybrid conflicts, it becomes especially relevant.

Another important aspect is cybersecurity support. Chatbots and virtual assistants can help to detect and respond to cyberattacks by analyzing log files and network traffic, identifying suspicious activity and recommending remediation measures. They can quickly provide information about current threats and help to make decisions to neutralize them, which increases the protection of information systems and critical infrastructure.

Chatbots integrated with cyber threat monitoring systems can provide actionable intelligence on cyberattacks and suspicious activity. They can send notifications about identified threats and offer recommendations on how to neutralize them.

Chatbots can analyze textual data, such as intercepted messages and open sources from the media or the Internet. They can provide regular reports and alerts to help commanders take preventive action [16].

The use of chatbots and virtual assistants like ChatGPT in military situation centers is dictated by the need to increase the speed and accuracy of decision-making, improve information interaction and coordination, automate routine tasks, improve personnel training, support cybersecurity, and analyze information flows. These technologies are becoming an important tool to improve the effectiveness and reliability of military operations in the face of today's challenges and threats.

The military can use chatbots to quickly access analytic data. For example, a commander can request information from a chatbot about the current situation on the battlefield, and the bot will provide a summary based on the latest data from UAVs and ground sensors. This allows for prompt decision-making and tactical adjustments.

Example of dialog with ChatGPT. In July 2024, we asked ChatGPT to give information about the current situation and military actions in Ukraine.

Question 1: "Find and analyze information about the current situation and military actions".

ChatGPT answer: 7 websites were searched.

The situation in Ukraine in July 2024 remains tense, with active military operations on several fronts. Russian forces continue to conduct offensive operations in the eastern regions of Ukraine, seeking to encircle Ukrainian forces and seize the entire Donetsk and Luhansk regions.

Russia's main efforts are concentrated in eastern Ukraine, in areas around Kharkiv and to the south, including Kherson and Zaporizhzhia (Reuters) (IISS).

Ukrainian forces continue to actively defend and conduct counter-offensive war operations, especially on the southern and eastern fronts, in an attempt to regain control of the lost territory. The fighting is accompanied by significant destruction of infrastructure and civilian casualties, exacerbating the humanitarian crisis in the region.

The international community continues to closely monitor the situation, providing Ukraine with support in the form of military aid and humanitarian assistance. At the same time, diplomatic efforts to resolve the conflict remain unsuccessful, as the parties continue to adhere to their positions and conditions for a ceasefire and peaceful settlement.

For a more detailed analysis of the current situation, a map of military operations and other relevant data can be found on the Reuters and IISS (Reuters) (IISS) websites (Fig. 1).

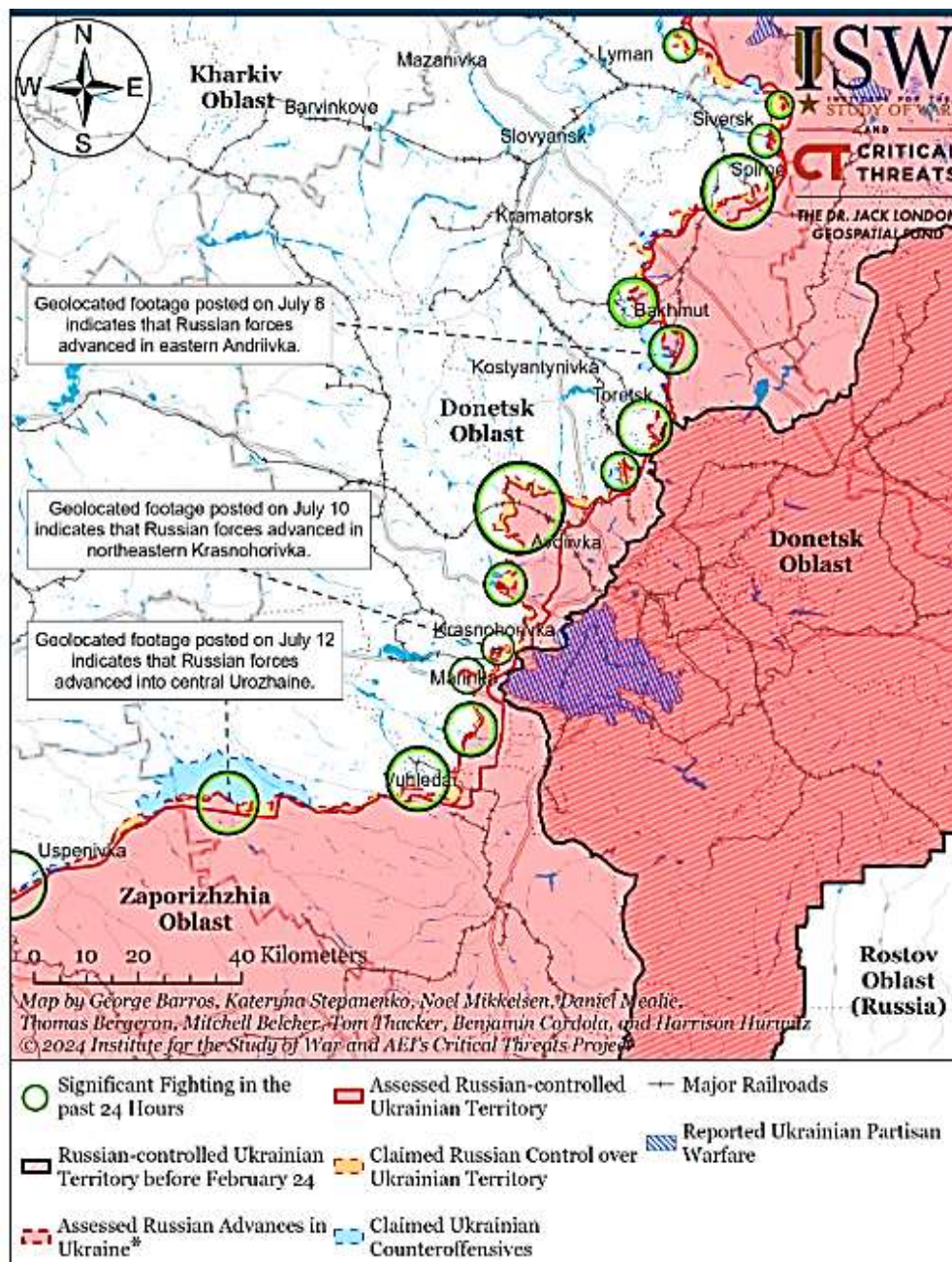


Figure 1 — Map of military operations in July 2024

Question 2: «Find and analyze information about the current situation and military actions in Ukraine in July 2024».

The answer is shown in Fig. 2 and Fig. 3.

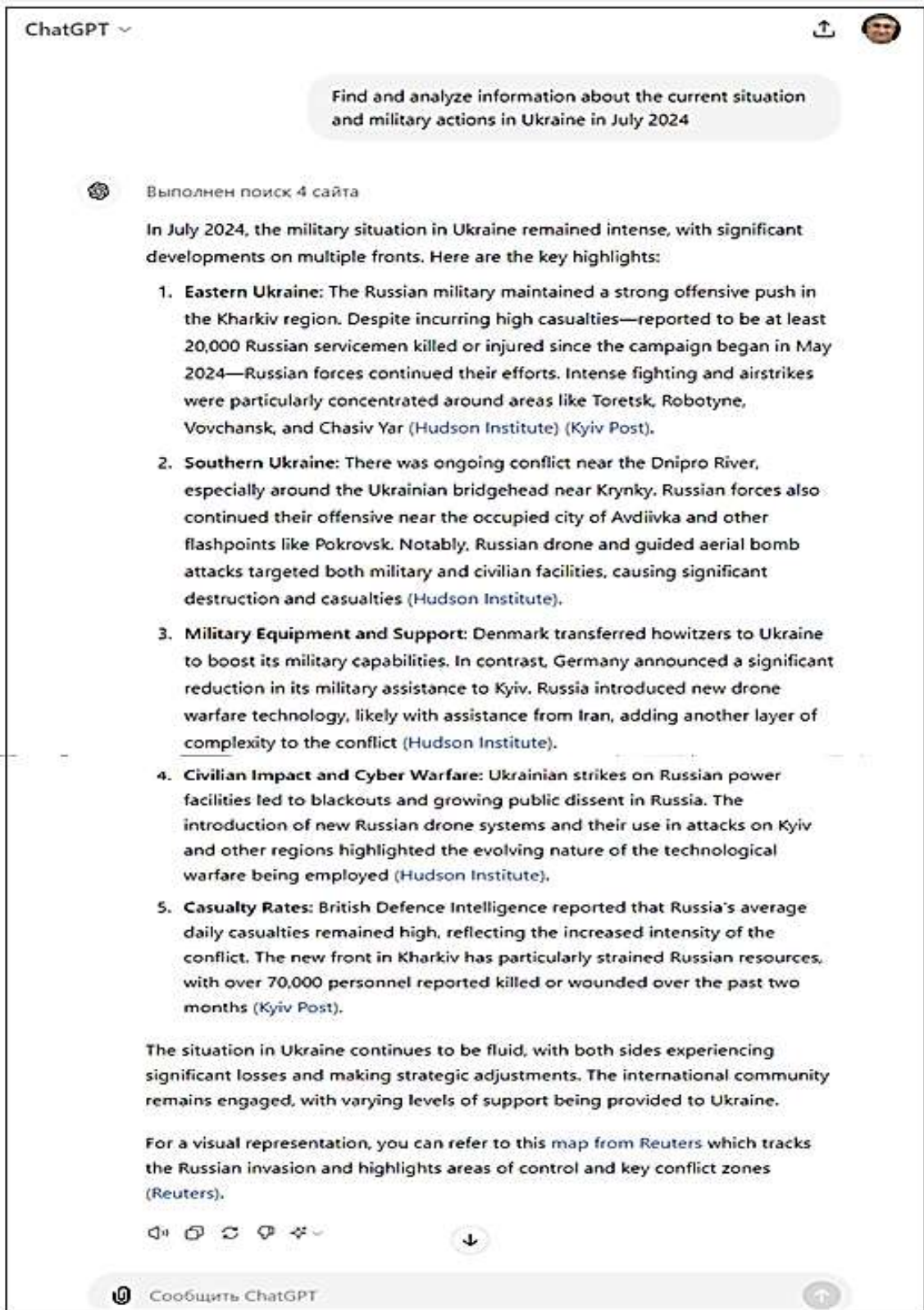


Figure 2 — Dialog with ChatGPT

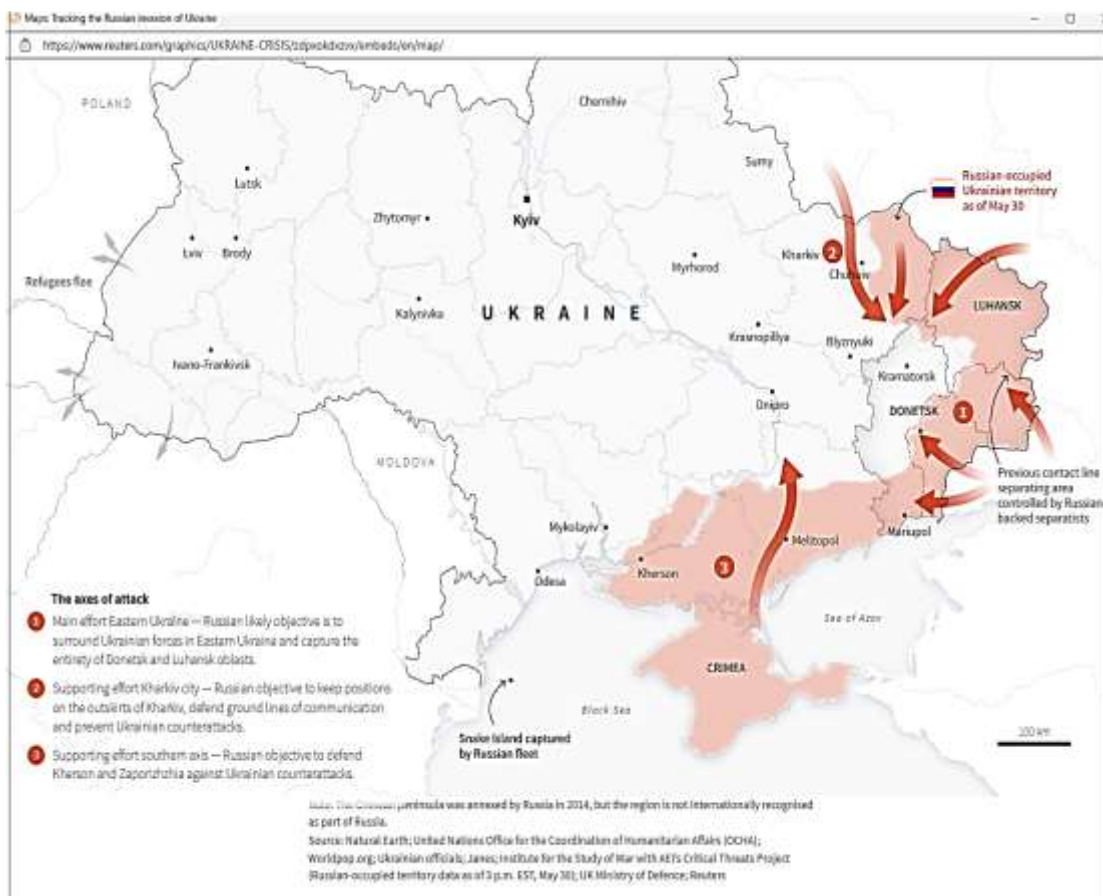


Figure 3 — Dialog with ChatGPT (map)

Challenges and issues. However, despite all the advantages, the application of AI in situation centers also faces a number of challenges and problems. One of them is the need to process and store huge amounts of data. Modern AI algorithms require significant computing resources and powerful servers for their operation. This creates additional demands on the infrastructure of situation centers and requires significant investments in equipment and technology.

Another important challenge is data security and privacy. Because the data and knowledge bases of existing AI systems and chatbots are concentrated on remote servers, their use for military purposes runs the risk of information leakage, loss of reliability and secrecy. AI systems process a large amount of information that must be protected from unauthorized access and cyberattacks. This requires the development of robust data protection methods and the implementation of strict security measures.

3.3. Ensuring data security and privacy in AI systems

In today's world, AI systems have become an integral part of various fields, including the military. These systems process huge amounts of data that need to be protected from unauthorized access and cyberattacks. However, existing security methods cannot always provide an adequate level of protection. Therefore, there is a need to develop new technologies and approaches to ensure data security and privacy in AI systems.

3.3.1. Security challenges in AI systems

Information leakage risk. AI systems often use remote servers to store and process data. This poses a potential risk of sensitive information leakage, especially in military applications, where data loss can have catastrophic consequences.

Cyberattacks. AI systems are an attractive target for cyberattacks such as DDoS attacks, supply chain attacks, and data attacks. Hackers can attempt to gain access to the systems and exploit their vulnerabilities to gain unauthorized access to information.

Data insecurity. Systems that depend on large amounts of data can become vulnerable if the data is corrupted or altered by attackers. This can lead to incorrect conclusions and decisions based on incorrect data.

Defense against inside threats. Not all threats come from the outside. Internal users with access to data can also pose a security threat by intentionally or accidentally compromising data confidentiality and integrity.

3.3.2. Methods for protecting data in AI systems

Data encryption. One of the most effective methods of data protection is encryption. The use of modern encryption algorithms can protect data both in transmission and at rest. However, the computational cost and possible slowdown of the system must be considered.

Data anonymization. Anonymization techniques that hide user identities can be used to protect sensitive information. This allows the data to be utilized without revealing personal information.

Multifactor authentication. Using this method to access AI systems increases security by requiring users to provide multiple factors to prove their identity.

Monitoring and anomaly detection. Regularly monitoring activity in the system and using machine learning algorithms to detect anomalies can help to detect and prevent cyberattacks at an early stage.

Data separation. Separating data and distributing it across different servers or network segments can reduce the risk of information leakage and make the system more resilient to attacks.

3.3.3. Fundamentally new technologies for data protection

Homomorphic encryption. This method allows you to perform computations on encrypted data without decrypting it. This provides a high level of security as the data remains protected throughout the processing.

Quantum encryption. Using the principles of quantum mechanics to encrypt data provides an unprecedented level of security. Quantum encryption is based on the use of quantum keys that cannot be copied or intercepted without changing the state of the system.

Blockchain technology. The use of blockchain technology to store and manage data ensures its immutability and transparency. Every change to the data is recorded in the blockchain, making it impossible to tamper with or make an unauthorized alteration of the data.

Federated learning. This method allows AI models to be trained on distributed data stored on users' devices without transferring the data itself to central servers. This reduces the risk of information leakage and ensures a high level of privacy.

Ensuring data security and privacy in AI systems requires a comprehensive approach and the application of various methods and technologies. Despite existing security measures, it is necessary to continue to develop and implement fundamentally new technologies that can cope with emerging threats and ensure reliable data protection. Only in this way will it be possible to utilize the potential of AI in various spheres without the risk of losing confidential information and security breaches.

3.4. Developing fundamentally new approaches to creating AI systems

Developing fundamentally new approaches to creating artificial intelligence systems, chatbots, and virtual assistants is necessary to overcome the existing limitations of machine learning and deep learning technologies for neural networks. Modern models, such as ChatGPT, demonstrate impressive results but face a number of serious drawbacks that limit their practical application and potential for further development.

One of the main drawbacks of modern technologies is the need to use extremely large volumes of training data. Models like ChatGPT are trained on billions of text data, which requires significant time and financial costs. GPT-4 was trained on ~13 trillion tokens, including text and code data. To train GPT-4, huge volumes of text data were collected from various sources, such as web pages, books, articles, etc. This stage can take months or even years. Collecting and pre-processing such volumes of data often becomes a difficult task, especially when it comes to specialized or highly specialized areas of knowledge. In addition, the reliance on big data creates a data quality problem: models can inherit and amplify biases and errors present in the original data, leading to unpredictable and undesirable results. Another significant problem is the long training time for models. The process of training modern neural networks requires a huge amount of computing resources and time. GPT-4 was trained on powerful graphics processing units (GPUs) and specialized accelerators. The training time depends on the computing power and the model size. It usually takes from several weeks to several months, which significantly slows down the innovation process and makes it difficult to quickly iterate and improve. The high cost of such operations also limits the capabilities of many organizations and research groups, creating barriers to the widespread adoption and use of these technologies.

The need for powerful computing systems also poses a major challenge. Training and running modern models requires specialized servers and graphics processing units (GPUs), which leads to significant financial costs for the hardware and its maintenance. GPT-4 was trained on Microsoft Azure AI supercomputers. The energy consumption of such systems is also a concern, as it significantly increases the carbon footprint and negative impact on the environment. This makes existing approaches less sustainable and cost-effective in the long term. In this context, it becomes obvious that there is a need to develop new approaches to creating AI systems that could overcome these limitations. One promising direction is the creation of neural networks similar to the structures of the human brain. In particular, multidimensional, multi-connected receptor-effector neural-like growing networks are an interesting and potentially revolutionary concept. Such networks differ from traditional neural networks in that they do not require a fixed structure to be pre-defined and can adapt and change during the training process. This reduces the dependence on huge amounts of data, as the network can optimize its parameters and structure based on the incoming information. As a result, such networks can learn more efficiently and with fewer resources.

In addition, multidimensional, multi-connected networks have the ability to self-organize and self-regenerate, which makes them more resilient to damage and failure. Unlike traditional models, where the failure of a single node can greatly affect the overall performance, neural networks can reroute signals and restore their functionality without significant losses. This increases the reliability and resilience of such systems, making them more suitable for use in mission-critical applications.

The use of such approaches also opens up opportunities for creating more intelligent and context-aware systems. Neural networks can process information multidimensionally, which allows them to better understand contexts and nuances by comparing and analyzing data from different perspectives. This leads to more accurate and adequate responses and decisions, which is especially important for chatbots and virtual assistants that must interact with users in natural language. Another significant advantage of new approaches is the possibility of reducing energy costs. Multi-connected neural networks can be more energy efficient due to their adaptive struc-

ture and ability to optimize data processing. This not only reduces the cost of operating such systems but also reduces their impact on the environment, making them more sustainable and environmentally friendly.

In conclusion, the need to develop fundamentally new approaches to the development of AI systems is evident against the background of the existing limitations of machine learning and deep learning neural network technologies. Huge data volumes, long training times, high cost, and the need for powerful computing systems create significant barriers to further progress. At the same time, new approaches, such as multidimensional multi-link receptor-effector neural-like networks, offer many advantages, including adaptability, robustness, intelligence, and energy efficiency. These networks represent a promising area of development that could revolutionize the creation and use of artificial intelligence systems, chatbots, and virtual assistants.

4. Multidimensional, multi-connected, receptor-effector, associative neural-like growing network

The new technology is a new type of neural network called a multidimensional, multi-connected, multilevel, receptor-effector, actively associative neural-like growing network (mmren-GN). It functions in a similar way to the human brain and has a number of advantages over conventional neural networks [17].

Mmren-GN is multi-connected because its neural-like elements have many interneuronal connections, just like biological neurons. This allows for a high degree of connectivity and parallelism in information processing.

The network is multidimensional because it is capable of simultaneous processing of various types of information presented in different dimensions (e.g., video, sound, text, etc.). This makes it possible to integrate heterogeneous data and obtain a more complete picture of reality.

The growing network is multilevel because it processes information level by level as its complexity increases (e.g., letters, words, sentences, phrases, texts, etc.). In this case, there is an alternation of levels of analysis and synthesis, as well as compression of information at each level. This allows for storing an unlimited amount of information in the network and extracting semantic connections from it.

Mmren-GN is receptor-effector because it has a receptor (sensory) zone that perceives and processes information and an effector (motor) zone that produces signals to control the actuators. Such a structure allows the formation of unconditional and acquisition of conditioned reflexes, as well as adaptation to changing environmental conditions.

The system is actively associative because it processes information based on actively associative choice. This means that the network independently selects the most appropriate data for the task and the connections between them, and also forms new associations based on experience.

The network is growing because its structure is created and grows as information enters the system's perceiving mechanisms. This allows the network to dynamically expand its capabilities and take into account new facts.

Thus, the new technology imitates the work of the human brain at different levels and in different modalities. It has a high degree of self-organization and adaptation to changing conditions. It is capable of processing large amounts of information and storing it in a compact form. It can be used to solve complex problems in various fields of science and technology. It carries out perception, analysis, synthesis, memorization, associative search, classification, and generalization of information presented in different dimensions of a neural-like growing network simultaneously. This gives it a significant advantage over conventional neural networks that work with homogeneous information, have a fixed structure and require large training samples, long training epochs, and powerful computing resources.

Mmren-GN represents a significant expansion of the capabilities of neural networks, in particular, due to the integration of many principles of operation similar to the operation of neural networks in the biological brain.

4.1. Comparison with existing technologies

Converged Neural Networks (CNNs) are often used for image and video processing, but they operate predominantly in a two-dimensional space and do not process different types of data simultaneously. Mmren-GNs, on the other hand, process information in a multidimensional space, which allows it to efficiently adapt to different types of input data, such as video, audio, text, etc.

Recurrent Neural Networks (RNN) are applied to process sequential data, such as text and speech. However, they may face the problem of vanishing gradients when processing long sequences. Mmren-GNs will be able to process such data more efficiently due to their multilayer structure and ability to handle different levels of analysis and synthesis.

Long Short-Term Memory (LSTM) recurrent networks are designed to process sequential data with long-term dependencies. They have memory management mechanisms to retain information over long sequences. Mmren-GN is also capable of storing and associating information at different levels, allowing it to process and memorize complex relationships in data.

Deep Neural Networks (DNNs) are widely used in machine learning for classification and data processing. They have multiple layers and are trained on large amounts of data. Mmren-GNs are also multilayer, but their structure allows them to adapt more flexibly to changing conditions and process a variety of information types simultaneously.

To sum up, compared to traditional neural networks, mmren-GN has a larger number of interneuron connections, which enhances information processing and contributes to the multiplication of system capabilities. Due to its multidimensional nature, mmren-GN is capable of simultaneous processing of different types of information, such as video, sound, and text, including their interactive and interconnected processing.

The multilevel structure of the mmren-GN allows information to be processed at different levels of complexity, interacting with it in different ways. This allows the network to perform deeper analysis and synthesis of information, as well as provide the ability to store a large amount of data.

The realization of the receptor-effector zone in the structure of mmren-GN allows for the ability to perceive and process information, as well as to control executive mechanisms in accordance with the received signals. It allows for creating conditional reflexes and forming complex associations.

The peculiarity of mmren-GN is its actively associative nature, based on the selection of relevant information during processing. This makes the system capable of learning and associating different elements of information.

Mmren-GN is an innovative technology that integrates many principles of the biological brain to process information. Its multilevel, multidimensional and receptor-effector structure allows it to process different types of data, make associations, and store information over time.

Compared to existing technologies, mmren-GN offers new possibilities for processing and analyzing information. It is capable of handling different types of data, integrating them in an interconnected manner, which increases the efficiency of the network and extends its functionality.

4.2. Integration of mmren-GN into situational centers

Integration of mmren-GN into situational centers can lead to significant improvements in their functioning and efficiency. Let's consider the main advantages of this integration.

Adaptability and flexibility. Mmren-GN has a unique ability to adapt to changing conditions and learn on the fly, changing its structure during operation. In situational centers, where information is constantly updated and a quick response to changes is required, such adaptability allows for more efficient data processing and decision-making. This ensures high flexibility of the system, which can quickly adapt to new tasks and conditions.

Stability and reliability. Due to the ability to self-regenerate and redirect signals, mmren-GN demonstrate high resistance to failure and damage. In situational centers, where continuity and reliability of operation are important, such networks can significantly reduce the risk of failures and data loss. This is especially important in critical situations, where every moment counts and mistakes can have serious consequences.

Energy efficiency. Mmren-GN can be more energy-efficient than traditional neural networks. In situation centers, which often operate around the clock and process huge amounts of data, reducing energy consumption is of great importance. This reduces not only operating costs but also the environmental impact, making the operation of the centers more sustainable and environmentally friendly.

Improved data processing. Mmren-GN can process information multidimensionally, which allows for deeper data analysis and consideration of various contexts. In situation centers, where complex and multidimensional data analysis is required to make informed decisions, such networks can provide more accurate and relevant results. This contributes to improved decision quality and more effective situation management.

Intelligent capabilities. Neural networks can imitate cognitive processes similar to human thinking. This allows them to better understand contexts and nuances, make predictions, and offer solutions that may not be obvious to traditional systems. In situational centers, where it is important to consider many factors and make decisions quickly, such intelligent capabilities can significantly improve the efficiency and accuracy of work.

Reduced dependence on big data. Mmren-GN can learn and adapt to smaller amounts of data due to its ability to self-optimize. In situational centers, where it is often necessary to work with incomplete or rapidly changing data, this advantage allows it to function effectively even with limited information. It also reduces the costs of collecting and storing data, making the system more cost-effective.

Scalability and modularity. Mmren-GN can be easily scaled and modified depending on the needs of the situational center. This allows the capacity and functionality of the system to be increased as needed without losing efficiency. This modularity makes the system more flexible and allows for rapid adaptation to new tasks and challenges.

Improved security and data protection. Due to its multi-connected structure and self-organizing ability, mmren-GN can provide higher security and data protection. In situational centers, where information security is of paramount importance, such networks can offer more reliable mechanisms for protection against hacking and data leaks. This is especially important in conditions of increased requirements for confidentiality and information protection.

Reduced operating costs. Due to its energy efficiency and adaptability, mmren-GN can reduce the overall operating costs of situational centers. This includes both direct costs for electricity and equipment and indirect costs associated with system support and maintenance. Higher network reliability and stability also reduce the costs of troubleshooting and restoring system operation.

Real-time operation. The ability to perceive, remember, analyze, and learn in real time is especially important for military situational centers, where efficiency and accuracy are the key factors. Mmren-GN are capable of continuous receiving and analyzing incoming information, storing important data and adapting their models based on changing conditions in real time. This allows the centers to instantly respond to new threats, adjust strategic plans, and improve operational management based on relevant data. The ability to learn in real time also increases the sys-

tem's resilience to new types of threats and enemy adaptation, which is critical in dynamically changing combat conditions.

All in all, the integration of such growing networks into situational centers can lead to significant improvements in their operation. Adaptability, resilience, energy efficiency, improved data processing, intelligence, reduced dependence on big data, scalability, improved security, reduced operating costs, and the ability to learn in real time make such networks a promising choice for modernizing and optimizing the operation of situational centers, especially in the military sphere, where the speed and accuracy of decisions are crucial.

In general, mmren-GN opens up new paths in the field of intelligent systems and its level of capabilities significantly exceeds existing technologies, providing new opportunities for processing, analyzing and classifying information in various dimensions. In order to fully confirm the effectiveness and potential of this technology, it is necessary to create a prototype of an intelligent system (artificial brain) similar to a biological brain based on the results of preliminary modeling.

4.3. Prototyping of mmren-GN for the use in SCs

Prototyping of mmren-GN is a complex and multi-stage process that includes the development, testing and optimization of this technology for use in SC. This process can be divided into several key stages that will ensure the successful creation and implementation of the prototype.

4.3.1. Theoretical research and practical modeling

At the initial stage, an in-depth study of existing neural-like networks and machine learning methods is carried out. The main focus is on the analysis of biological analogs, such as the structure and functions of neural networks in the brain. At this stage, theoretical models of mmren-GN are developed that describe the principles of their operation, including:

- multidimensionality — the ability of the network to process data in several dimensions simultaneously;
- multi-connectivity — a high degree of interconnection between network elements, ensuring stability and flexibility;
- receptor-effector mechanisms — the use of specialized nodes for receiving and transmitting signals similar to the sensory and motor functions of the brain.

4.3.2. Prototype architecture development

After theoretical modeling, the prototype architecture is developed. At this stage, a structural diagram of the mmren-GN is created, defining the main components and their interactions. The architecture includes:

- neural nodes — basic elements of the network that perform computational functions;
- connections between nodes — defining rules and algorithms for forming and changing connections during the learning and adaptation process;
- learning mechanisms — developing algorithms that allow the network to self-learn and adapt to new data in real time.

4.3.3. Software implementation and simulation

The next step is the software implementation of the mmren-GN architecture. Simulation models are created that allow for testing various aspects of the network in a virtual environment. Software implementation includes:

- algorithm development — coding the main functions and algorithms of the network in high-level programming languages;

- environment simulation — using specialized programs to model and test the network in conditions close to real ones;
- testing and debugging — conducting a series of experiments to identify and eliminate errors in the software implementation.

4.3.4. Testing and optimization

The testing stage involves a comprehensive check of the mmren-GN prototype. Testing includes:

- functional tests — checking the correctness of the main network functions;
- load tests — assessing network performance under various loads;
- adaptive tests — checking the network's ability to adapt to changing conditions and new data.

Based on the test results, optimization is performed. It includes:

- algorithm improvement — modifying algorithms to improve their efficiency and stability;
- link optimization — adjusting network parameters to improve its adaptive capabilities;
- increasing energy efficiency — developing methods to reduce energy consumption without losing performance.

4.3.5. Validation and real-world application

After successful testing and optimization, the mmren-GN prototype undergoes a validation stage, which includes checking for compliance with requirements and assessing its practical applicability. These stages include:

- pilot projects — implementing the prototype on a limited scale to evaluate its operation in real-world conditions;
- comparative analysis — comparing the prototype's performance with existing technologies to determine its advantages and disadvantages;
- adjustment and revision — making the necessary changes based on the results of pilot projects and comparative analysis.

4.3.6. Integration into situational centers

The final stage is the integration of the mmren-GN prototype into the situational center infrastructure. It includes:

- technical integration — configuring the prototype to work with existing systems and situational center data;
- staff training — conducting training for situational center employees on how to work with the new system;
- monitoring and support — creating a monitoring system to evaluate the mmren-RS operation and providing technical support.

4.3.7. Future development and research

After successful integration, ongoing research and development of the technology continues. This includes:

- results analysis — collecting and analyzing data on the operation of mmren-GN in real conditions for further improvement;
- exploring new possibilities — studying the potential of mmren-GN for application in other areas and tasks;
- developing methods for scaling the technology to larger and more complex systems.

Prototyping of mmren-GN is a multistep process that requires an integrated approach and interdisciplinary collaboration. Successful creation and implementation of this technology promises significant improvements in the fields of intelligent systems and national security.

Steps 4.3.1 and 4.3.2 have been completed to date.

5. Conclusions

In modern conditions, situational awareness centers play a crucial role in ensuring the elimination of natural disasters, crises, and threats. The most important function of state and military situational awareness centers is to protect national security, especially in military conflicts. These centers are central elements in the decision-making system, providing timely, accurate, and detailed information. Their ability to coordinate actions and promptly respond to threats is critical to protecting the country and its citizens.

This article highlights the key aspects of the architecture and components of situational awareness centers, data collection and processing technologies, as well as the role of machine learning and artificial intelligence in decision support systems. Particular attention is paid to the current state of AI in situational awareness centers, including the use of chatbots and virtual assistants in the military sphere, as well as the development of innovative approaches to creating AI systems.

One of the most promising technologies presented in the article is a multi-connected, multidimensional, receptor-effector associative neural-like growing network. This technology demonstrates significant superiority over existing AI methods, offering unique capabilities for adaptation, self-organization, and efficient processing of information in real time. The implementation of mmren-GN in situational centers is a revolutionary step forward, providing increased flexibility, reliability, and energy efficiency of systems. The ability of these networks to continuously learn and adapt significantly improves the quality and speed of decision-making, which is critical in the context of dynamically changing information and the need to quickly respond to threats. A comparative analysis of mmren-GN with existing technologies emphasized their superiority in the field of intelligent systems. Theoretical research, practical modeling, and development of the mmren-GN architecture open new horizons in the creation of intelligent systems similar to biological brains. The integration of mmren-GN into situational centers promises a significant technological breakthrough, making these centers more adaptive, resilient, and effective in ensuring national security and solving other critical tasks.

REFERENCES

1. Морозов А.А., Ященко В.А. Ситуационные центры — информационные технологии будущего. Киев: СП «Интертехнодрук», 2008. 332 с.
2. NORAD Agreement. URL: <https://www.norad.mil/About-NORAD/NORAD-Agreement/>.
3. Starovoytov V.G. Situation center as an effective mechanism in the management system. *National Security*. 2021. N 5. P. 22–29.
4. Evdokimov D.S. Strategic development of management systems of modern situational centers. *Strategizing: theory and practice*. 2021. Vol. 1, N 1. P. 89–97.
5. Command centre: a place for decision-making. URL: <https://motilde.com/en/command-center-place-for-decision-making/>.
6. Data Center | DPC and Energy. URL: <https://ca.itglobal.com/glossary/data-center/>.
7. Introduction to Geographic Information Systems (GIS). URL: <https://medium.com/@sakyathilakarathne96/introduction-to-geographic-information-systems-gis-a-comprehensive-overview-ea67c41af64b>.
8. Что такое конкурентная разведка: методы, этапы, основные источники информации. URL: <https://spectrumdata.ru/blog/proverka-soiskatelya/chto-takoe-konkurentnaya-razvedka-metody-etapy-osnovnye-istochniki-informatsii/>.

9. Морозов А.О., Косолапов В.Л., Колосов В.Є. та ін. Підтримка прийняття рішень із використанням прогнозно-аналітичних технологій. *Наука, технології, інновації*. 2002. № 2. С. 41–52.
10. Intelligent Decision Support Systems — An Analysis of Machine Learning and Multicriteria Decision-Making Methods. URL: <https://www.mdpi.com/2076-3417/13/22/12426>.
11. Classical decision-making model. URL: <https://study.com/academy/lesson/classical-decision-making-model.html>.
12. Classical decision-making. URL: <https://rvcc.pressbooks.pub/principlesofmanagement/chapter/5-3-classical-decision-making/>.
13. Game Theory: The Mathematics of Strategy and Decision-Making. URL: <https://medium.com/@enriqueavila.finance/game-theory-the-mathematics-of-strategy-and-decision-making-part-i-09f1b08f5a0d>.
14. Bayesian Decision Theory Explained. URL: <https://blog.paperspace.com/bayesian-decision-theory/>.
15. Machine learning. URL: https://en.wikipedia.org/wiki/Machine_learning.
16. AI Chatbot vs AI Virtual Assistant: What's the Difference? URL: <https://www.upwork.com/resources/ai-chatbot-vs-virtual-assistant>.
17. Яценко В.А. Искусственный интеллект. Теория. Моделирование. Применение. К.: Логос, 2013. 289 с.

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