МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ХЕРСОНСЬКИЙ НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ

ПРОБЛЕМИ ІНФОРМАЦІЙНИХ ТЕХНОЛОГІЙ

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РЕДАКЦІЙНА КОЛЕГІЯ

ЗМІСТ

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DEVELOPMENT OF VOICE INFORMATION FORMALIZATION IN MOTOR TRANSPORT DISPATCHING CONTROL SYSTEMS

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Abstract. Today, in the processes of delivery and distribution management, a large number of different information technologies are used, including the motor transport dispatching control systems. Voice interaction processes play an important role in delivery processes and distribution management, which are being actively automated to improve efficiency, save resources, etc. At the present stage of automation of voice control in organizational and technical systems, there is a problem of timely adjustment, if necessary, of planned routes of motor transport, which is sometimes time-consuming, and accordingly is the most grounded direction of voice interaction automation. In spite of the intensive development of motor transport dispatching control systems when interacting with the driver, it is the voice information that requires formalization in the case of automation of such systems. However, existing tools in the field of voice information formalization are not yet adapted for the analysis of the speech of drivers in order to improve and facilitate their interaction with the dispatching system, which urges the topic of developing the means of formalizing voice information in motor transport dispatching control systems. The objective of the paper is to develop a means for formalizing voice information in motor transport dispatching control systems. Research methods. The research is based on the main provisions of information theory, theory of non-force interaction and software for the development of means of voice information formalization. Research findings. The developed means of voice information formalization in motor transport dispatching control systems allows the driver to not distract from driving and monitor road conditions and situation that can accelerate the delivery of products in the process of distribution, as well as increase security level. The considered peculiarities of the use of the developed means of voice information formalization in motor transport dispatching control systems showed that the driver of the motor vehicle, who will deliver the products in the process of distribution, and will face for the first time a means of voice information formalization operating within the motor transport dispatching control system, should pre-check and, if necessary, "learn" the system to recognize his voice commands from relevant contexts. Scientific novelty. The means of voice information formalization in motor transport dispatching control systems which allows the driver to not distract from driving and monitor road conditions and situation that, in contrast to existing ones, can accelerate the delivery of products in the process of distribution, as well as increase security level was further developed. Practical significance. The developed means of voice information formalization of in motor transport dispatching control systems allow increasing the efficiency of management of the distribution process.

Key words: *means of formalization, voice information, motor transport dispatch control system, distribution process.*

Problem statement. Today, in the process of delivery, a wide range of information technologies such as RFID [1], GPS [1, 2] and GSM [1] trackers, the IoT [3] and "big data" [4] principles are used in the application of dispatch control systems for motor vehicles, applications on smartphones [2], web-system for managing the supply chain [5], and others are used in the motor transport dispatching control systems.

Information technology in distribution management in the application of motor transport dispatching control systems has already been adequately developed to provide the stages of receiving products and their safekeeping, therefore, the stage of delivery of products to end customers is being actively developed. In particular, systems for automation of building planned routes for motor transport [6], TMS (transport management) systems and real-time delivery monitoring are being developed.

Voice interaction processes play an important role in distribution management, which are now actively automated to improve efficiency, save resources, etc. Voice interaction is divided into direct and with the use of information technology. Information technology in this context can serve only as a means of communication, which can produce an effect itself, but the best result can be obtained through automation of voice interaction.

The voice information formalization in motor transport dispatching control systems is associated with information technologies in distribution management and is, to a large extent, designed to provide stages of product receipt and its safekeeping, but there is a problem with the stage of product delivery to end customers, especially as regards to the so called "last mile", which is one of the most expensive and complicated in the organization of distribution. During delivery, there are always some deviations from the plan, no matter how optimal it was, such deviations in each case require adjustments to the plan through communication with the dispatch operator. Drivers-freight forwarders and couriers are more likely to start delivering over and above the plan if communication with the dispatch operator and plan adjustment are not simple and effective. For a distribution problem, it can be difficult to provide permanent access to the Internet, since delivery can occur to places/regions where even mobile GPRS Internet is not available or it has too low data transmission rates for work with sound.

Significant role in distribution management is played by the voice interaction processes, whose automation can improve the efficiency of the distribution system.

At the present stage of voice control automation in organizational and technical systems, there is a problem of timely adjustment, if necessary, of planned routes of motor transport, which can be time-consuming, and accordingly is the most grounded direction of voice interaction automation.

Voice interaction automation for timely adjustment of the routes planned for motor transport should complement existing management automation tools in distribution systems, such as real-time vehicle tracking using a GPS track. The voice interaction automation system for storage management existing in the distribution is too simplified for use in delivery problems.

In spite of the intensive development of motor transport dispatching control systems when interacting with the driver, it is voice information that requires formalization in case of automation of such systems. However, existing tools in the field of voice information formalization are not yet adapted to the analysis of the speech of drivers, in order to improve and facilitate their interaction with the dispatching system.

The means of voice interaction formalization in distribution systems are not adequately developed. All this urges the topic of developing the means of voice information formalization in the systems of motor transport dispatching control.

Analysis of recent research and publications. Voice control already has a certain history of use in the transport sector. The leading automotive companies in the world, such as Ford Motor Company, BMW AG, Daimler AG, aim to increase driver's safety and comfort, thus creating the ability to control on-board electronics by voice [7]. The first such system, called Linguatronic, was presented by the engineers of Mercedes in the S-Class car in 1996 [8]. It implemented the voice control functions of the built-in phone and directory, radio and CD player, as well as air conditioning. Fiat, working jointly with Microsoft, developed a system with the driver-initiated Blue&Me system, in which it was necessary to press the button on the steering wheel before the start of the voice command. The BMW engineers have also developed a driver-initiated system

that was integrated with their iDrive on-board control system. Honda, using the IBM ViaVoice speech recognition system, provided the opportunity of GPS navigation control for voice indication of the destination [9].

In addition, provided a sufficiently powerful system, voice interaction with the driver can be used to maintain dialogue while driving at night in order not to let the driver fall asleep [10].

Studies were also conducted on the development of airborne equipment voice control systems, but due to high requirements for the speed and quality of recognition, especially in the conditions of powerful noise and interference, they have not yet been introduced [11].

The use of such partial voice control functions, which enhance the driver's comfort, should also have some positive effect. However, these functions do not provide optimization of the distribution processes.

In modern systems of automation of distribution, delivery and management of a vehicle fleet, the process of automation of building planned routes of motor transport is well developed [6]. It includes the components of the topology, the time parameters of the delivery point (time windows of availability and time required to service the point), the load of the motor vehicle, the number of available vehicles, etc. However, the communication for timely adjustment of the route in cases where the actual state of affairs does not match the planned route anymore is time-consuming. If these functions were implemented through automated voice interaction, this would have the maximum effect for improving distribution management.

To manage the delivery of cargoes in distribution, the stage of real-time monitoring the route of motor transport is extremely important. This allows analyzing the driver's performance, as well as predicting certain objectionable incidents.

GPS data of the vehicle route are used for such monitoring [12, 13].

Unfortunately, a GPS track alone is not enough for a clear understanding of the state of affairs. The track only shows that the driver was near the delivery point, but it is not clear whether the delivery has been performed or has been canceled for some reason. It is clear from the track that at the current speed the driver lags behind the plan and will not be in time for the next point, but the reason for the lag and whether the driver will be able to make up for the lost time is not clear. To obtain this information, additional communication between the driver and the dispatch operator is required. But the phone call or, even worse, the communication through a certain visual interface on the smartphone takes some time and reduces the concentration of the driver's attention on the road, which can cause an accident.

Therefore, it is necessary to have a system which would allow revealing the necessary information in the driver's voice data and sending it to the dispatch operator in a formalized form.

The most similar to the above-mentioned system is Pick-by-Voice [14]. This is a system used in another area of distribution management – management of warehouse processes. Pick-by-Voice allows the sorter to receive voice commands in turn in the following form: where, what and in what amount to be sorted, as well as in the form of a dialogue to report the need to repeat the task or go to the next, and so on. This system allows freeing sorter's hands and eyes and, in general, increases his efficiency by 35% [15].

Unfortunately, transport deliveries management requires a more complex system than the existing Pick-by-Voice capabilities, since it should have a significantly larger range of commands needed for recognition. In advanced urban freight distribution systems, time delivery windows are an important parameter [16, 17]. This parameter immediately introduces a whole range of additional information to be transmitted from the driver to the dispatch operator - how timely the delivery was made, how much time was spent on each of them, lagging behind the plan because of traffic jams or other unforeseen circumstances, etc. Moreover, the system should provide real-time interaction with the dispatch operator, and not to reproduce a predetermined list of tasks.

Thus, the obvious task is to develop a means for formalizing voice interaction between the driver and the dispatch operator to obtain the necessary information from the driver in a voice form and to automate distribution management.

In the works [18, 19, 20] the model of voice interaction of the driver in systems of motor transport dispatching control and the formalization of voice information with comparison of efficiency of two methods of voice interaction formalization is offered.

The objective of the study. On the basis of previous studies [18, 19, 20], it is necessary to develop means of formalizing voice information in the systems of motor transport dispatching control.

Research findings. In order to use the developed models, a mobile application for the Android platform was created, since it is more widespread, and the cost of smartphones on this platform is lower, which is important to reduce the cost of system implementation.

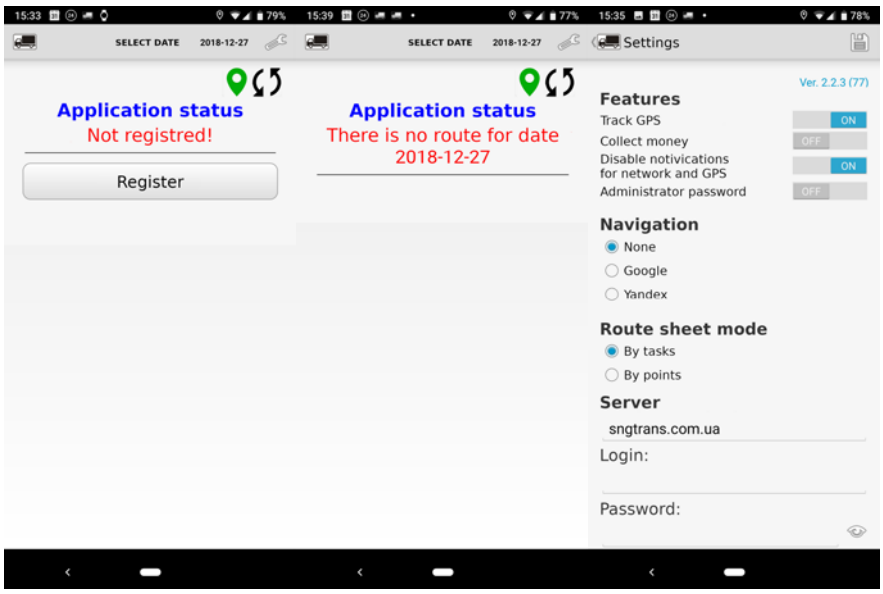
The application is available free of charge in the Google Play store and can be installed by any driver on his own Android smartphone. The application is called Plannary Last Mile.

Since the main way of managing an application is voice commands, the visual interface of the application is simple enough. In general, the interface consists of a settings window (Fig. 1, c), the window with general information about the route (Figure 2), driving directions (Figure 3), route map (Fig. 4, b and c) and the window with the information about the point (Fig. 4, a).

To successfully use the application, it must be registered on the system. The interface for the unregistered device is shown in Fig. 1, a. Self-registration by the driver is impossible, the system administrator shall register the application and the device in the motor transport dispatching control system. Upon registration, the login and password shall be entered in the settings window (Figure 1, c). In case of successful registration, the application will go to the general route information interface (Figure 2), or, if the route to the selected date does not exist, will report it (Fig. 1, b).

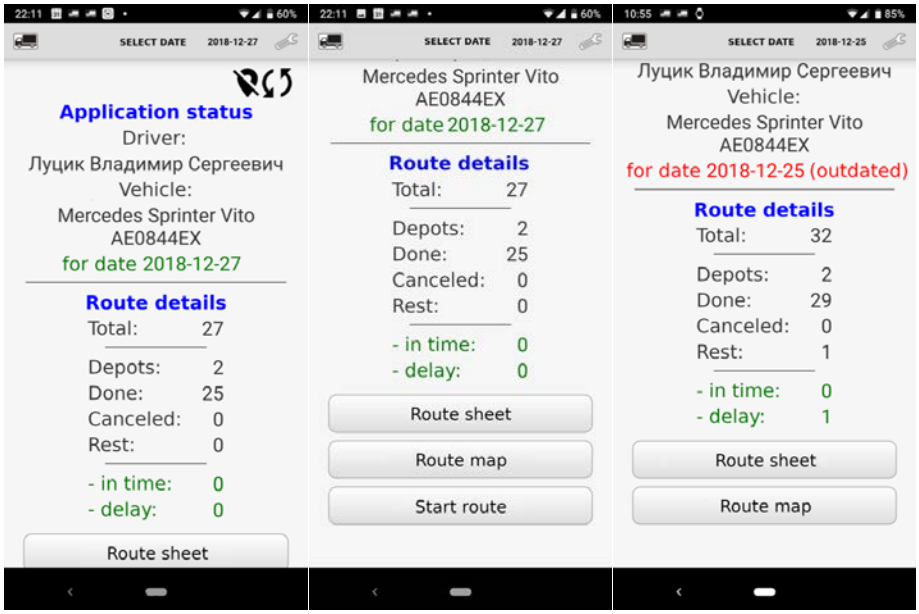
In addition to entering the login and password for registration in the system, the administrator can also set the administrator password to prevent the driver's access to the settings of the application. The main purpose of this function is to prevent the driver from interfering with the work of important components of the system, such as collecting GPS data.

The general view of the route information interface is shown in Fig. 2. This window shows the information such as the full name of the forwarding driver, the model and the vehicle identification number, the date of issue of the delivery route, etc. This window also shows the current and final number of delivery points by different categories, such as: total number of points in the route, number of arrivals to the warehouse, current number of successfully and unsuccessfully completed points, number of points to be completed and predicted values on how many of them the driver has time to complete on time, and to how many of them he is late (provided normal transport conditions).



а *б* *в*

Figure 1 – Application interface for unregistered device (a), for case when there is no route for the selected date (b) and the settings window (c)



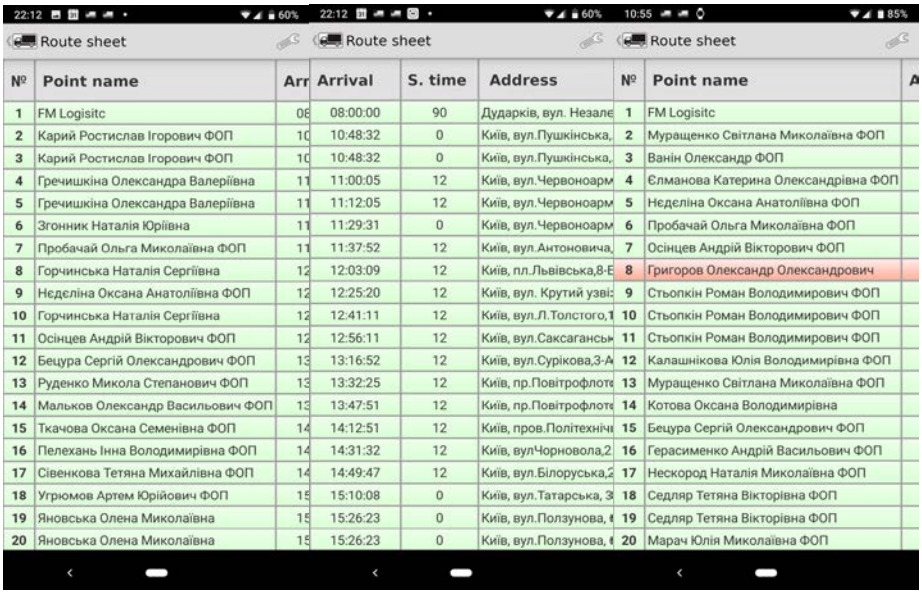
а *б* *в*

Figure 2 – Interface of general information about the route (a, b), including with the mark of uncompleted points (c)

Driving directions window is shown in Figure 3. This interface contains a table of delivery points in the required order of their completion. The table contains the following information about the points: the name of the point or contact name, address, estimated time of arrival and the estimated time of point service.

The rows of the table are highlighted with different colours depending on the different point status such as: warehouse, the point is successfully completed, the point is marked as not completed or cancelled, the point is scheduled for completion and the forecast shows the risk of being late to the point.

Clicking on any point of delivery, or when giving appropriate voice command, the window with the information about the point is displayed (Figure 4, a).



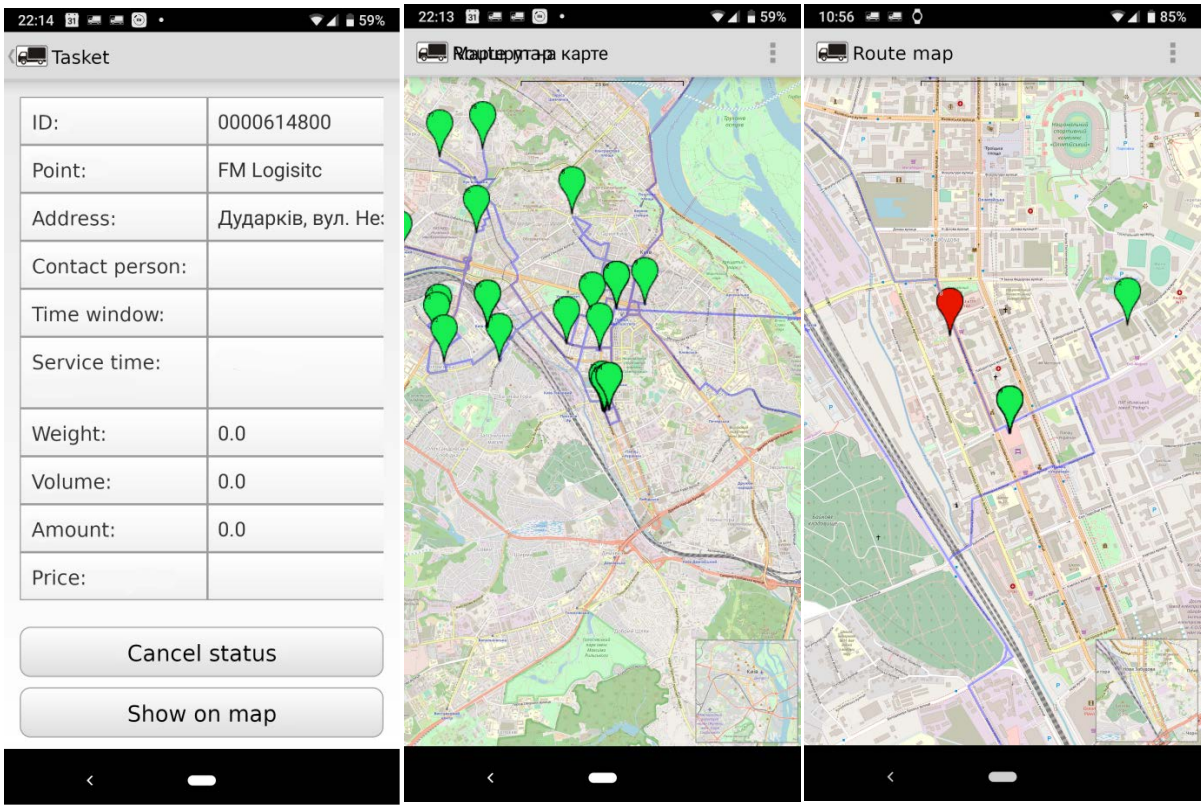
а *б* *в*

Figure 3 –Interface of the window of the driving directions (a, b), including with the mark of the non-completed point (c)

This interface contains the following information about the delivery point: identification number, delivery point name and contact name, address of the point, time within which the delivery to the point should be completed (for example, in case of delivery of goods to an individual before the beginning of the working day, this may be from 7:00 to 9:00) and the projected time of unloading. In addition, the interface shows the weight, volume and cost of the delivered goods, as well as any comments from the client or manager regarding this point.

The interface of the map of the route is shown in Figure 4, b and c. This window is a map showing the delivery points and the possible route between them in a different colour. The point colour depends on the delivery status, and matches the colour in the driving directions table.

An alien application, such as Google Maps, Yandex maps, or others, can be used to navigate to the point. The application for navigation can be selected in the settings window (Figure 1, c). When the corresponding voice command is received, the navigation will automatically begin for the address specified in the point information, and upon arrival at the destination the interface will return to the previous window.



а *б* *в*

Figure 4 – Interface of the information about the point (a) and the route map (b), including with the mark of uncompleted points (c)

As one can see from screenshots of the mobile application interface of the means of voice information formalization, most of the windows are informational in nature and are intended to show additional information in the process of voice control of the system.

Nevertheless, the main functions of changing between the windows of the software and navigation are duplicated in the form of touch buttons, which allows for a more fault-tolerant interface.

For the driver who will deliver the products during the distribution process, and will deal with a means of voice information formalization operating as part of the system of motor transport dispatching control for the first time, a training course on the operation of this system during

which he will need to teach this system to recognize his personal voice with appropriate specific words or commands will be integrated. The use of such means of voice information formalization aboard the vehicle allows extending the driver's performance in the process of distribution, providing and increasing the level of security.

Interactive interface in the system of voice information formalization allows the driver to talk with the vehicle (technical means), create requests, receive information and instructions, solving the tasks of delivery of products, as part of the system of motor transport dispatching control.

The accuracy of the driver's speech recognition is largely determined by the quality and stability of his pronunciation. Therefore, training information system is used for the preliminary training of drivers in the voice interface of this voice information formalization system with motor vehicles dispatching control. The resulting problem of pronunciation is of interest due to the large scope of practical application in various fields. In this case, there is a problem of variation of verbal communication of drivers for different carriers of the national language and is closely connected with it the problem of independent assessment of the quality of their pronunciation. There is an obvious contradiction in the very formulation of the task: one who is taught with insufficient language training at the moment and limited opportunities in the process of self-education should approach its pronunciation to some standard that it is poorly imagine. This contradiction is successfully overcome in the proposed system of formalization of voice information with control over the movement of motor vehicles based on the criterion of minimum information inconsistency - based on phonemes. In this approach, the availability of a reference pronunciation is ensured through the use of not one, but several "standards", which include the best samples of pronunciation from one or even several drivers who have successfully completed training earlier. Such a system for the formalization of voice information is able to memorize the best pronunciation by the driver of words and evaluate the quality of the subsequent proclamation of the same words in relation to these best words for the driver, and not only in relation to the default standards applied by the ideal driver (announcer). This system of voice formalization of supervisory control the movement of vehicles to assess the quality of pronunciation used test of distinguishing different sounds that can be made using one of the known methods of automatic speech recognition - speech recognition accuracy pofonemnoho.Sama driver is largely determined by the quality and the stability of his pronunciation. Therefore, for the preliminary training of drivers in the voice interface of this system of formalization of voice information with control over the movement of motor vehicles used information system training. The resulting problem of pronunciation is of interest due to the large scope of practical application in various fields. In this case, there is a problem of variation of oral speech of drivers for different carriers of the national language, and the problem of independent assessment of the quality of their own pronunciation closely connected with it. There is an obvious contradiction in the very formulation of the problem: one who is taught with insufficient language training at the moment and limited opportunities in the process of self-learning should approach with his pronunciation to some standard that he poorly imagines. This contradiction is successfully overcome in the proposed voice information formalization system of motor transport dispatching control based on the criterion of minimum information inconsistency - based on phonemes. In this approach, the availability of a standard pronunciation is ensured through the use of not one, but several "standards", which include the best samples of pronunciation from one or even several drivers who have successfully completed training earlier. Such a system for the formalization of voice information is able to memorize the best pronunciation by the driver of words and evaluate the quality of the further pronunciation of the same words in relation to these best for the driver words, and not only in relation to the default standards introduced by the ideal driver (announcer). At the same time, testing differentiation of sounds, which can be accomplished using one of the known methods of automatic speech recognition– phonemic – is used for assessing the quality of pronunciation in the system of voice information formalization with motor transport dispatching control.

Conclusions. The developed means of voice information formalization in motor transport dispatching control systems allows the driver to not distract from driving and monitor road conditions and situation that can acceler-

ate the delivery of products in the process of distribution, as well as increase security level.

The considered peculiarities of the use of the developed means of voice information formalization in motor transport dispatching control systems showed that the driver of a motor vehicle, who will deliver products in the process of distribution, and will deal with a means of voice information formalization operating within the motor transport dispatching control system for the first time shall pre-check and, if necessary, learn the system to recognize his voice commands from relevant contexts.

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РОЗРОБЛЕННЯ ЗАСОБУ ФОРМАЛІЗАЦІЇ ГОЛОСОВОЇ ІНФОРМАЦІЇ В СИСТЕМАХ ДИСПЕТЧЕРСЬКОГО КОНТРОЛЮ ЗА РУХОМ АВТОТРАНСПОРТУ

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Анотація. На сьогодні у процесах доставки і управлінні дистрибуцією застосовується значна кількість різноманітних інформаційних технологій, у тому числі, і застосування систем диспетчерського контролю за рухом автотранспорту. Значну роль у процесах доставки та управлінні дистрибуцією відіграють процеси голосової взаємодії, які зараз активно автоматизуються для підвищення ефективності, збереження ресурсів тощо. На сучасному етапі автоматизації голосового управління в організаційно-технічних системах існує проблема своєчасного коригування в необхідних випадках планових маршрутів руху автотранспорту, що інколи призводить до достатньо великих витрат часу на комунікацію, і відповідно є найбільш обґрунтованим напрямом автоматизації голосової взаємодії. Не дивлячись на інтенсивний розвиток систем диспетчерського контролю за рухом автотранспорту при взаємодії із водієм, саме голосова інформація потребує формалізації у випадку проведення автоматизації таких систем. Проте існуючі засоби в сфері формалізації голосової інформації поки не пристосовані для аналізу мовлення водіїв, з метою покращення та полегшення їх взаємодії з диспетчерською системою, що робить тему розробки засобів формалізації голосової інформації в системах диспетчерського контролю за рухом автотранспорту актуальною. Мета статті полягає у розробці засобу формалізації голосової інформації в системах диспетчерського контролю за рухом автотранспорту. Методи дослідження. Дослідження ґрунтуються на основних положеннях теорії інформації, теорії несилової взаємодії та програмного забезпечення для розробки засобів формалізації голосової інформації. Основні результати дослідження. Розроблений засіб формалізації голосової інформації в системах диспетчерського контролю за рухом автотранспорту дозволяє водію не відволікатись від управління автомобілем і слідкувати за дорожніми умовами та обстановкою, що дає змогу прискорити доставку продукції в процесі дистрибуції, а також підвищити рівень безпеки. Розглянуті особливості використання розробленого засобу формалізації голосової інформації в системах диспетчерського контролю за рухом автотранспорту показали, що водію автомобіля, який буде здійснювати доставку продукції в процесі дистрибуції і вперше зіштовхнеться із засобом формалізації голосової інформації, що діє в рамках системи диспетчерського контролю за рухом автотранспорту, необхідно попередньо перевірити і при потребі донавчити систему розпізнавати його голосові команди з відповідних контекстів. Наукова новизна. Набув подальшого розвитку засіб формалізації голосової інформації в системах диспетчерського контролю за рухом автотранспорту, який дозволяє водію не відволікатись від управління автомобілем і слідкувати за дорожніми умовами та обстановкою, що, на відміну від існуючих, дає змогу прискорити доставку продукції в процесі дистрибуції, а також підвищити рівень безпеки. Практична значимість. Розроблений засіб формалізації голосової інформації в системах диспетчерського контролю за рухом автотранспорту дозволяє підвищити ефективність управління процесом дистрибуції.

Ключові слова: *засіб формалізації, голосова інформація, система диспетчерського контролю за рухом автотранспорту, процес дистрибуції.*

РАЗРАБОТКА СРЕДСТВА ФОРМАЛИЗАЦИИ ГОЛОСОВОЙ ИНФОРМАЦИИ В СИСТЕМАХ ДИСПЕТЧЕРСКОГО КОНТРОЛЯ ЗА ДВИЖЕНИЕМ АВТОТРАНСПОРТА

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Аннотация. На сегодня в процессах доставки и управлении дистрибуцией применяется значительное количество разнообразных информационных технологий, в том числе и применение систем диспетчерского контроля за движением автотранспорта. Значительную роль в процессах доставки и управлении дистрибуцией играют процессы голосовых взаимодействий, которые сейчас активно автоматизируются для повышения эффективности, сохранение ресурсов и тому подобное. На современном этапе автоматизации голосового управления в организационно-технических системах существует проблема своевременного корректирования в необходимых случаях плановых маршрутов движения автотранспорта, иногда приводит к достаточно больших затрат времени на коммуникацию, и соответственно является наиболее обоснованным направлением автоматизации голосовой взаимодействия. Несмотря на интенсивное развитие систем диспетчерского контроля за движением автотранспорта при взаимодействии с водителем, именно голосовая информация требует формализации в случае проведения автоматизации таких систем. Однако существующие средства в сфере формализации голосовой информации пока не приспособлены для анализа речи водителей, с целью улучшения и облегчения их взаимодействия с диспетчерской системой, что делает тему разработки средств формализации голосовой информации в системах диспетчерского контроля за движением автотранспорта актуальной. Цель статьи заключается в разработке средства формализации голосовой информации в системах диспетчерского контроля за движением автотранспорта. Методы исследования. Исследования основываются на основных положениях теории информации, теории несиловыми взаимодействия и программного обеспечения для разработки средств формализации голосовой информации. Основные результаты исследования. Разработан способ формализации голосовой информации в системах диспетчерского контроля за движением автотранспорта позволяет водителю не отвлекаться от управления автомобилем и следить за дорожными условиями и обстановкой, что позволяет ускорить доставку продукции в процессе дистрибуции, а также повысить уровень безопасности. Рассмотрены особенности использования разработанного средства формализации голосовой информации в системах диспетчерского контроля за движением автотранспорта показали, что водителю автомобиля, который будет осуществлять доставку продукции в процессе дистрибуции и впервые столкнется со средством формализации голосовой информации, действующей в рамках системы диспетчерского контроля за движением автотранспорта, необходимо предварительно проверить и при необходимости доучить систему распознавать его голосовые команды из соответствующих контекстов. Научная новизна. Получил дальнейшее развитие средство формализации голосовой информации в системах диспетчерского контроля за движением автотранспорта, который позволяет водителю не отвлекаться от управления автомобилем и следить за дорожными условиями и обстановкой, в отличие от существующих, позволяет ускорить доставку продукции в процессе дистрибуции, а также повысить уровень безопасности. Практическая значимость. Разработан способ формализации голосовой информации в системах диспетчерского контроля за движением автотранспорта позволяет повысить эффективность управления процессом дистрибуции.

Ключевые слова: *средство формализации, голосовая информация, система диспетчерского контроля за движением автотранспорта, процесс дистрибуции.*

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IMPLEMENTATION AND TESTING OF HASH FUNCTION BASED ON MODIFIED SKEIN ALGORITHM

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Abstract. Context and objective. The article shows that the original Skein hash algorithm, which was developed as part of the competition for the new standard SHA-3 of the National Institute of Standards and Technology USA (NIST) and was one of five finalists can be modified to improve its operation efficiency in systems with multicore processors, which are used in almost all modern desktop and mobile devices. Analysis of the few publications that dedicated to such improvement of the original algorithm shows that all the authors focus on improving efficiency by optimizing the algorithm computations parallelization because computing speed was one of its main weaknesses. The simplification the original algorithm was not considered before and became the main purpose of the article.

Research methods. Analysis of the original algorithm showed that the basic premise for the modifications is flexibility for adjusting to build a hash function, particularly hash function is based on block encryption algorithm with adjustable block size. Block size and key are fixed, but they do not determine the size of the original hash function string, which complicates the method of attack, based on finding the key length. Alternating nature of the output line allows you to make hash function very flexible: it is possible to use a hash function and applications in devices with limited memory. Including mobile devices.

Results. Modification for Skein based on the fact that the original algorithm is assumed that the hash process can be represented as a multilevel tree structure. The basic idea is that the message on the first hashing level is divided into blocks, for each of the blocks calculated parameters for the second and higher levels become the input values for the next level. A significant simplification has been proposed no speed up the algorithm – use the only single-level hash that actually means abandoning the use of tree structure calculations.

Hash function based on the modified algorithm is implemented with the use of the programming language Python. Test results according to NIST SP 800-22 standard for set of 1,000 files with hash function results showed the percentage of files that have been tested successfully from 98.0 to 99.6% that indicates that the hash function under consideration meets random and pseudorandom generator integers and hash functions conditions.

The scientific novelty and practical significance. It is the first time then simplification of the structure for Skein hash algorithm calculations effectiveness improvement was proposed and it was shown that the hash function based on a simplified algorithm comply NIST SP 800-22.

Keywords: *hash functions, Skein, statistical methods of analysis of hash functions.*

Introduction.

Cryptographic hash function is an essential and common tool used to perform a variety of tasks: authentication, verification of data integrity, file protection, generation of associative arrays, finding duplication in a series of data sets, generation of unique identifiers for data sets etc. Hash function is a function that converts the arbitrary input data set to the output fixed size bit length string. The latter and simplicity of hash functions calculation are of their two main practical advantages. There are developed many hash algorithms with different properties (bit, computational complexity, cryptographical secure etc.). The best-known algorithms to obtain hash values are MD5, SHA, RIPEMD, TIGER [1].

In general, hash algorithms are such that it is almost impossible to find two messages with the same hash value. But it is impossible to completely avoid this, because it can results in collisions that denotes to forming the same strings as a result of hash functions with different input data [1]. In the early 2000s the cryptanalysts revealed the possibility of collision in such algorithms as MD4, MD5, and SHA-0 [2, 3]. Moreover, in is known the published method for finding collisions using SHA-1 algorithm.

Even though the new generation of standardized SHA-2 hash algorithms was ready to replace SHA-1, in late 2007 NIST decided to start a 4-year global process of developing a new hash algorithm, so called Standard SHA-3, which was developed through public competition [4]. In 2010 the 5 finalists were determined: BLAKE, Grostl, JH, Keccak and Skein. The results of a comparative analysis of the proposed algorithms can be found, for example, in [5, 6]. Keccak algorithm was chosen for the new standard and in [6] it is indicated that the choice was extremely difficult and each of the finalists had their advantages and disadvantages. Accordingly, each of the abovementioned algorithms can be used for further development and implementation.

Based on experts prediction [5] fourth generation hash algorithms is not expected until 2030, but the issue of implementation and testing of existing hash functions and their modifications is a topical research direction.

Skein is one of the promising hash algorithms and as mentioned earlier in 2010 was in the top five in the competition NIST [6]. The main feature of this algorithm is to obtain optimal performance when working with critical applications that require customized implementations efficiently on multicore processors. Given the fact that almost all modern computer systems are equipped with such processors the generation and study of the Skein algorithm modifications are promising.

Studies on the implementation of the Skein algorithm was carried out in most cases in the areas of its computation parallelization. Specifically, the authors [2] created a separate thread for each branch of calculations and showed that the effectiveness of the algorithm implementation in Java and C did not differ. The authors of [7] showed that it is possible to effectively calculate the hash value by parallelization of computations using a special tool «PLUTO». In general, in [5] it was indicated that in the implementation of this algorithm computation speed was one of its main weaknesses. As seen from the above works the authors did not consider the possibility of improving performance by simplifying the implementation of the original algorithm.

The objective of the study.

Consider all the above mentioned, the objective of the article is to propose, implement and verify modification for Skein algorithm. To achieve the objective following scientific and technological tasks must be settled:

- proposals generation for Skein algorithm modifications, which should be based on consideration of the principles of its construction;

- software implementation for hash function based on the modified algorithm;

- testing the implemented hash function.

Modified Skein hash function algorithm.

The general structure of the Skein algorithm. Principles of this algorithm, its structure, analysis of its cryptographic security are described in detail in [5, 6, 8-11], so let's consider only general information.

Skein main advantage is that it provides an opportunity to build a hash function with parameters that can be adjusted. Hash function is based on block encryption algorithm with adjustable block size. Block size and key are fixed, but they do not determine the size of the hash function output string, which complicates the attack methods based on finding the key length. Alternating the output string allows you to make hash function very flexible: it is possible to use a hash function in devices with limited memory, including mobile devices.

Skein has three components [8]:

- Threefish. Threefish is the tweakable block cipher at the core of Skein, defined with a 256-,512-, and 1024-bit block size.
- Unique Block Iteration (UBI). UBI is a chaining mode that uses Threefish to build a compression function that maps an arbitrary input size to a fixed output size.
- Optional Argument System. This allows Skein to support a variety of optional features without imposing any overhead on implementations and applications that do not use the features. An extra set of arguments allows Skein maintain a set of additional features that allow you to use not only as Skein hash function (such as encryption algorithm) without significant changes in the source code implementation.

UBI and Threefish are independent and can be used separately.

When used as a hash function, the message type is the only optional input type used. The output of configuration UBI becomes a precomputed initial chaining value. This is the simplest use of Skein. With the variable output size it becomes a drop-in replacement for almost any existing hash function.

Algorithm modification. To simplify the original algorithm, consider some functions in more detail.

Tweak function is presented as a description of individual components-bytes in original algorithm. It was designed as an auxiliary one for the values generation, which is formed as a unique unit for each 128-bit string. Tweak Fields indicated in Fig. 1 [5], and their description specified in Table 1.

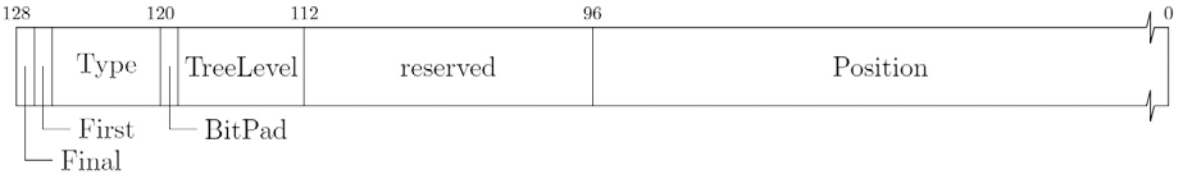

Figure 1 – The fields in the Tweak value

Tweak function takes as input the original message, hash tree level, type of Tweak and value lists for the respective blocks which are converted into binary form. Based on this input parameters a string to be form in the manner specified in Fig. 1. The following string is converted to decimal form. The function returns the number in decimal form.

In the original algorithm it is assumed that the hashing process can be represented as a multilevel tree structure. The basic idea is that the first level hash message is divided into blocks, each block is calculated from UBI, on the second and higher levels of UBI the values are used as input parameters. Block size and number of required levels specified in Tweak and Configuration_string function, which is described below.

Implementers of tree hashing have a number of decisions to make. There are three parameters to choose: the leaf node

size, the fan-out, and the maximum tree height. For efficiency, a larger leaf node size and fan-out is better; it reduces the number of nodes and thus the overhead. But large leaf nodes and high fan-out make some uses less efficient.

To speed up the algorithm a significant simplification has been proposed – use only single-level hashing that actually means abandoning the use of tree structure calculations.

Table 1

The fields in the Tweak value

Name	Position	Description
Position	0- 95 bits	The number of bytes in the string processed so far (including this block)
Reserved	96-111 bits	Reserved for future use, must be zero
TreeLevel	112-118 bits	Level in the hash tree, zero for non-tree computations
BitPad	119 bit	Set if this block contains the last byte of an input whose length was not an integral number of bytes. 0 otherwise.
Type	120-125 bits	Type of Tweak (key, block configuration, messages, etc.)
First	126 bit	Set for the first block of a UBI compression
Final	127 bit	Set for the last block of a UBI compression

Configuration_string function in original algorithm is presented as a description of individual components-bytes. It was designed as an auxiliary for the formation of values string configuration. According to the proposed modification of certain bytes are assigned fixed value (see last column of Table. 2).

Таблиця 2

The Fields in the configuration value

Offset	The number of bytes	Name	Description	Description modifications
0	4	Schema identi fi er	Constant	-
4	2	Version number	-	-
6	2	Reserved	Reserved bytes filled with zeros	-
8	8	Output length	Converted to bytes additional parameter ToBytes, defines the desired length of hash sum	-
16	1	Tree leaf size enc.	Size of tree leaf	zero
17	1	Tree fan-out enc.	Tree branching	zero
18	1	Max. tree height	The maximum level of the tree	zero
19	13	Reserved	Reserved bytes filled with zeros	-

An implementer that needs the hash function to process data at a very high data rate can use a leaf node size of a few kilobytes and a maximum tree height of 2. This allows multiple processors to each work on its own leaf node, with one processor doing the second level of the tree. Increasing the leaf node size makes this more efficient, but it increases the amount of memory needed for buffering, and will tend to increase latency.

Limiting the tree height is useful when memory-limited devices are involved. When computing a tree hash incrementally, the implementation must store data for each level of the tree. Limiting the tree height allows a fixed allocation of memory for small devices.

Thus, modifications of the algorithm consist of two simplifications:

- abandoning the use of multi-level hashing,

- several bytes in Tweak and Configuration_string have fixed values and do not depend on the size of the incoming message.

Software implementation of hash function based on the modified algorithm. The above-mentioned changes are implemented using software programming language Python. Graphical interface was created that allowed to choose a text file with message, for which the hash function value was calculated. Hash result is displayed in a separate GUI field and recorded in a separate file.

Preliminary analysis of hash function execution indicates that changing even one character in the initial report led to changes in the value of the final sequence, which is one of the requirements for hash functions in general.

Complete performance testing for modified algorithm has at least two stages:

1. Compliance Testing for statistical input and output data applicable to cryptographic hash functions. This must be done because simplification could lead to malfunction of the algorithm.

2. Implementation effectiveness testing. In particular, calculation speed comparison with known counterparts. This phase will be conducted in a separate study, because it is time-consuming, as can be seen, for example, in [12, 13].

Compliance Testing for statistical input and output data.

Hash function assessment methodology. The NIST STS 800-22 tests package. The basis for the software implementation of statistical tests in this work is NIST SP 800-22 «A Statistical Test Suite for Random and Pseudorandom Number Generators for Cryptographic Applications» [14].

NIST SP 800-22 highlights aspects of selection and testing of random and pseudorandom generators for integers and hash functions. It was suggested during the competition for the new US national standard block encryption which was used for the analysis of statistical properties of the candidates for the new block cipher. Test suite contains 15 statistical tests that are designed to test the hypothesis of randomness for binary sequences of any length. All tests are focused on detecting various defects of randomness.

Files from the NIST SP 800-22 with a programming code can be found at NIST web-site. This code is written in the programming language C and in [15] observed its following imperfections:

1. Incorrect implementation of the statistical test suite. Because test suit was compiled during testing without any revisions in the source code and was tested on reference sequences that were delivered with the test, it does not guarantee the absence of errors and impropriety in the code. During testing process there were error messages associated with the release of calculated values beyond significance limit. Although these errors were observed only in some samples (usually low accuracy calculations), they could in some way influence the overall test results.

2. Incorrect programming code implementation. Although the authors of the studies were carried fullest extent to study the reliability and reproducibility of research results relevant for code, it does not exclude errors in the code (for example, relating to incorrect alignment of data types) that lead to distortion and deterioration for test results.

3. Imperfection of statistical methods. Statistical methods imperfection include the preposition that sequence under analyzes considered to be the general sample from which the user must select a partial sample. In some cases, partial sample properties differ from those of a general sample.

4. The use of tests for hash functions has its own specific. Tests that have been developed are used for binary sequences, while the majority of hash functions calculate hash in hexadecimal, octal and other numerical systems. Changing the number system can affect statistics for input sequence.

Because of the above-mentioned drawbacks the implementation of selected tests in the programming language Python became in this work a separate task and among the 15 tests proposed by NIST 8 most often used test were chosen for the implementation to study hash function under consideration. Thus, in this paper were implemented the following tests:

1. The Frequency (Monobit) Test,
2. Frequency Test within a Block,
3. Tests for the Longest-Run-of-Ones in a Block,
4. The Linear Complexity Test,
5. The Serial Test,
6. The Approximate Entropy Test,
7. The Cumulative Sums Test,
8. The Cumulative Cusums Test.

For some tests implemented in the suite, it was assumed that the size of the sequence length n is large (on the order of 10^3 to 10^7). For such a large sample were ap-

plied asymptotic methods. Most tests can be used for smaller values of *n*. However, when applying for smaller values of *n* asymptotic methods would be unacceptable and they should be replaced exact distributions that are usually difficult to calculate.

Hash function test results. To assess the quality Skein-based hash functions a sample of 1000 files containing the results of hashing was tested.

Test binary matrices test and Maurer statistical test were not used for testing, since the minimum length of input sequences for these tests to be 38,912 bits and 387840 bits, respectively, and estimation of the time required to execute these tests showed significant duration.

Test results indicate the almost complete absence of deviation for sequences which were generated by simplified version of Skein hash function.

Table 3

Hash function testing results

Type of test	The percentage of files that have passed the test
The Frequency (Monobit) Test	98,6%
Frequency Test within a Block	99,6%
Tests for the Longest-Run-of-Ones in a Block	98,9%
The Linear Complexity Test	98,4%
The Serial Test	98,1%
The Approximate Entropy Test	98,0%
The Cumulative Sums Test	99,4%
The Cumulative Cusums Test	99,3%

Conclusions.

Further development of algorithms for hash functions associates with both the generation of new and improvement of existing algorithms.

It is shown that the Skein algorithm is one of the algorithms on which basis high quality hash functions can be build, and further development of the implementation feasibility for this algorithm lay in simplification of some features that make up the structure of the original algorithm. In particular, the following simplifications were proposed in this work:

- abandoning the use of multi-level hashing,

- several bytes in Tweak and Configuration_string have fixed values and do not depend on the size of the incoming message.

The first phase of implemented hash function testing was performed by analyzing statistical input and output data applicable to cryptographic hash functions. In particular NIST SP 800-22 «A Statistical Test Suite for Random and Pseudorandom Number Generators for Cryptographic Applications» from NIST was used. To elude some shortcomings of program implementation for these tests proposed by NIST in the programming language C in this work software implementation has been established using language Python.

The testing results for set of 1,000 files with hash function results showed the percentage of files that have been tested successfully from 98.0 to 99.6% that indicates that the hash function under consideration meets random and pseudorandom generator integers and hash functions conditions.

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РЕАЛІЗАЦІЯ ТА ТЕСТУВАННЯ ГЕШ-ФУНКЦІЇ НА ОСНОВІ МОДИФІКОВАНОГО АЛГОРИТМУ SKEIN

Анотація. Актуальність та мета статті. У статті показано, що оригінальний алгоритм гешування Skein, який був розроблений в рамках конкурсу на новий стандарт SHA-3 Національного інституту стандартів і технологій США (NIST) і був одним з п'яти фіналістів може бути модифіковано для підвищення ефективності його роботи в системах з багатоядерними процесорами, якими комплектуються практично всі сучасні настільні та мобільні пристрої. Аналіз нечисленних публікацій, які присвячені розвитку можливостей оригінального алгоритму, показує, що всі автори зосереджують увагу на підвищенні ефективності виконання алгоритму шляхом оптимізації розпаралелювання обчислень, які скла-

дають структуру алгоритму. При цьому саме швидкість обчислень при імплементації цього алгоритму була однією з основних його недоліків. Спрощення оригінального алгоритму раніше не розглядалась, що стало метою статті.

Методи дослідження. Аналіз оригінального алгоритму виявив, що базовою передумовою запропонованої модифікації є те, що він дає можливість побудувати геш-функцію з параметрами, які можна налаштовувати. Геш-функція будується на основі блокового алгоритму шифрування з регульованим розміром блоку. Розміри блоку та ключа є фіксованими, але вони не визначають розмір вихідного рядка геш-функції, що ускладнює методи атак, які ґрунтуються на знаходженні довжини ключа. Змінний розмір вихідного рядка дозволяє зробити геш-функцію дуже гнучкою: з'являється можливість використовувати геш-функцію у додатках та пристроях з обмеженим обсягом пам'яті. Зокрема на мобільних пристроях.

Результати. Запропоновано модифікацію Skein засновану на тому, що в оригінальному алгоритмі передбачається, що процес гешування може бути представлений у вигляді багаторівневої деревоподібної структури. Основна ідея полягає у тому, що на першому рівні гешування повідомлення розбивається на блоки, для кожного з блоків обчислюється відповідні параметри, на другому та вищих рівнях вже отримані значення цих параметрів використовуються у якості вхідних. Для пришвидшення роботи алгоритму було запропоноване суттєве спрощення – використання лише однорівневого гешування, що фактично означає відмову від застосування деревоподібної структури обчислень.

Геш-функцю, яка заснована на модифікованому алгоритмі, реалізовано із використання мови програмування Python. Результати тестування відповідно до стандарту NIST SP 800-22 на виборці, яка складалася з 1000 файлів з результатами гешування, показали відсоток файлів, які пройшли тестування, від 98,0 до 99,6%, що свідчить про те, що реалізована геш-функція на основі модифікованого алгоритма Skein відповідає вимогам до випадкових і псевдовипадкових генераторів цілих чисел та геш-функцій.

Наукова новизна та практична значимість. Вперше запропоновано пришвидшити ефективність імплементації алгоритму гешування Skein шляхом спрощення структури обчислень та показано, що геш-функція заснована на спрощеному алгоритмі відповідає стандарту NIST SP 800-22.

Ключові слова: *геш-функції, Skein, статистичні методи аналізу геш-функцій.*

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РЕАЛИЗАЦИЯ И ТЕСТИРОВАНИЕ ХЭШ-ФУНКЦИИ НА ОСНОВЕ МОДИФИЦИРОВАННОГО АЛГОРИТМА SKEIN

Аннотация. Актуальность и цель статьи. В статье показано, что оригинальный алгоритм хеширования Skein, который был разработан в рамках конкурса на новый стандарт SHA-3 Национального института стандартов и технологий США (NIST) и был одним из пяти финалистов может быть модифицирован для повышения эффективности

его работы в системах с многоядерными процессорами, которыми комплектуются практически все современные настольные и мобильные устройства. Анализ немногочисленных публикаций, посвященных развитию возможностей оригинального алгоритма, показывает, что все авторы сосредоточены на повышении эффективности выполнения алгоритма путем оптимизации распараллеливания вычислений, которые составляют структуру алгоритма. При этом именно скорость вычислений при имплементации этого алгоритма была одной из основных его недостатков. Упрощение оригинального алгоритма ранее не рассматривалась, что стало целью статьи.

Методы исследования. Анализ оригинального алгоритма выявил, что базовой предпосылкой предложенной модификации является то, что он дает возможность построить хеш-функцию с параметрами, которые можно настраивать. Хеш-функция строится на основе блочного алгоритма шифрования с регулируемым размером блока. Размеры блока и ключа являются фиксированными, но они не определяют размер исходной строки хеш-функции, что усложняет методы атак, основанных на нахождении длины ключа. Переменный размер исходной строки позволяет сделать хеш-функцию очень гибкой: появляется возможность использовать хеш-функцию в приложениях и устройствах с ограниченным объемом памяти. В частности, на мобильных устройствах.

Результаты. Предложена модификация Skein основанная на том, что в оригинальном алгоритме процесс хеширования может быть представлен в виде многоуровневой древовидной структуры. Основная идея заключается в том, что на первом уровне хеширования сообщение разбивается на блоки, для каждого из блоков исчисляется соответствующие параметры, на втором и высших уровнях уже полученные значения этих параметров используются в качестве входных. Для ускорения работы алгоритма было предложено существенное упрощение – использование только одноуровневого хеширования, что фактически означает отказ от применения древовидной структуры вычислений.

Хеш-функция, которая основана на модифицированном алгоритме, была реализована с использованием языка программирования Python. Результаты тестирования в соответствии со стандартом NIST SP 800-22 на выборке, состоящей из 1000 файлов с результатами хеширования, показали процент файлов, которые прошли тестирование, от 98,0 до 99,6%, что свидетельствует о том, что реализованная хеш-функция на основе модифицированного алгоритма Skein соответствует требованиям к случайным и псевдослучайным генераторам чисел и хеш-функциям.

Научная новизна и практическая значимость. Впервые предложено ускорить эффективность имплементации алгоритма хеширования Skein путем упрощения структуры вычислений и показано, что хеш-функция основана на упрощенном алгоритме соответствует стандарту NIST SP 800-22.

Ключевые слова: *хеш-функции, Skein, статистические методы анализа хеш-функций.*

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IMPROVEMENT OF THE METHOD OF COLLABORATIVE FILTERING, TAKING INTO ACCOUNT THE CHARACTERISTICS OF THE CONSUMER TO PERSONALIZE RECOMMENDATIONS IN THE E-COMMERCE SYSTEM

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Abstract. The purpose of the article. The purpose of the article is to improve the method of collaborative filtering with implicit feedback by combining the characteristics of the consumer and his behavior to improve the efficiency of building recommendations in cases of lack or insufficient information about consumer preferences.

Research methods. Collaborative filtering methods with implicit feedback used in the process of sales personalization.

The main results of the research. The problem of improving the method of collaborative filtering with implicit feedback for personalizing sales in the recommendatory subsystem in the e-commerce system, taking into account the characteristics of the consumer and the characteristics of his behavior when choosing goods and services, is considered. The importance of using additional contextual filters to improve the quality of recommendations received is shown. It is shown that the existing hybrid methods of collaborative filtering take into account separately the characteristics of the consumer or the characteristics of the domain. At the same time, in situations of "cold start" for personalizing sales, there is a practical need to build recommendations taking into account changes in the interests of users of different demographic groups. Hybrid method of collaborative filtering was improved. The main idea of the improved method is to complement the algorithm of collaborative filtering with implicit feedback, taking into account the attributes of the user, as well as the dynamics of changing his interests. The method uses as input data information about purchases without user ratings and with the date of purchase, as well as demographic information about the user. This information can be obtained from other subsystems of the e-commerce system. The result of the method is a refined list of recommended purchases for the user. This list corresponds to the age group of the user and the context-sensitive sequence of changes in his interests.

Scientific novelty. The method of collaborative filtering with implicit feedback has been improved by taking into account additional features of users, as well as changes in consumer interest over time.

Practical significance. In practical terms, the proposed method allows to increase the relevance of the recommendations when personalizing sales to the user in the recommender subsystem in the e-commerce system. Experimental verification showed an increase in the effectiveness of the recommendations received according to the AUC criterion. The improved method can also be used in the promotion of promotional offers in social networks.

Keywords: *collaborative filtering, implicit feedback, recommendation subsystems, personalization of sales, e-commerce.*

Problem statement.

Recommendation systems are designed to form the most relevant list of consumer goods and services in e-commerce systems [1]. They use the similarity between the characteristics of the goods that the consumer chooses, or between the characteristics of consumers to form a list of recommendations. Ratings or information about user selection are considered as feedback. In the first case, an explicit feedback is used, and in the second case it is implicit [2].

Such systems provide the possibility of personalized consumer choice in a large number of alternative options and lack of consumer detailed knowledge of goods or services [3].

Personalization of products and services in recommendation systems has been widely used in search engines and e-commerce, for example, in Amazon stores and Netflix streaming services [4, 5].

Recommendation systems that forms list of the consumer-friendly products and services are mainly based on collaborative filtration and content filtering methods [1, 3]. In the first case, the recommendations are based on the similarity of consumers, and in the second - the goods. To improve the effectiveness of the basic approaches, hybrid methods are also used, taking into account the semantic characteristics of the product and the context of the choice of the consumer [6, 7].

However, in the lack of information about consumer or incomplete product information, existing hybrid approaches do not always allow us to form relevant recommendations. This indicates the relevance of the problem considered in this paper.

Analysis of recent research and publications.

One of the basic and most common algorithms for constructing recommendations that take into account the similarity of consumers is collaborative filtration (CF). This algorithm allows you to recommend products and services that have received high ratings by other users with similar preferences and interests [2].

A user profile is determined based on a set of ratings assigned to different products and services. These ratings can be recorded explicitly, that is, based on the results of user replies or implicitly, as a result of analysis of its interaction with the advisory system [1].

The rating can be represented by unary (only relevant elements), binary (which distinguishes between good and bad elements) or more generally as a numerical value on the corresponding final scale.

Existing methods of collaborative filtration do not solve a number of similar issues of issuing recommendations in non-typical conditions. These include, in particular, the problems of cold start, spam attacks, inconsistency of consumer interests, and scalability [8].

The problem of a cold start is due to the complexity of providing advice to new users, information about which was only recently introduced in the recommendation system. The users have not yet chosen and appreciated a sufficient number of products, so the recommendation system cannot predict their interests [6].

Initial ratings are used to solve this problem, that is, the system forces the user to first evaluate a particular set of goods. However, this creates inconvenience to the user. Also, these primary ratings may lead to erroneous recommendations, as consumer responses do not always reflect their interests. The cold start issue also affects new products, as they will not be in the list of recommendations until sufficient users have been rated [8].

The problem of spam attacks occurs when unscrupulous consumers mislead the recommendation system [1, 8].

The issue of user inconsistency (or Gray Sheep problem) occurs if there are users whose opinions are not consistently

consistent or inappropriate with any group of people. Such consumers do not benefit from the use of the advisory system [9].

The problem of scalability arises as a result of finding recommendations for the entire database of consumer ratings. This does not allow for personalization of recommendations.

Hybrid methods integrating collaborative filtration with user profile analysis are used to solve a set of problems. [6] A more generalized approach proposed in [7, 10] relates to the consideration and generalization of the context of consumer choice.

To clarify the recommendations, associative rules are also found, and they form a list of goods and services using these [11, 12].

However, these methods do not allow solving the problem of the formation of recommendations in the absence of detailed information about the consumer.

To solve this problem it is necessary to combine information about the user and his behavior when choosing goods and services, that is, taking into account not only the properties of objects, but also the temporal aspect. Temporal characteristics are used in the construction of knowledge bases [13, 14], as well as the formation of recommendations using these knowledge bases [15].

This indicates the importance of completing the collaborative filtration method taking into account the temporal characteristics of the consumer and the product.

The aim of the study.

The purpose of the article is to improve the method of collaborative filtering with implicit feedback by combining the characteristics of the consumer and his behavior, and to increase the effectiveness of constructing recommendations in cases of lack or insufficient information about consumer preferences.

To achieve the research objectives are solved the following tasks:

– to substantiate the possibility of obtaining additional data on the consumer taking into account the structure of e-commerce systems;

– formalize additional characteristics of consumers and goods that may affect the resulting recommendations;

– to supplement the method of collaborative filtration on the basis of taking into account the characteristics of the consumer and his preferences.

Presentation of research material.

E-commerce is a form of trade in which the selection and ordering of goods is carried out through computer networks, and settlements between the buyer and the supplier are carried out using electronic documents and / or payment methods.

Therefore, the e-commerce system combines a number of subsystems that control internal processes and interact with customers:

– ERP-subsystem, which is intended to control the state of the warehouse and movement of goods and money;

– PIM - subsystem of content support for goods and categories of goods;

– CRM - subscriber interaction seller with customers;

– Service desk - automation module for customer request processing;

– Cost accounting module;

– Recommender subsystem.

The presented structure of the e-commerce system makes it possible to conclude that the Recommender subsystem may use additional data about the consumer and goods received from other subsystems in addition to purchasing information.

Input data of the developed method is:

– Data about the purchase of goods;

– Consumer data for which recommendations are being generated.

Data on purchases of goods are presented in the form of an ordered table: $P = \{ p_k \}$.

Each item in this table contains information about the selected product, the consumer who chose the product, and the date of purchase:

$$p_k = \{ e_i, u_j, d_k \}, \quad (1)$$

where e_i - the goods or services chosen by the consumer; u_j - consumer data; d - the date of purchase.

Each purchase is displayed as a separate item in this table.

Product information can also be detailed using additional attributes, such as the name and product group, the physical characteristics of the product (size, resolution, weight, etc.), etc.

$$E = \{e_i\},\ e_i = \{Ie_i, n_i, c_i, A_i\}, \qquad (2)$$

where Ie_i - the unique product code in the e-commerce system; n_i - the name of the product; c_i - the price of the goods; $A_i = \{a\}$ - additional attributes of the goods.

Every consumer $u_j \in U$ in the advisory system has the following demographic characteristics:

$$u_j = \{Id_j, n_j, D_j\}, \qquad (3)$$

where Id - the unique consumer code in the recommendation system (or e-commerce system); n_j - the registration name of the consumer; $D_j = \{d_{jm}\}$ - additional attributes of the consumer.

Additional attributes of the consumer include at least the year of birth, gender and region of residence. The year of birth and sex is usually set when forming a consumer profile in the e-commerce system. The region or city of residence is usually determined automatically.

$$D_j = \{b_j, g_j, r_j\}, \qquad (3)$$

where b_j - data on the year of birth of the consumer; g_j - human sex; r_j - place of residence of the consumer.

Recommendations are formed for a specific customer, which has characteristics (3) and (4).

In this paper, the construction of recommendations based on implicit feedback is considered., That is, the input data only contains information about the fact of purchases and do not contain the ratings given by the consumer.

The main idea of the proposed hybrid method of collaborative filtering with implicit feedback is to filter out irrelevant input data, taking into account temporal and object characteristics.

Temporal characteristics specify changes in the interests of consumers in time. Such changes can be cyclic, one-time or permanent.

Cyclical changes are related, for example, to the seasonal selection of goods. One-time changes occur in cases of single external influences. For example, increasing the availability of transport in the remote area may change the range of goods in demand in this city.

Permanent changes are characteristic of areas related to the creation and use of computer technology, technology, computer games, and the like. Also, such changes are typical for choosing things based on fashion trends.

In general, the input data can be represented as a set of pairs (e_i, u_j) for a specified time interval.

$$M = \{M_l\}, M_l \subseteq E \times U : \forall (e_i, u_j) \in M_l\ \exists d_k, d_{\min} \le d_k \le d_{\max}, \qquad (4)$$

where $d_{\min}, d_{\max}$ - they determine the time interval for which the preferences of the consumer are considered to be unchanged.

Representation (4) shows that the input data can be filtered in the temporal aspect, for example according to the seasonal preferences of the consumer. Only topical purchases can be selected.

The temporal aspect should also be taken into account when filtering goods based on the proximity of consumer interests. Obviously, the demand for certain groups of goods depends on the age of the consumer:

$$M_l = \{(e_i, u_j)\} : b_{\min} \le b_j \le b_{\max}, \qquad (5)$$

where $b_{\min}, b_{\max}$ - determine the age of the consumer with the eastern interests of goods and services.

Similarly, input data can be detailed according to consumer attributes and attributes:

$$M_l = \{(e_i, u_j)\} : a_{ls} \in A_l, A_l \subseteq A, \qquad (6)$$

$$M_l = \{(e_i, u_j)\} : d_{lm} \in D_l, D_l \subseteq D, \quad (7)$$

where a_{il} - the attribute of the goods; A_l - a set of attributes defining a group of goods for consumer choice; d_{lm} - attribute of the consumer; D_l - set of attributes defining a group of consumers; A - set of attributes of all goods; D - the set of attributes of all consumers.

The improved method involves the following steps.

Stage 1. Selection of a subset of input data for consumer attributes:

$$M_l^{(1)}{}_l = \{(e_i, u_j)\} : \forall u_j \forall m \; d_{lm} \in D_l^* \,|\, d_{lm}^* \in D_l^*, \quad (8)$$

Where d_{lm}^* - the attribute of the target consumer; D_l^* - a subset of attributes that characterize the target group of consumers.

At this stage, consumers are selected in the target group with properties similar to the consumer for whom the recommendations are made.

Stage 2. Selection of a subset of input data for attributes of goods. At this stage, the selection of such goods, the properties of which are similar to the properties selected by the target consumer is carried out:

$$M_l^{(2)} = \{(e_i, u_j)\} : M_l^{(2)} \subseteq M_l^{(1)}, \forall e_i \forall s \; a_{ls} \in A_l^* \,|\, \forall s \; a_{ls}^* \in A_l^*, \quad (9)$$

where a_{ls}^* - the attribute of the product chosen by the target consumer; A_l^* - a subset of attributes that characterize the target group of goods; a_{ls} - the attribute of the product from the target group.

Data filtering in the second stage is performed only if the consumer has selected at least one item. Therefore, for the cold start situation, this stage is optional, unlike filtering according to the customer.

Stage 3. The subset of input data by temporal characteristics of the consumer is selected.

Selection at this stage is performed according to the expression (5). The date range $[b_{\min}; b_{\max}]$ is based on the input data using the configuration parameter ε_1:

$$b_{\min} = b_j^* - \varepsilon_1, \; b_{\max} = b_j^* + \varepsilon_1. \quad (10)$$

The result of the phase is a subset of input data $M_l^{(3)} \subseteq M_l^{(2)}$.

Stage 4. The subset of input data by temporal characteristics of the product is selected. Selection at this stage is performed according to the expression (4). The temporal interval $[d_{\min}; d_{\max}]$ is determined on the basis of the input data using a configuration parameter ε_2 similar to the previous step.

The result of the phase is a subset of input data $M_l^{(4)} \subseteq M_l^{(3)}$.

Stage 5. Collaborative filtering with implicit feedback is used to build recommendations. The input subset is $M_l^{(4)}$.

At this stage, there are latent factors that connect users and goods. Recommendations are formed using these latent factors.

The result of this phase is the recommended list of products $E_R \subset E$ that may be of interest to consumers with the characteristics specified in the input data.

The developed method was tested on the data on the sale of goods in the Internet stores in the UK.

To evaluate the proposed method, we compared the results of traditional collaborative filtration and the improved hybrid method using the area under the ROC (Receiver operating characteristic) indicator – AUC.

The Receiver operating characteristic is an indicator used to assess the quality of a binary classification. It represents the ratio between the proportion of correctly classified objects from the total number of sign attributes and the proportion of mistakenly classified, not relevant attributes.

The AUC reflects the area that is limited by the ROC curve and the axis of the fraction of false positive classifications. The value of the indicator is less than 0.5 indicates that the classifier inverts the results, that is, it works with the exact opposite. The value of indicator 0.5 demonstrates the unsuitability of the selected classification method. The quality of the classification depends on the AUC value.

In the course of an experimental verification, 2 calculations of the AUC for the sample with regard to the filtration were performed.

The first calculation was carried out using traditional collaborative filtration, the second - taking into account the temporal characteristics of the goods.

The results of the experiments are as follows. With traditional filtration $AUC = 0,872$. When filtering using temporal characteristics of goods $AUC = 0,881$. Thus, even without taking into account the characteristics of the consumer, the quality of the recommendations increases.

Conclusions.

The problem of hybrid collaborative filtration is considered. It is shown the importance of using additional filters to improve the quality of the recommendations.

It is shown that the methods of collaborative filtration during personalization of sales, especially in the "cold start" situation, do not allow giving recommendations of high accuracy. Therefore, in the case of new consumers, there is a practical need for constructing recommendations taking into account the combination of attributes of users and goods.

The result of the work is the improved method of collaborative filtering with implicit feedback, which takes into account additional signs of users and goods, including temporal ones.

The difference between the proposed methods consists in generalization of several methods of filtration. This synthesis makes it possible to combine the benefits of each method to increase the effectiveness of providing recommendations.

In practical terms, the proposed method allows to increase the relevance of the recommendations when personalizing sales to the user in the Recommender subsystem in the e-commerce system.

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УДОСКОНАЛЕННЯ МЕТОДУ КОЛАБОРАТИВНОЇ ФІЛЬТРАЦІЇ ІЗ УРАХУВАННЯМ ХАРАКТЕРИСТИК СПОЖИВАЧА ДЛЯ ПЕРСОНАЛІЗАЦІЇ РЕКОМЕНДАЦІЙ В СИСТЕМІ Е-КОМЕРЦІЇ

Анотація. Мета статті. Метою статті є удосконалення методу колаборативної фільтрації з неявним зворотним зв'язком шляхом комбінування характеристик споживача та його поведінки для підвищення ефективності побудови рекомендацій у випадках відсутності або недостатньої кількості інформації про вподобання споживача.

Методи дослідження. Методи колаборативної фільтрації з неявним зворотним зв'язком рекомендаційних системах.

Основні результати дослідження. Розглянуто проблему удосконалення методу колаборативної фільтрації з неявній зворотним зв'язком для персоналізації продажів в рекомендаційної підсистемі в системі електронної комерції з урахуванням характеристик споживача і особливостей його поведінки при виборі товарів та послуг. Представлено важливість використання додаткових контекстних фільтрів для підвищення якості отриманих рекомендацій. Показано, що існуючі гібридні методи колаборативної фільтрації враховують окремо характеристики споживача або характеристики предметної області. У той же час в ситуаціях «холодного старту» для персоналізації продажів існує практична потреба в побудові рекомендацій з урахуванням змін інтересів користувачів різних демографічних груп. Удосконалено гібридний метод колаборативної фільтрації. Основна ідея вдосконаленого методу полягає в доповненні алгоритму колаборативної фільтрації з неявним зворотним зв'язком з урахуванням атрибутів користувача, а також динаміки зміни його інтересів. В якості вхідних даних метод використовує інформацію про покупки із зазначенням їх дати та без рейтингів користувачів, а також додаткову інформацію про користувача. Ця інформація може бути отримана із других підсистем системи електронної комерції. Результатом роботи методу є уточнений список рекомендованих покупок для користувача. Цей список відповідає віковій групі користувача і контекстно-залежною послідовності зміни його інтересів.

Наукова новизна. Удосконалено метод колаборативної фільтрації з неявним зворотнім зв'язком шляхом врахування додаткових ознак користувачів, а також зміни інтересу споживачів у часі.

Практична значимість. В практичному плані запропонований метод дозволяє збільшити релевантність рекомендацій при персоналізації продажів для користувача в рекомендаційній підсистемі в системі електронної комерції. Експериментальна перевірка показала підвищення ефективності отриманих рекомендацій згідно з критерієм AUC. Вдосконалений метод може використовуватися також при просуванні рекламних пропозицій в соціальних мережах.

Ключові слова: *колаборативна фільтрація, неявний зворотній зв'язок, рекомендаційні підсистеми, персоналізація продажу, електронна комерція.*

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УСОВЕРШЕНСТВОВАНИЕ МЕТОДА КОЛАБОРАТИВНОЙ ФИЛЬТРАЦИИ С УЧЕТОМ ХАРАКТЕРИСТИК ПОТРЕБИТЕЛЯ ДЛЯ ПЕРСОНАЛИЗАЦИИ РЕКОМЕНДАЦИЙ В СИСТЕМЕ Е-КОММЕРЦИИ

Аннотация. Цель статьи. Целью статьи является усовершенствование метода коллаборативной фильтрации с неявной обратной связью путем комбинирования характеристик потребителя и его поведения для повышения эффективности построения рекомендаций в случаях отсутствия или недостаточного количества информации о предпочтениях потребителя.

Методы исследования. Методы коллаборативной фильтрации с неявной обратной связью в процессе персонализации продаж.

Основные результаты исследования. Рассмотрено проблему усовершенствования метода коллаборативной фильтрации с неявной обратной связью для персонализации продаж в рекомендательной подсистеме в системе электронной коммерции с учетом характеристик потребителя и особенностей его поведения при выборе товаров и услуг. Показана важность использования дополнительных контекстных фильтров для повышения качества полученных рекомендаций. Показано, что существующие гибридные методы коллаборативной фильтрации учитывают отдельно характеристики потребителя или характеристики предметной области. В то же время в ситуациях «холодного старта» для персонализации продаж существует практическая потребность в построении рекомендаций с учетом изменений интересов пользователей различных демографических групп. Усовершенствован гибридный метод коллаборативной фильтрации. Основная идея усовершенствованного метода заключается в дополнении алгоритма коллаборативной фильтрации с неявной обратной связью учетом атрибутов пользователя, а также динамики смены его интересов. В качестве исходных данных метод использует информацию о покупках без рейтингов пользователей и с указанием даты покупок, а также демографическую информацию о пользователе. Эта информация может быть получена из других подсистем системы электронной коммерции. Результатом работы метода является уточненный список рекомендованных покупок для пользователя. Этот список соответствует возрастной группе пользователя и контекстно-зависимой последовательности изменения его интересов.

Научная новизна. Усовершенствован метод коллаборативной фильтрации с неявной обратной связью путем учета дополнительных признаков пользователей, а также изменения интереса потребителей во времени.

Практическая значимость. В практическом плане предложенный метод позволяет увеличить релевантность рекомендаций при персонализации продаж для пользователя в рекомендательной подсистеме в системе электронной коммерции. Экспериментальная проверка показала повышение эффективности полученных рекомендаций согласно критерию AUC. Усовершенствованный метод может использоваться также при продвижении рекламных предложений в социальных сетях.

Ключевые слова: *коллаборативная фильтрация, неявная обратная связь, рекомендательные подсистемы, персонализация продаж, электронная коммерция.*

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DEVELOPMENT OF INFORMATION TECHNOLOGY TO SUPPORT MANAGEMENT DECISIONS USING THE PROBABILISTIC INFERENCE IN A TEMPORAL KNOWLEDGE BASE

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Abstract. The purpose of the article. The purpose of the article is to develop a technology for the support of management decisions in the conditions of uncertainty based on the probabilistic output in the temporal knowledge base. The technology provides an increase in the effectiveness of organizational management at the tactical and strategic levels of the organizational hierarchy.

Research methods. Methods of decision-making support, methods of probabilistic inference in the knowledge base.

The main results of the research. The problem of construction of managerial decisions in the conditions of uncertainty is considered. This problem is related to the discrepancy between the practical need for management decision making using knowledge bases and the capabilities of existing knowledge-based methods that use only causal relationships. An analysis of the structure of the process of preparation of management decisions was made. It is shown that the general structure of the process of making managerial decisions involves a consistent solution to the tasks of preparing and implementing a solution. When solving the task of preparing a solution, a set of possible managerial decisions is formed. The task of realization of the decision involves its choice and implementation. Structuration of temporal dependencies in the structure of the management solution is performed. The method of generalization of temporal dependences is developed. The technology of management decision support using the temporal knowledge base is suggested. The developed technology allows you to build many alternative managerial decisions in the form of controlling impacts or the corresponding sequence of states of the control object with the estimation of the probability of implementation of each of the alternatives of management decisions. The resulting set of alternative management solutions is a complex management solution and may be associated with a certain level of organizational hierarchy. This provides the opportunity to form a comprehensive management solution both at the level of individual units and at the organizational level as a whole.

Scientific novelty. The method of generalization of temporal dependencies is proposed, which, based on the transformation of the input temporal rules at the level of separate control actions and taking into account the hierarchy of context

artifacts, enables to construct rules for a given level of the context hierarchy. The technology of support of managerial decisions as sequences of actions on the basis of probabilistic output in the temporal basis of knowledge is proposed.

Practical significance. Technology provides more effective management decisions in uncertainty due to the choice of the most probable sequences of control actions by the decision maker.

Keywords: *management decision, decision support, temporal dependence, temporal knowledge base.*

Problem statement.

The process of making managerial decisions is carried out in conditions of uncertainty at the strategic and tactical levels of enterprise management. This process consists of a consistent solution to the tasks of finding and selecting and implementing solutions. In solving the first problem, it is necessary to identify an abnormal situation and formulate a set of alternative solutions to get out of this situation. This task is labor-intensive due to the need to build possible solutions in the absence of complete information on the state of the object of management. It is decided taking into account the knowledge of the decision maker. Therefore, knowledge-based approaches are used to support managerial decisions. According to the above mentioned approaches, a logical output in the knowledge base is used to form the set of alternatives to managerial decisions. The managerial decision includes an algorithm for executing control actions that has temporal characteristics, that is, the terms of execution, the duration of individual actions, and so on. This testifies to the urgency of developing methods and technology to support managerial decisions based on the output in the knowledge base, taking into account the temporal aspect of management decisions.

Analysis of recent research and publications.

In tactical decision support systems modeling and knowledge-based approaches are applied at the tactical level of organizational management. The latter implies the use of logical derivation in knowledge bases [1]. Traditionally, such knowledge bases contain causal relationships. To remove these dependencies, communicative methods [2] are used, which are intended to transform the implicit knowledge of experts by default [3]. Deleting such knowledge requires a lot of time and additional checks for inconsistency. An alternative approach to decision support is the seizure and use of built-in knowledge [4]. This makes it possible to continuously replenish the BR in an automated way [5].

However, existing approaches to using embedded knowledge are focused on information retrieval and information systems [6] and do not include temporal dependencies. At the same time, such dependencies determine the sequence of processing the constituents of the control object - artifacts and, therefore, are important in constructing a managerial decision as a sequence of control actions [7].

Thus, there is a discrepancy between the need to formulate managerial decisions using knowledge bases and the capabilities of existing knowledge-based methods that use only causal relationships.

The aim of the study.

The purpose of the article is to develop a technology to support management decisions under uncertainty on the basis of probabilistic output in the temporal knowledge base for improving the effectiveness of organizational management at the tactical and strategic levels of the organizational hierarchy.

To achieve the goal, the following tasks are solved:

- analysis of the structure of the process of preparing management decisions;
- structuring of temporal dependencies in the structure of management decision;
- development of the method of generalization of temporal dependencies;
- formation of information technology supporting management decisions using developed methods and models.

Presentation of research material.

The proposed technology integrates a number of models and methods developed by the author [8-11]. It is based on a generalization of the process of making managerial decisions.

The general structure of the decision-making process involves the consistent solution of the tasks of preparing and implementing the decision (Fig. 1).

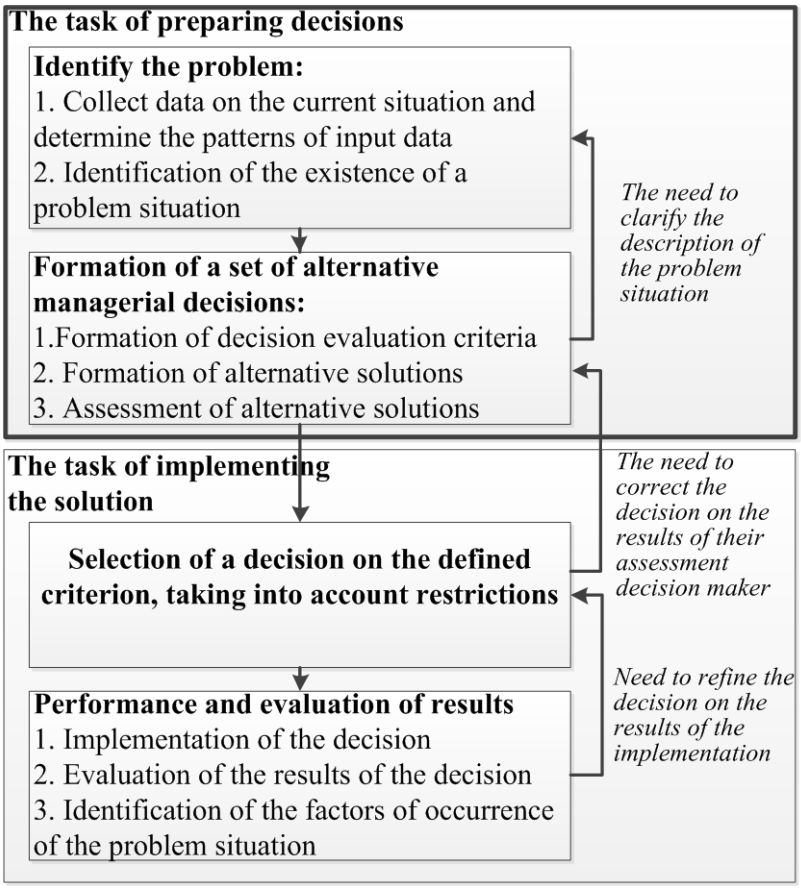

Fig. 1 – Generalized decision-making process

When solving the problem of preparing a solution, a set of possible managerial decisions is formed. Preparation of solutions consists of identifying a problem situation. Initially, the collection of data on the status of the organizational system. The result is context-sensitive data patterns that allow you to identify a problem situation. Then a set of alternative managerial decisions is being made. At this stage, the criteria for evaluating these decisions, the set of alternative solutions in the form of ordered sets of actions, as well as the estimation of each of these decisions by the determined criterion, are formed.

The task of implementing the solution involves the choice and implementation of the solution. The choice of rational or limited-rational decision is performed by the ODA according to the defined evaluation criterion and the existing restrictions.

The implementation of the solution consists in its implementation (coordination and implementation), the evaluation of the results, as well as the analysis of the cause of the problem situation.

To solve the problems are:

- Data characterizing the state of the organizational system;

- Formalized explicit knowledge about objects and processes of management, for example, their models;

- Informal knowledge about context-dependent patterns of functioning of the object of management; such knowledge reflects the experience of staff and depends on the level of the hierarchy in the organizational structure of the enterprise.

The analysis of the process of making managerial decisions makes it possible to make such conclusions. First, for the decision maker to make effective decisions, it is necessary to have a set of pre-prepared and evaluated criteria for management decisions. Secondly, the preparation of a spectrum of all possible managerial decisions for the problem situation, as well as the identification of

data patterns and this situation is carried out under uncertainty and therefore requires considerable resources.

Thus, recognizing the problem situation and forming a set of possible management decisions in this situation is a "bottleneck" of the considered process, which determines the relevance of their automated support. In this case, it is necessary to take into account the uncertainty not only about the values of the parameters of the organizational system as an object of management, but also on the management process. The second component of uncertainty relates to the use of ODA and performers of informal personal knowledge when selecting and implementing managerial decisions at tactical and strategic levels of management. This indicates the importance of using knowledge-oriented decision support with the ability to quickly replenish the knowledge base with the personal knowledge of the performers.

The structure of a management decision in the form of a context-dependent sequence of control actions, between which there are temporal and contextual dependencies, is shown in Fig. 2.

The managerial decision Π_i includes a sequence of control actions that corresponds to the transitions between the states of the control object.

$$\Pi_i = \left\langle u_{i,1}^0, ..., u_{i,j+1}^{i,j}, ..., u_{aim}^{i,J} \right\rangle : u_{i,j+1}^{i,j} \to \pi_{i,j+1}^{i,j}, \pi_{j+1}^{j} = \left\langle s_j, s_{j+1} \right\rangle, \quad (1)$$

where $u_{i,j+1}^{i,j}$ - management action i - managerial decision; $s_{i,j+1}$ - j - state of the object of management, in the implementation i - management decision; π_{j+1}^{j} - transition between the states of the control object.

On the set of states $S = \{s_j\}$ a subset of allowable transitions between states is given $\Pi = \{\pi_{j+1}^{j}\} \subseteq S \times S$.

Each permissible conversion can be used in one or more alternative management options. Then, if we know a few variants Π_i, then we can form weighted temporal dependences $R_i = \{r_{i,j+1}^{i,j}\}$ for each managerial decision. Subsequently, these dependencies can be used to build new managerial decisions Π_i^*.

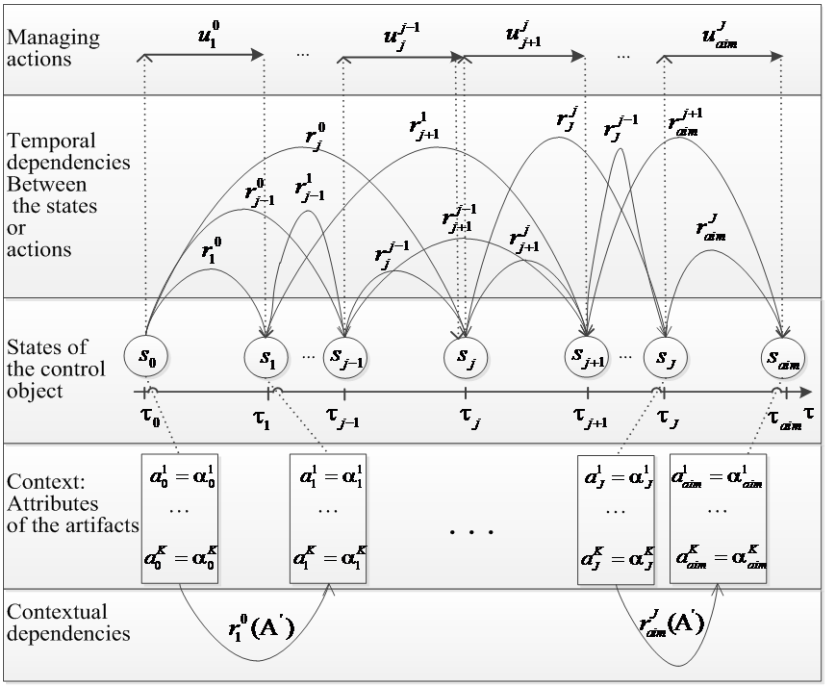

Fig. 2 - Temporal dependencies in the structure of management decision

That is, the general approach to maintaining managerial decisions based on temporal dependencies is to formulate rules $r_{i,j+1}^{i,j}$ for known decision variants, and to further use these rules to construct new alternate sequences of control actions. The result of support is a comprehensive management solution in the form of:

$$\mathcal{M}_U = (S = \{s_0, \{s_j\}, s_{aim}\}, \Pi = \{\Pi_i\}, R, L), \quad (2)$$

where $R = \{R_i\}$ – set of temporal rules; L - evaluation of temporal rules that determines their weights for given transitions between states S.

Each state is characterized by a set of attributes $s_j = \{a_j^k\}$ for which values α_j^k are given. Each of the attributes specifies the properties of elementary objects that are part of the control object. According to IBM terminology, such objects are called artifacts.

Temporal rules, as shown in Fig. 2, specify the relationship between the states of the object of management in general, or for a subset of properties of these states.

In [11], the temporal type rules X (NeXt) for the sequence of control actions, F (Future) for actions between which there are other actions, as well as context-sensitive rules of the type U (Until), are proposed and used.

The proposed technology uses the above-mentioned management decision structure, the temporal rules, probabilistic derivation methods [9, 10] and is based on the method of maintaining management decisions under conditions of uncertainty based on temporal knowledge.

The method of support of managerial decisions takes into account the level of organizational hierarchy based on the use of the results of the method of generalization of temporal dependencies.

The method of generalizing temporal dependencies allows you to construct rules for a given level of the context hierarchy.

The input method of the method is the set of artifacts (elementary objects) Af^0 that correspond to the current level of the hierarchy of the context of executing actions on the control object.

This level of hierarchy can be set, for example, through one of the levels of organizational management. This level defines the appropriate set of artifacts. So, the definition of a specific unit causes a set of artifacts belonging to this unit: documents, equipment, performers, etc.

The method includes the following steps:

Stage 1. Selection of a subset of artifacts Af^* that determines the states of an object of management at a given level of the context hierarchy Af^0.

At this stage, the artifacts that belong only to the subset Af^0 specified in the input data are selected. For example, if an employee performs work in several divisions of an enterprise, then only the artifacts with which he works in the unit Af^0 will be selected.

This stage is performed in the case when the list of artifacts in the input data is not explicitly defined.

Stage 2. Selection of a subset of states S^* of the control object for a subset Af^*. The condition for selection of states S^* is as follows:

$$S^* = \{s_0, \{s_j^*\}, s_{aim} : \forall a_j^k \in s_j^* \; \exists a_n^l = a_j^k, a_n^l \in af_n^*, af_n^* \in Af^*\}, \quad (3)$$

where a_n^l – attribute of the artifact af_n^*.

Step 3. Formation of the rules of the type X (NeXt) for the specified level of the context hierarchy.

The purpose of this stage is to combine rules from the lower levels of the hierarchy into one rule at a given hierarchical level.

Step 3.1. Converts the rules of type F (Future) to rules of type X in the case if the initial and final states are set at the level Af^0.

Step 3.2. The combination of sequential rules X into one rule X is performed for the case if the intermediate states do not correspond to the level Af^0.

Stage 4. Formation of the F (Future) rules for the specified level of the context hierarchy.

This step is performed similarly to step 3.2 and differs only with the type of rules.

Step 5. Formation of rules of type U (Until) for the specified level of the context hierarchy.

At this stage, rules are set with contextual conditions only for a given level of the context hierarchy.

Stage 6. Calculate the weight of the received rules.

The method of supporting managerial decisions includes the stages of analysis of the current situation and the formation of a comprehensive management solution.

At the stage of the situation analysis, the selection of the sequence of states that led to the current state s_j, the formation or selection of temporal dependences for this sequence of states, the comparison of the weight of the received dependences with the total weight of the temporal rules corresponding to the alternative management decision, that is, the alternative sequence of control actions, is performed. By comparison, the presence or absence of an atypical (abnormal) situation is detected. It is believed that the situation is abnormal in the case of a significant deviation of the weight of the temporal rules. Since the weight of the temporal rules is determined depending on the likelihood of their use, this stage allows you to distinguish between unlikely situations. Such situations are considered as abnormal at the next stage.

At the stage of forming a complex managerial decision on the temporal knowledge base, the rules are selected taking into account the specified level of the context hierarchy. Using these rules creates a set of alternative sequences of actions, which is part of a comprehensive management solution. Each sequence is evaluated based on the weight of the temporal rules that it describes.

In the case that the current situation is abnormal, the temporal dependences for the state s_j are formed at subsequent stages. After an optional semantic verification, the resulting dependencies are added to the database.

The technology of support for managerial decisions based on the probabilistic inference in the temporal knowledge base as inputs uses information about the current state of the control object. The technology includes the following steps.

Stage 1. Analysis of the current state of the control object, taking into account the temporal dependencies.

At this stage the verification of the typical or non-typical of the current state is performed using the method [8]. The main idea of the test is to compare the weight of the temporal rules for the current and alternative state sequences. The current sequence of control actions has led to the current state of the control object. Alternative sequences reflect the possible successful implementation of managerial decisions.

In the case of a typical current state of implementation of other stages of technology is unnecessary. Stage 1 will be cycled every time a new state occurs.

If the current state is non-standard, then a new management solution needs to be implemented.

Stage 2. Verification of the organizational hierarchy level.

At this stage, the choice of probabilistic method is performed. In the event that the condition $Af \equiv Af^0$ is fulfilled, you must go to step 3. Otherwise, the transition to step 4 is performed.

Note that the implementation of the above condition indicates the choice of a detailed solution that reflects all operations on the processing of artifacts at the level of individual performers.

If the condition is not fulfilled, then the solution is formed at a given level of the organizational hierarchy.

Stage 3. Formation of a detailed integrated management solution using the method [9].

After completing this stage, you will be transitioning to step 6.

Stage 4. Specification of temporal rules for a given level of the hierarchy.

This stage is preparatory to the formation of a comprehensive management solution and involves a generalization of temporal dependencies for a given level of the hierarchy considered by the above method.

Stage 5. Formation of a comprehensive management solution for a given level of the hierarchy by the method [10].

Stage 6. Semantic verification and selection of management decisions.

At this stage, from an ordered subset of decisions that were formed as a result of probabilistic output, decisions whose semantics does not correspond to the subject domain are excluded.

Conclusions.

The proposed method of generalization of temporal dependencies implements the transformation of input temporal rules at the level of separate control actions into rules for a given level of the context hierarchy, taking into account the hierarchy of context artifacts, which makes it possible to construct a hierarchy of managerial decisions according to the organizational structure of the control object.

The developed technology of support of managerial decisions on the basis of probabilistic output in the temporal knowledge base uses the model of management decision, the method of decision support using the temporal knowledge base, the method of generalizing the objects of the control object, the method of detecting abnormal states, and also the methods of probabilistic conclusion in the temporal knowledge base.

Technology makes it possible to build a set of alternative managerial decisions in the form of control actions or an appropriate sequence of states of the management object, with the estimation of the probability of implementing each of the alternatives of management decisions. The resulting set of alternatives to managerial decisions is a complex management solution and can be linked to a certain level of organizational hierarchy.

Technology provides more effective management decisions in uncertainty due to the choice of the most probable sequences of control actions by the decision maker.

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РОЗРОБКА ІНФОРМАЦІЙНОЇ ТЕХНОЛОГІЇ ПІДТРИМКИ УПРАВЛІНСЬКИХ РІШЕНЬ НА ОСНОВІ ЙМОВІРНІСНОГО ВИВОДУ В ТЕМПОРАЛЬНІЙ БАЗІ ЗНАНЬ

Анотація. Мета статті. Метою статті є розробка технології підтримки управлінських рішень в умовах невизначеності на основі ймовірнісного виводу в темпоральній базі знань для підвищення ефективності організаційного управління на тактичному та стратегічному рівнях організаційної ієрархії.

Методи дослідження. Методи підтримки прийняття рішень, методи ймовірнісного виведення в базі знань.

Основні результати дослідження. Розглянуто проблему побудови управлінських рішень в умовах невизначеності. Ця проблема пов'язана із невідповідністю між практичною потребою формування управлінських рішень з використанням баз знань та можливостями існуючих знання-орієнтованих методів, що використовують лише причинно-наслідкові залежності. Виконано аналіз структури процесу підготовки управлінських рішень. Показано, що узагальнена структура процесу прийняття управлінських рішень передбачає послідовне вирішення задач підготовки та реалізації рішення. При вирішенні задачі підготовки рішення виконується формування множини можливих управлінських рішень. Задача реалізації рішення передбачає його вибір та імплементацію. Виконано структуризацію темпоральних залежностей у структурі управлінського рішення. Розроблено метод узагальнення темпоральних залежностей. Запропоновано технологію підтримки управлінських рішень з використанням темпоральної бази знань. Розроблена технологія дає можливість побудувати множину альтернативних управлінських рішень у вигляді послідовностей управляючих дій або відповідних послідовностей станів об'єкту управління з оцінкою ймовірності реалізації кожного із альтернативних варіантів управлінських рішень. Отримана множина альтернативних варіантів управлінських рішень складає комплексне управлінське рішення та може бути зв'язана із визначеним рівнем організаційної ієрархії. Це дає можливість сформувати комплексне управлінське рішення як на рівні окремих підрозділів, так і на рівні організації в цілому.

Наукова новизна. Запропоновано метод узагальнення темпоральних залежностей, який на основі перетворення вхідних темпоральних правил на рівні окремих управляючих дій та з урахуванням ієрархії артефактів контексту дає можливість побудувати правила для заданого рівня контекстної ієрархії. Запропоновано технологію підтримки управлінських рішень як послідовностей дій на основі ймовірнісного виводу в темпоральній базі знань.

Практична значимість. Розроблена технологія забезпечує більш ефективне прийняття управлінських рішень в умовах невизначеності за рахунок вибору найбільш ймовірних послідовносте управляючих дій особою, що приймає рішення.

Ключові слова: *управлінське рішення, підтримка прийняття рішень, темпоральна залежність, темпоральна база знань.*

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РАЗРАБОТКА ИНФОРМАЦИОННОЙ ТЕХНОЛОГИИ ПОДДЕРЖКИ УПРАВЛЕНЧЕСКИХ РЕШЕНИЙ НА ОСНОВЕ ВЕРОЯТНОСТНОГО ВЫВОДА В ТЕМПОРАЛЬНОЙ БАЗЕ ЗНАНИЙ

Аннотация. Цель статьи. Целью статьи является разработка технологии поддержки управленческих решений в условиях неопределенности на основе вероятностного вывода в темпоральной базе знаний. Технология обеспечивает повышения эффективности организационного управления на тактическом и стратегическом уровнях организационной иерархии.

Методы исследования. Методы поддержки принятия решений, методы вероятностного вывода в базе знаний.

Основные результаты исследования. Рассмотрена проблема построения управленческих решений в условиях неопределенности. Данная проблема связана с несоответствием между практической потребностью формирования управленческих решений с использованием баз знаний и возможностями существующих знание-ориентированных методов, использующих только причинно-следственные зависимости. Выполнен анализ структуры процесса подготовки управленческих решений. Показано, что обобщенная структура процесса принятия управленческих решений предполагает последовательное решение задач подготовки и реализации решения. При решении задачи подготовки решения выполняется формирование множества возможных управленческих решений. Задача реализации решения предусматривает его выбор и имплементацию. Выполнена структуризация темпоральных зависимостей в составе управленческого решения. Разработан метод обобщения темпоральных зависимостей. Предложена технология поддержки управленческих решений с использованием темпоральной базы знаний. Разработанная технология позволяет построить множество альтернативных управленческих решений в виде последовательностей управляющих воздействий или соответствующих последовательностей состояний объекта управления с оценкой вероятности реализации каждого из альтернативных вариантов управленческих решений. Полученное множество альтернативных вариантов управленческих решений составляет комплексное управленческое решение и может быть связано с определенным уровнем организационной иерархии. Это дает возможность сформировать комплексное управленческое решение как на уровне отдельных подразделений, так и на уровне организации в целом.

Научная новизна. Предложен метод обобщения темпоральных зависимостей, который на основе преобразования входных темпоральных правил на уровне отдельных управляющих действий и с учетом иерархии артефактов контекста дает возможность построить правила для заданного уровня контекстной иерархии. Предложена технология поддержки управленческих решений как последовательностей действий на основе вероятностного вывода в темпоральный базе знаний.

Практическая значимость. Технология обеспечивает более эффективное принятие управленческих решений в условиях неопределенности за счет выбора наиболее вероятных послидовносте управляющих действий лицом, принимающим решения.

Ключевые слова: *управленческое решение, поддержка принятия решений, темпоральная зависимость, темпоральная база знаний.*

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INFORMATION TECHNOLOGIES OF FORMATION OF THE CONTENT OF DISCIPLINES AND OPTIMIZATION OF THE CURRICULUM OF THE SPECIALTY

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Abstract. The main purpose of the higher education system is the professional training of highly qualified specialists in accordance with the social order. Therefore, it is the professional activity of specialists that sets and defines the goals of studying all academic disciplines, and hence the content, structure and forms of the corresponding educational activities of students preparing for future professional work. In this context, of great importance is the formation of a variable part of the curriculum specialty. The variable part provides an opportunity to expand and (or) deepen the knowledge and skills determined by the content of the basic disciplines, allows the student to gain in-depth knowledge and skills for successful professional activity and (or) to continue professional education in the master's degree. The disciplines of the variable part of the curriculum of the specialty must meet a number of indicators: the importance of the discipline in the system of training of specialists in this profile; the content of the discipline material (scientific level, depth of presentation); methodical level of presentation (logic of material placement, clarity of presentation) and others.

Since Universities and experts of this profile of professional activity are scattered throughout Ukraine and it is not always possible to collect them in one place, proposed to use the Internet survey system to collect the necessary expert assessments with their subsequent processing.

The article proposes an approach to the formation of the content of academic disciplines of the University using a systematic approach that reflects the main didactic indicators of the educational process. The proposed approach to the formation and optimization of the variable part of the curriculum of the specialty is universal to solve such problems in various fields of human activity. There are no restrictions on the number of experts, indicators of the quality of the studied objects. The main problem is the multi-criteria nature. When a small number of criteria, this problem solved on the paired dominance of the criteria as shown in this article. With a large number of criteria proposed to use a linear convolution. At the same time, the use of the Internet survey system allows you to connect a wide range of experts to increase the confidence probability of the optimality of the results.

Keywords: *optimization, training plan, Internet survey, expert estimations, linear convolution, the Pareto set.*

Problem statement. The education system in Ukraine has entered a period of fundamental changes, characterized by a new understanding of the goals and values of education, awareness of the need to move to the widespread use of computer technology for the formation of the material of academic disciplines of the University.

According to the national program "Education Ukraine of XXI century" the main goal of the higher education system is the professional training of highly qualified specialists in accordance with the social order. Therefore, it is the professional activity of specialists that sets and defines the goals of studying all academic disciplines, and hence the content, structure and forms of the corresponding educational activities of students preparing for future professional work. That is why research aimed at the study of professional activity and the development of a "portrait" of a specialist of a particular profile are now of particular importance. The practical result of such studies was the creation of qualification characteristics of specialists with higher education. The characteristics describe the main activities of the specialist, his functional responsibilities, the requirements for his training. Preparation of qualification characteristics is an important step in solving the problem of formulating the goals of training and determining the content of his professional activity

In this context, of great importance is the problem of formation informative content of academic disciplines in the field of selected specialties. Currently, there are many works devoted to the study of this problem, in particular [1-3]. However, due to the specifics of the subjects studied, most of them are highly specialized. Nevertheless, it is possible to approach the formation of the content of academic disciplines of the University from a single system positions, reflecting the main didactic indicators of the educational process. In this sense, it is necessary to create universal targets for different subjects, forms of presentation of theoretical material and models of its assimilation, a system of criteria for objective control and evaluation of knowledge of the student. This paper proposes one of the solutions to this problem.

In addition, it is important to optimize the curriculum of the specialty. This gives the opportunity to expand and (or) deepen the knowledge, skills and abilities determined by the content of the basic disciplines, allows the student to gain in-depth knowledge and skills for successful professional activity and (or) to continue professional education in the master's degree. The disciplines of the curriculum of the specialty must meet a number of indicators, such as: the importance of discipline in the system of training of specialists in this profile; content of the discipline material (scientific level, depth of presentation); methodical level of presentation (logic of material placement, clarity of presentation) and others.

The most preferable method for the formation and optimization of such a plan is the method of expert assessments [5]. In this case, the optimal qualitative composition of disciplines curriculum will be the result of collective work of experts in the field of future activities of students of this specialty, and specialists of higher education with high competence in relation to the selected indicators of quality of academic disciplines

Since Universities and experts of this profile of professional activity is scattered throughout Ukraine and it is not always possible to collect them in one place, it is proposed

to use the Internet survey system to collect the necessary expert assessments with their subsequent processing by the method proposed below.

Form of presentation and model of learning. There are four forms of presentation of educational material corresponding to different levels of abstraction in the description:

- Phenomenological (descriptive) level;
- Analytical and logical level;
- Mathematical level;
- Axiomatic level.

The form of presentation of educational material depends on the specific subject area. However, for any of the above forms, a universal model for the development of educational material is proposed. This model of educational material shows the sequence of the study of all topics and the logical links between them [4].

At the initial stage of designing the training course, the training material planned for study divided into separate training elements.

In the model included the relationship matrix of the sequence and logical relationships of the educational elements, the sequence of learning topics, count logical links of training elements.

The construction of the model carried out in four stages:

- Formation of the matrix of priority relations of educational elements;
- Building a sequence of learning elements of educational content
- Formation of the matrix of logical connections of educational elements;
- Construction of a graph of logical connections of educational elements.

The size of the square matrix of relations of sequence and logical relations of elements equals to the number of training elements. First, empty matrices are constructed, and their rows and columns numbered according to the number of training elements (see Fig. 1 and Fig. 2). Then the matrix cells filled with zeros and ones row by row.

	1	2	3	4	5	6	7	8	9	10	Σ
1	1	1	1	1	1	1	1	1	1	1	10
2	0	1	0	0	1	1	1	1	1	1	7
3	0	1	1	0	1	1	1	1	1	1	8
4	0	1	1	1	1	1	1	1	1	1	9
5	0	0	0	0	1	0	1	1	1	1	5
6	0	0	0	0	1	1	1	1	1	1	6
7	0	0	0	0	0	0	1	0	0	0	1
8	0	0	0	0	0	0	1	1	0	0	2
9	0	0	0	0	0	0	1	1	1	0	3
10	0	0	0	0	0	0	0	1	1	1	3

Fig. 1. Relationship matrix of the sequence of training elements

	1	2	3	4	5	6	7	8	9	10
1	0	1	1	1	0	0	0	0	0	0
2	0	0	0	0	1	1	0	0	0	0
3	0	1	0	0	1	1	0	0	0	0
4	0	1	1	0	0	1	0	0	1	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	1	0	1	1	1	1
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	0	0	0
9	0	0	0	0	0	0	1	0	0	0
10	0	0	0	0	0	0	1	0	0	0

Fig. 2. Matrix of logical connections of educational elements

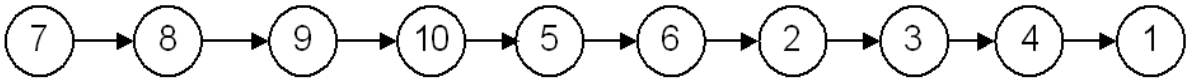

Fig. 3. Sequence of learning elements

When filling in the cells of the matrix, the sequence relationships analyze the sequence relationship between the two training elements. The unit put in the cell if the training element specified in the row number studied after the training element specified in the column number. The opposite relation of precedence denoted by zero. All cells of the main diagonal of the matrix of sequence relations filled with units. Matrix cells that are symmetric about the main diagonal must have opposite values. Therefore, the analysis of the pair sequence relations carried out only for the lower left or for the upper right triangle of the matrix, filling its remaining part on the anti-symmetry property. When filling in the matrix of logical connections we must put the unit in a cell, if the educational topic specified in the row number logically linked with the educational topic in column number. Drawing up a matrix of logical relations is convenient to conduct on the basis of the matrix of priority relations by excluding units from those cells for which there are no logical, reference links between the elements (Fig.1, Fig.2). The process of filling in the matrices is advisable to conduct, having before the eyes of the texts with educational material for all educational elements. The analysis of the content of the educational material allows reveal more objectively the pair relations of priority and logical connections between educational elements.

Not only objective but also subjective factors of the experts have an impact on the form of matrices of priority relations and logical connections, and, consequently, on the form of presentation of educational material.

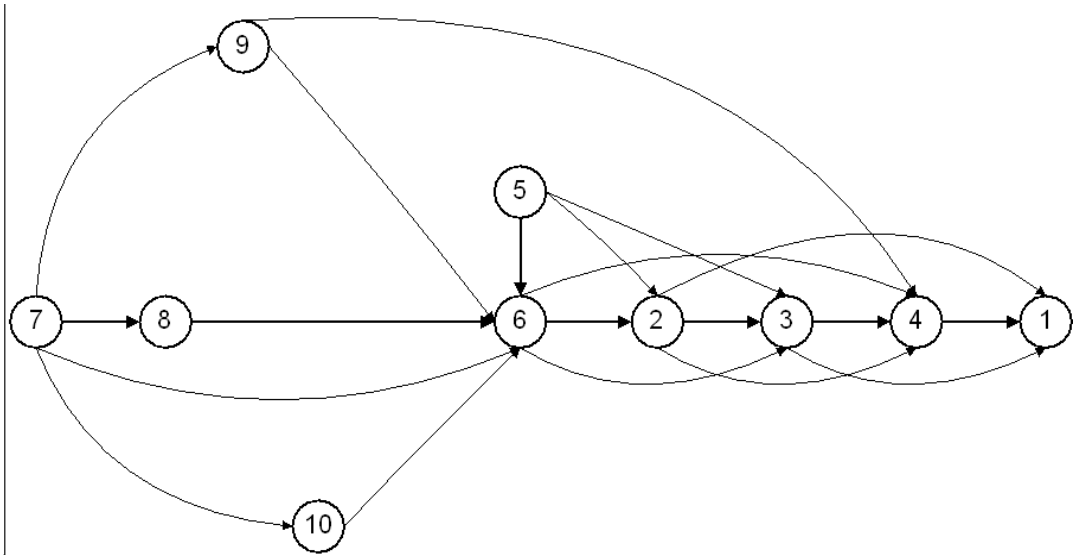

Fig. 4. Graph of logical connections

The sequence of studying the elements in the training procedure is determined in the process of processing the matrix of priority relations, summing up the coefficients of each row of the matrix. The totals recorded in the column to the right of the matrix (Fig.1). The values of the sums indicate the sequence numbers of the corresponding training elements in the list of the sequence of study of the training material (Fig.1, in Fig.3). Logical connections of educational elements displayed for clarity in the form of a directed graph (Fig. 4). A graph builds on the matrix of logical connections of educational elements.

The edges of the graph logical connections indicate the reference links between the educational elements. For example, the link between of a training element 2 and training

elements 5 and 6 (Fig.4), shows that in order to master the content of the training material from the training element 2, it is necessary to first study the material of the training elements 5 and 6. The model of development of the educational material determines the sequence of its presentation in the learning system, variants of the trajectories of its study, logical connections in the construction of hypertext. The complete graph of logical connections constructed similarly to the complete matrix of logical connections.

Optimization of curricula of specialties. Let there be N academic disciplines offered for inclusion in the curriculum of the specialty, M - the number of experts interviewed via the Internet, a specific discipline (training course) will be designated through k_i ($i = \overline{1, N}$).

We must select L disciplines ($L < N$) that meet the selected quality indicators J_k ($L < N$).

By the Internet survey system enters the experts 'assessments in the table of academic disciplines' grade grades (table. 1).

Here r_{ij}^k - rank (assessment) of the i-th discipline (*i*=1, . .,N) of j-th expert (*j*=1,…,M) by k-th quality indicator (k=1,...Q). The rank is a natural number in the accepted score scale.

Table 1

Assessments of experts

Quality indicator	J_1				…	J_Q			
Discipline / Expert	k_1	…	…	k_N	…	k_1	k_2	…	k_N
$Э_1$	r_{11}^1	…	…	r_{1N}^1	…	r_{11}^Q	r_{12}^Q	…	r_{1N}^Q
$Э_2$	r_{21}^1	…	…	r_{2N}^1	…	r_{21}^Q	r_{22}^Q	…	r_{2N}^Q
…	…	…	…	…	…	…	…	…	…
$Э_M$	r_{M1}^1	…	…	r_{MN}^1	…	r_{M1}^Q	r_{M2}^Q	…	r_{MN}^Q
The sum of the ranks	$\sum_1^1$	…	…	$\sum_N^1$	…	$\sum_1^Q$.	$\sum_2^Q$	…	$\sum_N^Q$
Average rank	$\overline{r}_1^1$	…	…	$\overline{r}_N^1$	…	$\overline{r}_1^Q$	$\overline{r}_2^Q$	…	$\overline{r}_N^Q$

The sum of ranks and the average rank are determined according to the formulas:

$$\sum_i^k = \sum_{j=1}^M r_{ij}^k \quad . \tag{1}$$

$$r_j^k = \frac{1}{M} \sum\nolimits_j^k \quad . \tag{2}$$

Without losing the generality of the result, let us assume that we have 7 academic disciplines, which as a result of ranking the experts ' assessments on the indicators of the content of the material (J_1) and the methodological level of presentation (J_2) formed the following system of inequalities relative to the average rank of the discipline:

$$J_1 : k_6 > k_1 > k_2 > k_3 > k_7 > k_5 > k_4 . \quad (3)$$

$$J_2 : k_6 > k_2 > k_1 > k_7 > k_3 > k_5 > k_4 . \quad (4)$$

The meaning of inequalities (3) and (4) lies in the pair preferences of one discipline in relation to another within the chosen quality indicator.

It known that the correctness of the expert estimates obtained during the processing depends on the consistency of the expert group. To assess the consistency of the experts, we calculate the variance coefficient of concordance for the selected quality indicators [6]:

$$W^k = \frac{12S^k}{M^2(N^3 - N) - M\sum_{j=1}^{M} T_j^k} . \quad (5)$$

where

$$S^k = \sum_{i=1}^{N}(\sum_{j=1}^{M} r_{ij}^k - r_0^k) . \quad (6)$$

r_0^k - the average rank score on the k-th indicator

$$r_0^k = \frac{1}{N}\sum \bar{r}_i^k . \quad (7)$$

T_j^k – the index of related ranks in the ranking of the j-th expert, which is defined as:

$$T_j^k = \sum_{p=1}^{H_j}(h_p^3 - h_p) . \quad (8)$$

where: $\mathrm{H_j}$ - number of groups of equal ranks of the j-th expert; $\mathrm{h_p}$ - the number of equal ranks in the p-th group of related ranks when ranked by the j-th expert.

If $\overline{\mathrm{W}}^{\mathrm{k}} \geq 0.7$ the expert group considered to be working in a coordinated manner. Otherwise, the group of experts must restructure.

In addition, it is useful to distinguish between experts by the degree of competence and the importance of their views, i.e. it is necessary to rank the experts themselves. When ranking, each of them is assigned a rank of significance from 1 (the most influential expert) to M (the least influential expert). The opinion of each expert is taken in the calculations with a coefficient proportional to1/m_j, where m_j - the rank of the j-th expert ($j = \overline{1, M}$).

To assess the relationship of ranked disciplines of training courses, we calculate the Spearman rank correlation coefficient [7]:

$$\rho = 1 - \frac{6S}{N^3 - N}. \quad (9)$$

If the value is close to one, it characterizes the linear average relationship between the rankings on the indicators under consideration.

For the two indicators considered in our case, this suggests that the disciplines that have received a high assessment of the content, are highly rated on the methodological level.

Then we perform the ordering of subjects on two quality indicators, the highlighting from the inequalities (3) and (4) consistently dominating subset of (Pareto set). For clarity, we give a graphical interpretation of this approach. For ratios (3) and (4) in Fig. 5 academic disciplines are presented according to table. 1. with a central point, the coordinates of which are determined by the place of the discipline among the disciplines under consideration, according to its average rank.

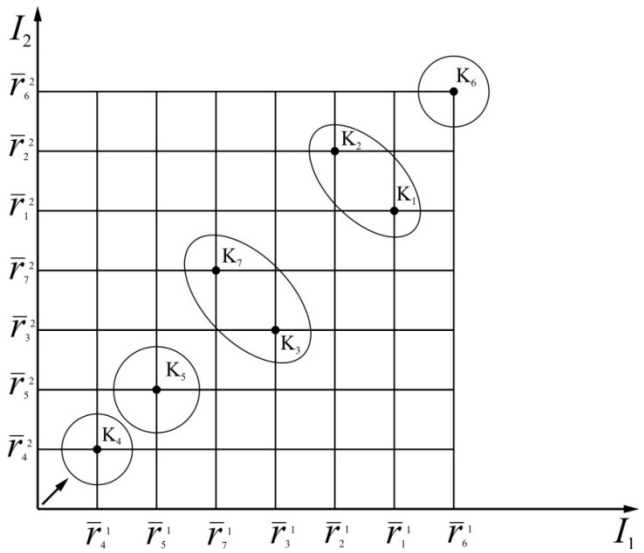

Fig. 5. Graphic interpretation of rank correlation of academic disciplines

Assume that the quality indicators J_1 and J_2 are equal, i.e. the total quality indicator is defined as:

$$J = J_1 + J_2. \quad (10)$$

In this case, the vector of change $\overline{J}$ in the quality index passes at an angle 45^0 (Fig. 5). Then, as can be seen from fig. 5, the Pareto set for the whole set of disciplines includes only one discipline k_6. Excluding discipline from consideration, we again highlight the set of Pareto, which includes two discipline each of these is more effective than any other in both respects, but they are incomparable, because for J_1 $k_1 > k_2$, but for J_2 $k_2 > k_1$.

Continuing this procedure, we get the following chain of preferences of academic disciplines:

$$k_6 > (k_1 k_2) > (k_3 k_7) > k_5 > k_4. \quad (11)$$

Hence, if, for example, we need to choose 5 out of 7 academic disciplines, the disciplines k_5 and k_4 excluded from consideration. If you need to select 4 courses, in addition k_5 and k_4 , we must exclude one of the k_3 or k_7 that can be done by the introduction of an additional indicator. It should note that with this approach, with a large number of indicators and disciplines, the task of forming the optimal variable part of the curriculum of the specialty is significantly complicated, which is associated with the analysis of the hyperspace of quality criteria.

In the case of a multi-purpose problem, it is necessary to find a solution that belongs to the intersection of sets of optimal solutions to all one-objective problems. However, this intersection is usually an empty set, so we should consider the so-called negotiating set of effective solutions (Pareto optimality). The optimality criterion of the Italian economist V. Pareto used in solving such problems, when optimization means improvement of some indicators, that others do not get worse.

We can distinguish the following main methods for solving multi-criteria optimization problems:

1) Optimization by one criterion, which recognized as the most important, while other criteria play the role of additional restrictions;

2) Convolution of many criteria to one by introducing expert weights for each criterion in such a way that the more important criterion gains higher weight;

3) Ordering of a given set of criteria and sequential optimization for each of them (this approach is the basis of the method of successive concessions) [8].

The most common of these methods is the second method, which uses a linear convolution of criteria at each level of the hierarchy. In our case, we can distinguish two levels of hierarchy. At the lower level is formed on the basis of table 1 criterion of assessment by experts of the i-th discipline on the k-th criterion. Let's denote it as E_{ik}. Table 1 shows, what $E_{ik}= \overline{r_i^k}$. Then the criterion of the upper level for the evaluation of the i-th discipline on the set of criteria of the lower level will have the form:

$$J_i = \sum_{k=1}^{Q} \lambda_{ik} E_{ik} . \qquad (12)$$

where λ_{ik} –weight coefficients of importance of the k-th criterion in the evaluation of the i-th discipline, which from table 1 are defined as

$$\lambda_{ik} = \frac{(\sum_{k=1}^{Q} \overline{r_i^k})}{(\sum_{i=1}^{N}\sum_{k=1}^{Q} r_i^k)} . \qquad (13)$$

with

$$\sum_{k=1}^{Q} \lambda_{ik} = 1, \lambda_{ik} \geq 0 . \qquad (14)$$

Taking into account the integer ranking of criteria, which leads to a large range of estimates spread, it is proposed to use a convolution of the relative values of the criteria of i-th disciplines relative to their maximum and minimum values for a more accurate assessment [7,9]. The convolution method consists in solving the problem of minimization of a linear combination with non-negative weighting coefficients denoting the importance of the k-th criterion and satisfying the condition (13):

$$j_i = \sum_{k=1}^{Q} \lambda_{ik} \frac{(E_{ik\max} - E_{ik})}{(E_{ik\max} - E_{ik\min})}. \quad (15)$$

Further, according to the obtained (12) values of the upper level criteria, we rank the list of disciplines in descending order and select the specified number of disciplines in the variable part of the curriculum of the specialty.

Conclusion. This article propose to approach the formation of the content of academic disciplines of the University with a single system positions, reflecting the main didactic indicators of the educational process. In this sense, it is necessary to create universal targets for different subjects, forms of presentation of theoretical material and models of its assimilation, a system of criteria for objective control and evaluation of knowledge of the student. The paper propose a universal approach to optimizing the curriculum of the specialty, based on the methods of expert assessments, and which can be used to solve such problems in various fields of human activity. At the same time, there are no restrictions on the number of experts, quality indicators and studied objects. The main problem is the multicriteria nature of the problem solved. With a small number of criteria solved on the pair dominance criteria as shown in this article. With a large number of criteria proposed to use a linear convolution. At the same time, the use of the Internet survey system allows you to connect a wide range of experts to increase the confidence probability of the optimality of the results.

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ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ ФОРМУВАННЯ КОНТЕНТУ НАВЧАЛЬНИХ ДИСЦИПЛИН І ОПТИМІЗАЦІЇ НАВЧАЛЬНОГО ПЛАНУ СПЕЦІАЛЬНОСТІ

Анотація. Основною метою системи вищої освіти є професійна підготовка фахівців вищої кваліфікації в відповідності з соціальним замовленням. Тому, саме професійна діяльність фахівців задає і визначає цілі вивчення всіх навчальних дисциплін, а значить і зміст, структуру і форми відповідної навчальної діяльності студентів, які готуються до майбутньої професійної роботи. У цьому контексті велике значення набуває формування варіативної частини навчального плану спеціальності. Варіативна частина дає можливість розширення та (або) поглиблення знань, умінь і навичок, визначених змістом базових дисциплін, дозволяє студенту отримати поглиблені знання і навички для успішної професійної діяльності та(або) для продовження професійної освіти в магістратурі. Дисципліни варіативної частини навчального плану спеціальності повинні відповідати цілому ряду показників, таких як: важливість дисципліни в системі підготовки фахівців даного профілю; змістовність матеріалу дисципліни (науковий рівень, глибина викладу); методичний рівень викладу (логіка розміщення матеріалу, ясність викладу) та інші.

Оскільки Вузи, де є дана спеціальність, і фахівці-експерти даного профілю професійної діяльності розкидані по всій Україні і не завжди є можливість зібрати їх в одному місці, пропонується використовувати систему Інтернет-опитування для збору необхідних експертних оцінок з наступною їх обробкою.

У статті пропонується підхід до формування контенту навчальних дисциплін вузу з єдиних системних позицій, що відображають основні дидактичні показники навчального процесу. Запропонований підхід до формування та оптимізації варіативної частини навчального плану спеціальності носить універсальний характер і може бути використаний для вирішення подібних завдань в різних сферах діяльності людини. При цьому немає обмежень на кількість експертів, показників якості та досліджуваних об'єктів. Головна проблема полягає в багатокритеріальності розв'язуваної задачі. При невеликому числі критеріїв вона вирішується на основі парної домінантності критеріїв так, як це показано в даній статті. При великому числі критеріїв пропонується використовувати лінійну згортку. При цьому використання системи Інтернет-опитування дозволяє підключити широке коло фахівців-експертів для підвищення довірчої ймовірності оптимальності отриманих результатів.

Ключові слова: *оптимізація, навчальний план, Інтернет-опитування, експертні оцінки, лінійна згортка, множина Парето.*

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ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ ФОРМИРОВАНИЯ КОНТЕНТА УЧЕБНЫХ ДИСЦИПЛИН И ОПТИМИЗАЦИИ УЧЕБНОГО ПЛАНА СПЕЦИАЛЬНОСТИ

Аннотация. Основной целью системы высшего образования является профессиональная подготовка специалистов высшей квалификации в соответствии с социальным заказом. Поэтому, именно профессиональная деятельность специалистов задает и определяет цели изучения всех учебных дисциплин, а значит и содержание, и структуру, и формы соответствующей учебной деятельности студентов, готовящихся к будущей профессиональной работе. В этом контексте большое значение приобретает формирование вариативной части учебного плана специальности. Вариативная часть дает возможность расширения и (или) углубления знаний, умений и навыков, определяемых содержанием базовых дисциплин, позволяет обучающемуся получить углубленные знания и навыки для успешной профессиональной деятельности и(или) для продолжения профессионального образования в магистратуре. Дисциплины вариативной части учебного плана специальности должны отвечать целому ряду показателей, таких как: важность дисциплины в системе подготовки специалистов данного профиля; содержательность материала дисциплины (научный уровень, глубина изложения); методический уровень изложения (логика размещения материала, ясность изложения) и другие.

Поскольку ВУЗы, где есть данная специальность, и специалисты-эксперты данного профиля профессиональной деятельности разбросаны по всей Украине и не всегда есть возможность собрать их в одном месте, предлагается использовать систему Интернет-опроса для сбора необходимых экспертных оценок с последующей их обработкой.

В статье предлагается подход к формированию контента учебных дисциплин ВУЗа с единых системных позиций, отражающих основные дидактические показатели учебного процесса. Предложенный подход к формированию и оптимизации вариативной части учебного плана специальности носит универсальный характер и может быть использован для решения подобных задач в различных сферах деятельности человека. При этом нет ограничений на количество экспертов, показателей качества и исследуемых объектов. Главная проблема состоит в многокритериальности решаемой задачи. При небольшом числе критериев она решается на основе парной доминантности критериев так, как это показано в данной статье. При большом числе критериев предлагается использовать линейную свертку. При

этом использование системы Интернет-опроса позволяет подключить широкий круг специалистов-экспертов для повышения доверительной вероятности оптимальности полученных результатов.

Ключевые слова: *оптимизация, учебный план, Интернет-опрос, экспертные оценки, линейная свертка, множество Парето*

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MODELING OF COOPERATIVE BEHAVIOR IN MULTIAGENT SYSTEMS

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Abstract. Cooperative behavior is understood as a community of agents who decide to cooperate to reduce the average weighted fines to solve a task or achieve a certain goal, in our case, synchronize the lightning.

The problem of forming cooperative behavior is intensively investigated in modern scientific literature on the use of multi-agent systems, for example, for distance learning, management of organizational systems, the construction of various virtual organizations and communities, management of distributed computing, management of public institutions and socio-economic processes, and others.

In this paper an actual theme of optimal policies in games with local interaction is considered, the stimulating training of multiagent systems in gaming is considered.

The purpose of this work is to consider the method of constructing a system with local interaction of agents based on the task of "synchronization" with the help of the Markov model of stochastic game.

The research method is a computer program for modeling a task using the Q-method of training. Formation of coalitions in multiagent systems is formulated as a competitive or cooperative task of assigning an object to one of the clusters. The problem of solving such problems is the theory of games, and in the conditions of uncertainty the theory of stochastic games. In this regard, from the scientific and practical point of view, the use of stochastic game methods for the formation of coalitions under conditions of incomplete information is relevant. The decision of the stochastic game is to find policies for agents that maximize their winnings to provide a certain collective balance of interests for all players. To find optimal players' policies under uncertainty, we will use the method of stimulating learning.

The result is a developed game model that provides a dynamic MAS self-organization, which manifests itself in the rhythmic change of pure agent policies that mimic the light effects of the colony of fireflies. A characteristic feature of the considered game self-organization is locally defined information about the policies of the behavior of neighboring agents, which as a result of learning leads to global coordination. policy of all agents.

The scientific novelty of the obtained results consists in the development of a gaming model, the effectiveness of the game self-organization of the MAS policies for solving the decision-making problem in systems with co-operative behavior of agents under uncertainty has been determined. The repetition of the values of the characteristics of the game in various experiments with unique sequences of random variables confirms the reliability of the results.

Results can be used in practice to model the dynamics of social processes, management of social Internet services in the Internet and others.

Key words: *multiagent system, stochastic game, adaptive gaming method, Q-method.*

Introduction. Core functionality of most modern information systems (IS) is based on strictly programmed algorithms. Due to unforeseen environmental influences on such systems, stability of operating modes may be affected, which may lead to various types of emergency situations. In order to prevent critical states, distributed IS software should consist of interacting autonomous modules, be intelligent, able to independently monitor changes in the state of the environment and make right in-time decisions. The IS agent is an autonomous software module with elements of artificial intelligence that is able to make decisions on its own, interact with the environment, other agents and user while solving the task. Interaction of IS agents is carried out within the computer network. A population of computer network agents that solve a common task is called the multi-agent system (MAS).

The work of MAS [2, 3], as a rule, is carried out in a state of uncertainty about the state of the environment, decision-making and the actions of other agents[4]. In connection with this policy of conduct, agents must be adaptive due to the ability of agents to self-study. Among methods of teaching in conditions of uncertainty methods based on incentives [5, 6] showed the best results since they do not require a mathematical model of the environment and provide a possible decision directly in the learning process. The basis of encouraging training include mechanisms of reflex behavior of living organisms with the nervous system. An effective method of encouraging learning is the marking of Q-learning [7], which performs the numerical identification of the characteristic system of a dynamic system in the state of action space. As the characteristic feature used, uses the functional expected remuneration.

Compared to single-agent systems, the structure, operation and research of multi-agent Q-learning methods are significantly complicated. Due to the collective interaction of agents, the stationary environment is translated into non-stationary. States changes of the environment and the value of the wins of each agent depends on the actions of other agents. In the general case, the MAS agent can not achieve the maximum winnings which is equal to its winnings in a single-agent system. The optimal benefits of agents must be balanced and meet the criteria of benefit, equity, and equilibrium. So, instead of scalar maximizing the benefits of a single-agent system, the criteria for vector maximization of MAS wins are introduced, for example Nash equilibrium, Pareto efficiency or others.

Under conditions of use of Q-learning methods MAS there is an iterative construction of the system of characteristic Q-functions in the space of state-action, and the growth of the elements of these functions is carried out in the direction of achieving their collective equilibrium.

The purpose of the work is to construct an iterative method of incentive training for solving a stochastic MAS game under uncertainty. In order to achieve the goal, it is necessary to develop a multi-agent stochastic game model, determine the criteria for collective equilibrium, the method and algorithm for solving the game problem.

In order to create an MAS it is necessary to perform preliminary research on the basis of mathematical models that enable to study the dynamics of the system under uncertainty conditions, to construct the policies of the behavior of agents that provide optimal parameters for the functioning of the system. Taking into account the peculiarities of the subject area, namely, multi-agency, uncertainty of the decision-making environment, antagonism or competition of goals, communicative, coordination of actions, adaptive strategies of agents, for the construction of MAS models we use the mathematical apparatus of the theory of stochastic games [6, 7].

The solution to a stochastic game is to seek out strategies of agents that maximize their winnings so as to provide a certain collective balance of interests for all players. To search optimal strategies of players in conditions of uncertainty we will use the method of encouraging learning.

The object of research is the processes of self-organization of multiagent systems under uncertainty, aimed at achieving the coordinated work of the constituent elements of multiagent systems due to the properties of self-study and adaptation, which results in the fact that the distributed system of elements functions as a coherent harmonious organism.

The subject of this work is a stochastic game model of the self-organization of multi-agent systems, which provides a balance of the values of payment functions of the team of players and is manifested in the achievement of coordinated strategies of agents.

The purpose of the work is to build a gaming model of self-organization of multi-agent systems to support decision-making under uncertainty. This goal is achieved by solving next problems: developing a mathematical model of multi-agent stochastic game; development of self-learning method and algorithm for solving stochastic game; development of software for simulation of stochastic game; analysis of the results and recommendations for their practical application.

To achieve the goal, it is necessary to analyze and solve the following problems: collective development and decision making; ensuring coordination and cooperation in the IAU; exploration of the states of the MAS functioning environment; definition of optimal structural organization of MAS; development of methods and means of multi-agent training; development of methods, languages and means of communication agents. The research method is a computer program for modeling a task. The research method is a computer program for modeling a task.

The ideas of the article P.O. Kravets [1] "The game model of self-organization of multi-agent systems" were used, which considers the main properties of the MAS and the connection of the task of "simulating the synchronized rhythmic glow of colony of fireflies" from MAS. The purpose of modeling is to determine the conditions and mechanisms of local coordination of agents, for the self-organization of MAS. To do this, we need to solve the following tasks: build a model of the game, develop a method and algorithm for solving, and execute computer simula tion software to identify the coordination and self-organization of the MAS.

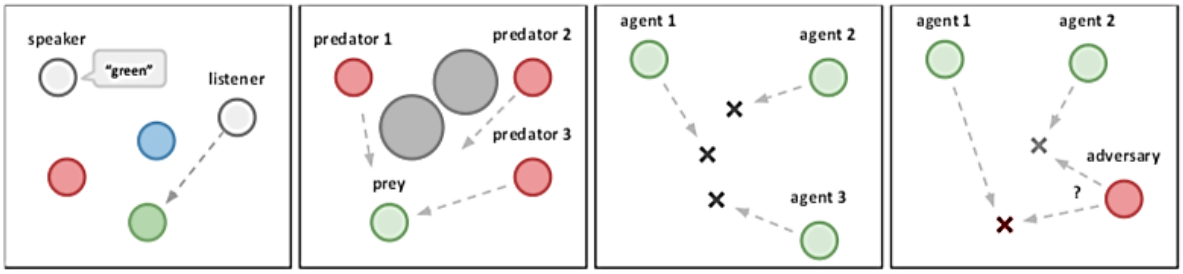


Figure 1. Illustrations of the experimental environment and some of the considered tasks, including: a) cooperative communication, b) predator-victim, c) cooperative navigation, d) physical deceit.

Cooperative behavior. To carry out experiments, we use a well-grounded communication environment consisting of N agents and L milestones that inhabit a two-dimensional world with continuous space and discrete time. Agents can do physical actions in the environment and communication actions that are passed to other agents. We do not assume that all agents have the same space of action and observation, or act on the same policy π. We also consider games that are cooperative (all agents must maximize joint return) and competitive (agents have opposite goals). Some environments require explicit communication between agents to achieve the best rewards, while in other environments, agents can only perform physical activity. Information about each environment is listed below.

For the construction of MAS it is necessary to perform preliminary research on the basis of mathematical models that enable to study the dynamics of the system under uncertainty conditions, to construct policy of agents behavior, which provide optimal technical and economic parameters of the system's operation. Taking into account the peculiarities of the subject area, namely, multiagency,

uncertainty of the decision-making environment, antagonism or competition of goals, communicative, coordination of actions, adaptive strategies of agents, for constructing MAS models we will use the mathematical apparatus of the theory of stochastic games. The solution to a stochastic game is to seek out strategies of agents that maximize their winnings so as to provide a certain collective balance of interests for all players. To search optimal strategies of players in conditions of uncertainty we will use the method of encouraging learning.

Mathematical model of stochastic game. Average loses of agents

$$\theta_n^i\left(\left\{\tau, u_n^{Di}\right\}\right) = \frac{1}{n}\sum_t^n \xi_t^i, \forall i \in D \qquad (1)$$

characterize the quality of the game at time n.

The purpose of each agent is to minimize their own average loses function:

$$\lim_{n\to\infty} \theta_n^i \to \min_{\{u_n^i\}} \forall i \in D. \qquad (2)$$

The task of the stochastic game lies in the fact that agents are based on observing current losses $\{\xi_t^i\}$, must learn to choose a clean policy $\{u_n^i\}$so that with the course of time n = 1,2, ... ensure fulfillment of the system of criteria (2).

To solve the problem (2), it is necessary to determine the method of forming sequences of clean policies $\{u_n^i\}$ in time that ensure the fulfillment of condition (4) due to the asymptotic adequacy of the functions of average payoffs (3).

The value of the function θ_n^i for the average player losses is approaching the values of the V^i functions of the average loses of the matrix game:

$$\forall i \in D \ \lim_{n\to\infty} n^k M\left\{\left[\theta_n^i - V^i(p^{Di^*}\right]^2\right\} < \infty. \qquad (3)$$

The condition of complementary non-rigidity, weighed by the elements of the vectors of mixed strategies, describes the game's solutions in both mixed and pure strategies:

$$diag(p_i)\left(\nabla_{pi} V_i(p) - e^{N_i} V_i(p)\right) = 0, \forall i \in D, \qquad (4)$$

where $diag(p_i)$ is a square diagonal matrix of order N_i, constructed of elements of the vector p_i.

The current losses of agents will be determined as a penalty for violating the spatial and temporal coordination of strategies:

$$\xi_n^i = \lambda \sum_{s\epsilon D} \frac{|u_n^i - u_n^s|}{L_i} + (1-\lambda)\left|\overline{u_n^i} - u_{n-1}^i\right| + \mu_n, \qquad (5)$$

where $\xi_n^i \epsilon R^1$; $\lambda\epsilon[0;1]$ - weight coefficient; Di is the set of neighboring agents corresponding to the Figure 2 bonds; L_i=|Di| - number of neighboring agents; u_n^i- clean policy with binary meaning; $\overline{u_n^i}$- inversed value of pure strategy; $\mu_n \sim Normal(0,d)$ - white Gaussian noise, normally distributed random value with zero expectation and dispersion d> 0.

The first component of expression (5) defines a penalty for violating the spatial (reciprocal) coordination of player strategies within a subset of D_i; the second component is a fine for violation of time coordination in two consecutive moments of time, and the third component defines the action of random noise in the form of white noise.

Taking into account the magnitude of the period $\tau = N_i$ of the dynamic self-organization of the MAS, we construct the sequences of pure strategies with the desired properties on the basis of the matrices of the probabilities of transitions between the pure policies $\{u_n^i\}$ of the agents:

$$p_n^i = \left[\begin{pmatrix} p_n^i(1.1) & \cdots & p_n^i(1,N_i) \\ \vdots & \ddots & \vdots \\ p_n^i(N_i,1) & \cdots & p_n^i(1N_i,N_i) \end{pmatrix}\right], \forall i \in D. \qquad (6)$$

The matrix lines p_n^i are the mixed strategies of the i player if he chose a clean policy $u_n^i \in U^i$. Lines elements $p_n^i(j.k)$ are conditional probabilities of choosing clean strategies depending on the current version of action u_n^i and the resulting loss ξ_n^i. Let's assume that the selected clean strategies match the agent's states. Then p_n^i (6) is a matrix of probabilities of changing agent states.

The game begins with uninformed mixed strategies $p_n^i(j.k) = \frac{1}{N_i}$ j, k $= 1 \ldots N_i$. To adapt the formation of the distribution of random strategies that minimizes the average losers (1) of all players, the probability of choosing strategies with less losers should increase over time *n=1,2,...*

Taking into account (4), we obtain the following recursive method of changing the vectors of mixed strategies:

$$p_{n+1}^i = \pi_{\varepsilon_{n+1}}\{p_n^i(u_n) - \gamma_n \xi_n^i[e(u_n^i) - p_n^i(u_n)]\}, \forall i \in D, \quad (7)$$

where $p_n^i(u_n)$ - mixed policy of i-player in a state $u_n \in U^i$; $\pi_{\varepsilon_{n+1}}$ - design operator for a single ε -simplex $S_\varepsilon^{N_i} \subseteq S_\cdot^{N_i}$(11), which is a subset of the unit simplex $S_\cdot^{N_i}$; $\gamma_n > 0$ - a monotonically decreasing sequence of positive quantities that regulates the size of the step of the method; ερ> 0 is a monotonically decreasing sequence of positive quantities that governs the expansion rate of the ε -simplex.

The study of the convergence of the method (11) will be performed in the class of monotone sequences $\{\gamma_n\}$ and $\{\varepsilon_n\}$.

$$\gamma_n = \gamma(n+\alpha)^{-\alpha};\ \alpha > 0;\ \varepsilon_n = \varepsilon(n+\beta)^{-\beta};\ \beta > 0. \quad (8)$$

The convergence of the method (11) is observed:

1) with probability 1, if α ∈ (0.5; 1); β> 0;

2) in the rms, if α ∈ (0,1); β> 0

Method (7) provides an adaptive selection of agents for clean strategies through the dynamic rebuilding of mixed strategies based on the processing of current losses.

Based on the current distribution of probabilities $p_n^i(u_n{}^i)$, the agent carries out a random selection of a clean policy $\forall i \in D$.

$$u_n^i = \{\frac{u^{i(l)}}{l} = arg\ \min_l \sum_{k=1}^{l} p_n^i(j,k) > \omega(j, l = 1..N_i)\}, \quad (9)$$

where w∈ [0,1] is a random variable with uniform distribution.

So, if at time n the agent is in a state u_n^i then based on a mixed strategies $p_n^i(u_n)$ it choose clean policy $u_n^{i\prime}$according to (3), for which, by the time *t +1*, the current loss is received ξ_n^i which uses to calculate the mixed policy $p_{n+1}^i(u_n)$ according to (7), after which it becomes a new state $u_{n+1}^i = u_n^{i\prime}$.

Evaluating the effectiveness of the game self-organizing MAS will perform on the following indicators:

1) Average loss function or game price:

$$\theta_n = \frac{1}{L}\sum_{i=1}^{L} \theta_n^i,$$

where *L*=|*D*|- number of players;

2) spatial coordination coefficient of player strategies:

$$K_n = \frac{1}{nL}\sum_{t=1}^{n}\sum_{i=1}^{L} \chi(\sum_{s\epsilon D_i}|u_t^i - u_t^s|=0),$$

where $\chi\epsilon\{0,1\}$ - indicator function of the event;

Example modeling. For an example, consider a stochastic game model of self-organizing fireflies from the Lampyridae family that lead a nightlife in tropical regions of the world. Males of these insects for attracting females launch a mechanism of luminescent radiation of their abdomen. Self-organization is manifested in the emergence of the phenomenon of rhythmic synchronized glow throughout the colony of males.

Modeling the behavior of fireflies will be done using a stochastic game of agents, each of which can be in one of two states $u_n^i \epsilon \{0,1\}$, where 0 indicates absence, and 1 - presence of glow.

We solve the stochastic game of two agents with two clean strategies in a two-state environment. The matrices of the average winnings of such a game are given in the table.

Table 1.

Matrices of the winnings agents

state	strategie	agents 1		agents 2	
s_1	-	$\pi_2(s_1, u_2[0])$	$\pi_2(s_1, u_2[1])$	$\pi_2(s_1, u_2[0])$	$\pi_2(s_1, u_2[1])$
	$\pi_1(s_1, u_1[0])$	0.5	0.2	0.4	0.1
	$\pi_1(s_1, u_1[1])$	0.6	0.7	0.1	0.9
s_2	-	$\pi_2(s_2, u_2[0])$	$\pi_2(s_2, u_2[1])$	$\pi_2(s_2, u_2[0])$	$\pi_2(s_2, u_2[1])$
	$\pi_1(s_2, u_1[0])$	0.9	0.2	0.4	0.6
	$\pi_1(s_2, u_1[1])$	0.2	0.9	0.6	0.8

Each agent can observe the states of neighboring agents and change their own state so that the actions can be as close as possible to their neighbors. The structure of the relationships between agents is depicted in Figure 2.

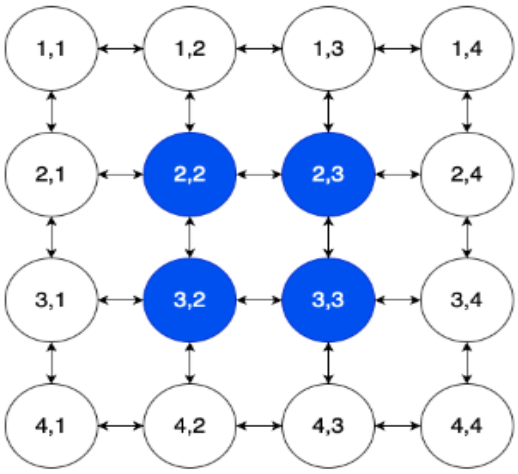


Figure 2. Model of stochastic game "Firefly"

The regular structure of the game is given by the number of agents $L = m*m$, $m \geq 2$, subsets of the neighboring agents D_i and the number of clean strategies $N_i = N = 2$, $i = 1..L$.

The dynamics of the process of self-organization consists of spatial and temporal coordination of the strategies of agents. Spatial coordination is to observe the ratio of agent strategies in locally defined areas of D_i, N_i as shown in Figure 2. Time coordination is determined by observing the ratio of agent strategies over time $\tau = 2$.

In game terminology, spatial coordination will consist in choosing the same values of players' pure strategies at fixed moments of time (agents try to repeat each other's actions), and time coordination - in changing binary strategies to opposite values at two consecutive moments of time. The result of the self-organizing of agents is the inverse change of the matrices of binary clean strategies $[0]_{m*m}$-$[1]_{m*m}$-$[0]_{m*m}$-$[1]_{m*m}$ - in time that simulates the rhythmic glow of the colony of fireflies:

$$p^{i*}(u_n^i) = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}.$$

Such a change is provided by the matrix of trained mixed strategies agents with identical initial states.

Algorithm for solving a stochastic game

1. Set the initial values of the parameters:

- $n = 0$ - the initial time;
- $L = |D|$ - number of players;
- N - the number of players' pure strategies;
- $Ui = (u^i[1], u^i[2], ..., u^i[N])$, $i = 1..L$ - vectors of pure player strategies;
- $p^i_0 = (1 / N, ..., 1 / N)$, $i = 1..L$ - initial mixed player strategies;
- $\gamma > 0$ is the parameter of the learning step;
- $\alpha \in (0,1)$ - the order of the learning step;
- ε is the parameter of the ε -simplex;

– β> 0 is the order of the expansion rate of the ε - symplex;

– d> 0 - dispersion of noise;

– max n - maximum number of steps of the method.

2. Select action options $u^i_n \in U_i$, i = 1..L according to (9).

3. Get the value of current losses ξ^i_n, i = 1..L according to (5). Current values of Gaussian white noise are calculated by the formula, where ω ∈ [0,1] is a real random number with uniform distribution law.

4. Calculate the values γ_n, ε_n of the parameters γn, εn according to (8).

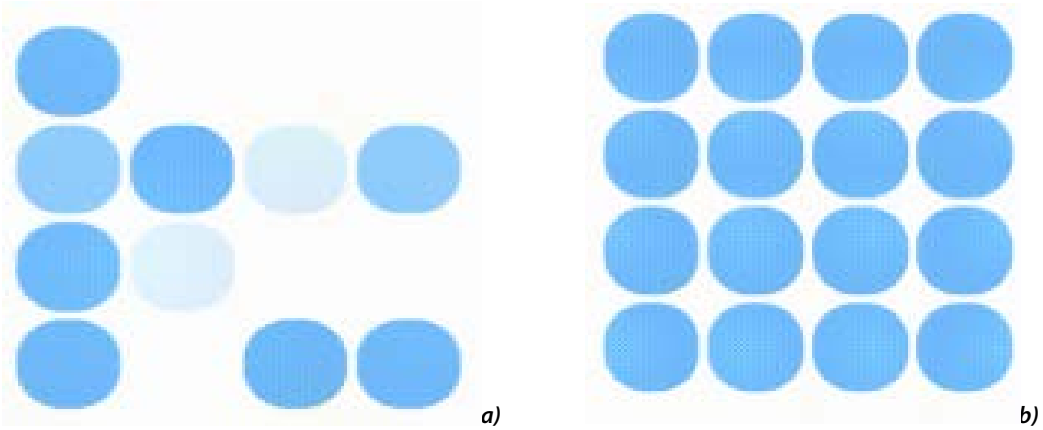
5. Calculate the elements of the vector of mixed strategies pin, i = 1..L according to (7).

6. Calculate the quality characteristics of the decision making θn (10), Kn (11).

7. Specify the next time point n: = n +1.

8. If n <nmax, then go to step 2, otherwise - end.

Thanks to the local coordination of the strategy of agents, this solution ensures the self-organization of the MAS "firefly". Each player watches the actions of neighbors and gets their own losses through non-matching, which forces him to dynamically choose strategies with less fines. The dynamic selection of strategies transforms locally coordinated actions of players into global coordination of the game, when the team of players behaves as a holistic organism.



a) *b)*

Figure 3. a) in the learning process b) self-organized agents

Conclusions. The developed game model provides a dynamic self-organization of the MAS, which manifests itself in the rhythmic change of the pure agent strategies that simulates the light effects of the colony of fireflies. A characteristic feature of the considered game self-organization is the locally determined collection of information about the strategies of the behavior of neighboring agents, which as a result of learning leads to global coordination. strategies of all agents.

The generation of sequences of clean strategies with the required properties is provided by random distribution, built on dynamic mixed player strategies. The calculation of mixed strategies is carried out using the adaptive recurrent method obtained on the basis of the stochastic approximation of the complementary non-rigidity condition, which describes the collective solutions of the game satisfying the equilibrium condition according to Nash.

The effectiveness of the game self-organization of MAS strategies was studied with the help of the functions of average losses, co-ordinates and norms of deviation of dynamic mixed strategies from optimal values. The decline of the function of average losers and the function of rejection of mixed strategies, the growth of co-ordination factors indicate the convergence of the game method and the entry of MAS into self-organization. Repeating the values of the game's characteristics in various experiments with unique sequences of random variables confirms the reliability of the results.

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МОДЕЛЮВАННЯ КООПЕРАТИВНОЇ ПОВЕДІНКИ В МУЛЬТИАГЕНТНИХ СИСТЕМАХ

Анотація. Під кооперативною поведінкою розуміють спільноту агентів, які для зменшення середньозважених штрафів вирішують співпрацювати, щоб розв'язати поставлену задачу або досягти певної мети, в нашому випадку синхронізувати світіння.

Проблема формування кооперативної поведінки інтенсивно досліджується у сучасній науковій літературі із застосування мультиагентних систем, наприклад, для дистанційного навчання, керування організаційними системами, побудови різноманітних віртуальних організацій та спільнот, керування розподіленими обчисленнями, керування суспільними інститутами та суспільно-економічними процесами та інших.

У даній роботі розглянуто актуальну тему оптимальних стратегій в іграх з локальною взаємодією, розглянуто стимулююче навчання мультиагентних систем у ігровій постановці.

Метою даної роботи є розгляд методу побудови системи з локальною взаємодією агентів на основі завдання «синхронізації» за допомогою марковської моделі стохастичної гри.

Метод дослідження - комп'ютерна програма для моделювання завдання з використанням Q-методу навчання. Формування коаліцій у мультиагентних системах формулюється як конкурентна або кооперативна задача зарахування об'єкта до одного із кластерів. Розв'язування подібних задач вивчає теорія ігор, а в умовах невизначеності – теорія стохастичних ігор. У зв'язку з цим з наукової та практичної позицій актуальне застосування методів стохастичних ігор для формування коаліцій в умовах неповноти інформації. Рішення стохастичної гри полягає в пошуку стратегій агентів, які максимізують свої виграші, щоб забезпечити певний колективний баланс інтересів для всіх гравців. Для пошуку оптимальних стратегій гравців в умовах невизначеності будемо використовувати метод стимулювання навчання.

Результатом є розроблена ігрова модель, яка забезпечує динамічну самоорганізацію МАС, що проявляється в ритмічній зміні чистих стратегій агентів, які імітують світлові ефекти колонії світлячків. Характерною особливістю

розглянутої самоорганізації гри є локально визначена інформація про стратегії поведінки сусідніх агентів, які в результаті навчання призводить до глобальної координації. стратегії всіх агентів.

Наукова новизна отриманих результатів полягає в розробці ігрової моделі, визначені ефективності ігрової самоорганізації стратегій МАС для розв'язування задачі прийняття рішень в системах з кооперативною поведінкою агентів в умовах невизначеності. Повторність значень характеристик гри в різних експериментах з унікальними послідовностями випадкових величин підтверджує достовірність результатів.

Результати можуть бути використані на практиці для моделювання динаміки соціальних процесів, керування соціальними інтернет-сервісами у мережі інтернет та інших.

Ключові слова: *мультиагентна система, стохастична гра, адаптивний ігровий метод, Q-метод.*

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МОДЕЛИРОВАНИЕ КООПЕРАТИВНОГО ПОВЕДЕНИЯ В МУЛЬТИАГЕНТНЫХ СИСТЕМАХ

Под кооперативным поведением понимают деятельность множества агентов, которые для уменьшения средневзвешенных штрафов решают сотрудничать для решения поставленной задачи или достичь определенной цели, в нашем случае синхронизировать свечение. Проблема формирования кооперативного поведения интенсивно исследуется в современной научной литературе по применению мультиагентных систем, например, для дистанционного обучения, управления организационными системами, построения различных виртуальных организаций и сообществ, управления распределенными вычислениями, управления общественными институтами и общественно-экономическими процессами и другое.

В данной работе рассмотрена актуальная тема оптимальных стратегий в играх с локальным взаимодействием, рассмотрено стимулирующее обучение мультиагентных систем в игровой постановке.

Целью данной работы является рассмотрение метода построения системы с локальным взаимодействием агентов на основе задания «синхронизации» с помощью марковской модели стохастической игры.

Метод исследования - компьютерная программа для моделирования задачи с использованием Q-метода обучения. Формирования коалиций в мультиагентных системах формулируется как конкурентная или кооперативная задача присоединения объекта к одному из кластеров. Решение подобных задач изучает теория игр, а в условиях неопределенности - теория стохастических игр. В связи с этим с научной и практической позиций актуально применение методов стохастических игр для формирования коалиций в условиях неполноты информации. Решение стохастической игры заключается в поиске стратегий агентов, которые максимизируют свои выигрыши, чтобы обеспечить определенный коллективный баланс интересов для всех игроков. Для поиска оптимальных стратегий игроков в условиях неопределенности будем использовать метод стимулирующего обучения.

Результатом является разработанная игровая модель, которая обеспечивает динамическую самоорганизации МАС, что проявляется в ритмической смене чистых стратегий агентов, которые имитируют световые эффекты колонии светлячков.

Научная новизна полученных результатов заключается в разработке игровой модели, определении эффективности игровой самоорганизации стратегий МАС для решения задачи принятия решений в системах с кооператив-

ным поведением агентов в условиях неопределенности. Повторность значений результатов самообучения агентов в игре со случайными последовательностями начальных стратегий подтверждает достоверность результатов.

Результаты могут быть использованы на практике для моделирования динамики социальных процессов, управления социальными интернет-сервисами в сети интернет и других.

Ключевые слова: *мультиагентная система, стохастическая игра, метод адаптивных игр, Q-метод.*

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FONT VISUAL CLASSIFICATION SYSTEM USING NEURAL NETWORKS

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Abstract. Context and objective. The purpose of the paper is research and development of font visual classification system, that will allow users to work with fonts more effectively. That includes: select the required font using preview, apply various filters and font management tools. With the help of classification system users will be able to search fonts by slope, basic style and weight according to their actual representation avoiding the problem of incorrect sub-family styles names.

Research methods. In this paper the basic approaches of fonts classification with relevant advantages and disadvantages were described. After analyzing the approaches, it was decided to apply neural network that takes the images with font symbols as input. Neural network selects patterns (filters, features maps), to be considered in classification process based on the teacher's correct answers. Possible use of alternative fonts classification techniques was suggested, and the main related problems were described.

Results. Computer fonts classification system driven by convolutional neural networks, that allows to classify fonts by slope, basic style and weight according to their graphical representation, was developed. Percentage of fonts that were correctly classified by the system is: in determining slope – 96%, in determining basic style – 92%, in determining weight – 91%.The developed system can be applied to solving fonts classification tasks as an assistance tool for determination of digital documents structure, and as font selection system for design creation. Based on results, it may be concluded that neural networks were successfully applied to the fonts classification problem solving.

The scientific novelty and practical significance. In the work were investigated the main approaches to the classification of fonts, analyzed their advantages and disadvantages. The effectiveness of mulilayer perceptronsand convolutional neural networks were tested. Experimentally revealed the most optimal parameters of the models of neural networks.

A visual font classification system that works on convolutional neural networks was developed and integrated into the font organizer. Control tests were carried out confirming the high accuracy of classification of the developed neural network models.

Keywords: *machine learning, convolutional neural network, font classification, image classification.*

Introduction. The computer font is a file that contains description of a set of alphabetical, digital, reserved and pseudo-graphic characters and serves for displaying these characters (particularly, the text) by the program or the operating system. Every font has its weight (100-900), slope and one of the basic typefaces: Serif, Sans-Serif, Script, Decorative. There is an enormous number of fonts, however there is not a single standard of their classification. Fonts with a common subfamily name often considerably differ one from another by weight as much as by slope. In some cases, when development of all types of weight is not needed, the authors of the font families make so called "shifts", when actual weight of the font corresponds to another weight. Also, after developing the single font in the sub-family, author names it Regular regardless of the font type.

The lack of the standard causes the problem of font search and selection. For example, when searching the font by style Regular, the results may contain fonts more similar to Black or even Thin Italic.

Problem definition. The purpose of the paper is research and development of font visual classification system, that will allow users to work with fonts more effectively. That includes: select the required font using preview, apply various filters and font management tools. With the help of classification system users will be able to search fonts by slope, basic style and weight according to their actual representation avoiding the problem of incorrect sub-family styles names. Developed system must correctly classify >= 90% of fonts.

Problem solution. Classification problem consists of 3 sub-tasks: recognition of "basic" slope, classification by weight, classification by style.

To determine the font's weight it is possible to apply a simple approach: one can calculate the number of black pixels in the image and assign font by this sum to the closest class (by the average value).

However, during the fonts analysis the fonts with weight that depends on image edges rather than number of black pixels were found. Those are outlined fonts with edges being hollow inside. Given that to solve this issue Edge Detection methods could be used, the attempt was made to apply them. The result of symbol image processing using convolutional matrix is shown in Fig. 1.

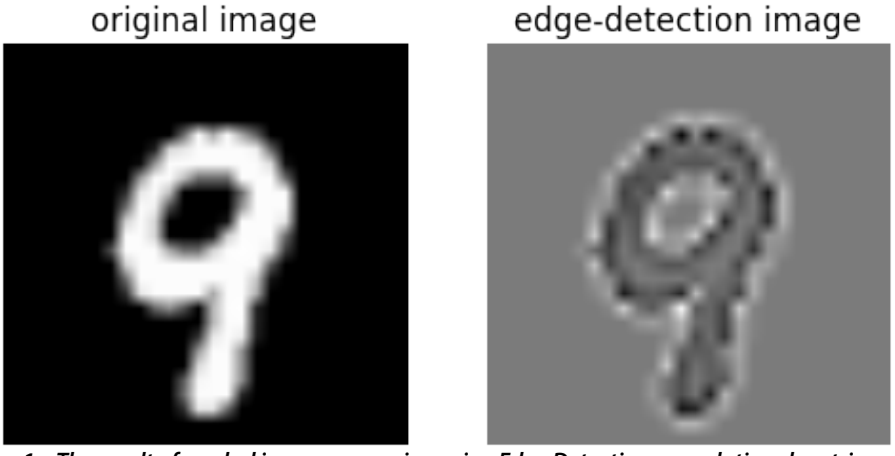


Fig. 1 – The result of symbol image processing using Edge Detection convolutional matrix

The study shows that used methods are not sufficient since they don't consider the symbol's width. Also, some fonts have combined edges that are difficult to interpret, therefore these fonts can be classified only based on patterns of human perception of symbols.

Serif and Sans-Serif fonts in most cases have a sharp slope line, however the study of Script and Decorative fonts shows collisions – one symbol can consist of straight and slope lines at the same time, making the classification more complicated even for a human.

The problem of classification by style is the most difficult of the sub-tasks listed above because of the vast number of various fonts that cannot be easily described by basic distinct features which allow to associate the font with one certain style (fig. 2).

Fig. 2 – Example of variability of "a" symbol

Considering the complexity of the problems and inability to describe the features of various font classes without assistance, it was decided to apply methods of machine learning, namely neural networks. Neural networks are the most frequently used algorithms for solving the image classification problems, as they demonstrate the best results of patterns recognition and classification.

After analyzing the structure features of different font styles, specifically how much their design differs, it was decided to use Convolutional Neural Network (CNN). This type of network allows to recognize fonts features regardless of their position and deformation. Network itself selects patterns that are important for classification (filters, feature maps), considering teacher's correct responses [2].

Because of wide symbol variation by size and design, the use of typical Multi Layer Perceptron (MLP) network would lead to difficulty in high accuracy classification, as it would require construction of a big number of neurons, and therefore would require power efficiency.

To solve the slope classification problem, i.e. if font belongs to Italic type, firstly it was decided to apply MLP network, that properly coped with the task, however during further data increasing by more complex fonts of Script style, network started to reduce its accuracy. Therefore, it was decided to use CNN network as well (fig. 3).

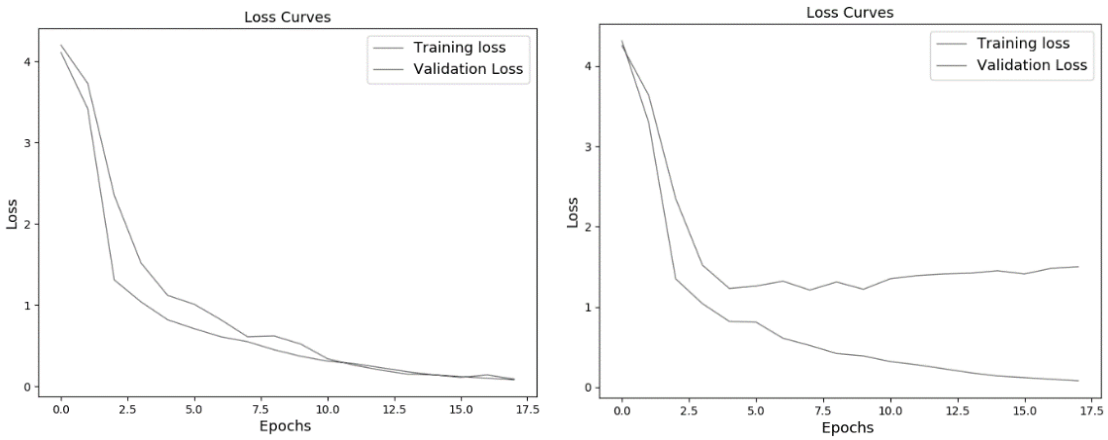


Fig. 3 – Value of Loss function during training of MLP network before and after addition of Script type fonts

Network build and training were performed using Python library called Keras. Inspired by "VGG NET" architecture, one of the most accurate networks at this time [4], it was decided to take an approach of sequential application

of layer combinations: Conv > Conv > MaxPooling. This approach doesn't require lots of filters and layers to solve the problems of given complexity, so it is well-suited for execution on the client's side. Number and size of kernels were selected on an individual basis for every task with priority to processing speed with condition that final accuracy of classification should be at least 90%. During the experiment it was established that for slope classification for Conv layers 8 kernels with a size 5x5 work best, and for classification by weight and style – 16 kernels with a size 3x3. Popular technique Dropout was used to avoid fast retraining of neural network, with network's element inactivation based on certain probability.

ReLU activation function was selected for all layers except for the last one. It can be described by concise formula: $f(x) = max(0, x)$. There is a research that indicates that this function can increase the convergence speed of stochastic gradient descent by factor 6 compared to sigmoid function and hyperbolic tangent. It is thought that this feature based on linear nature and absence of the function saturation [3].

For the last layer softmax function is used, therefore confidence of belonging to one of the classes depends on confidence in other classes. It can be defined by the formula:

$$y_i = \frac{e^{z_i}}{\sum_{j=1}^{n} e^{z_j}}, \quad (1)$$

where z_i – input value of i-th neuron
y_i – output value of i-th neuron

As error determination function was selected categorical_crossentropy, that is used for Multi Class classification, where the only one class can belong to the font. This function's expression is:

$$H(p, q) = -\sum_x p(x) log q(x) \quad (2)$$

where p and q – values of expected and received result.

Adadelta (or adaptive learning rate method) algorithm was used as an algorithm of weight update. The method considers gradient values history and weight update history. It presents way over fast convergence than regular SGD during the training on simplified data sample. The example of neural network model is given in Fig. 4.

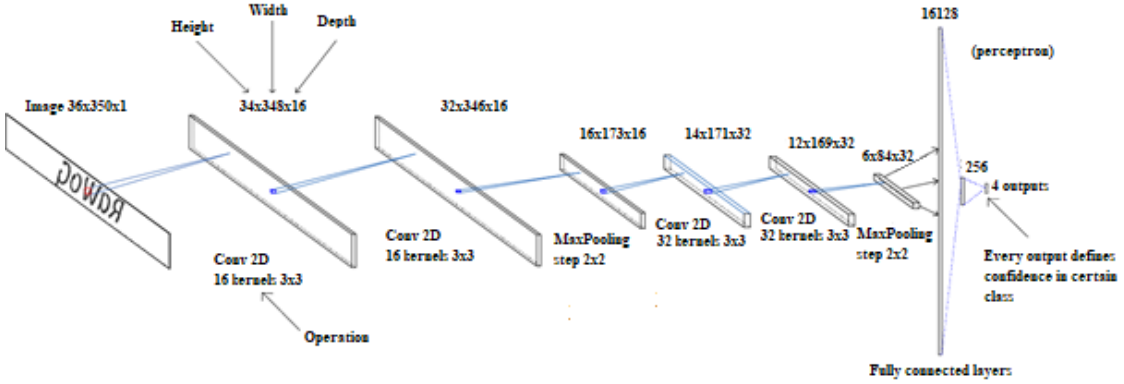


Fig. 4 – Neural network model of style classification

For font classification by slope "IW" symbols were used, and "RoWGa" were used for classification by weight and style. Corresponding image sizes are 90x36 and 350x36. These symbols were selected analytically, as they appropriately depict the most typical features of corresponding classes.

The number of fonts in one class can be substantially lower comparing to other classes. Network trains badly and outputs incorrect metrics due to data imbalance, and small data set leads to early retraining. To solve this issue the application that performs operations over images with their content being intact was developed.

Table 1

Operations over images

Operation	Allowability of applying
Rotate	Allowable for all sub-tasks, except for slope determination
Scale	Allowable for all sub-tasks, except for weight determination
Horizontal flip	Allowable for all sub-tasks
Vertical flip	Allowable for all sub-tasks
Vertical and Horizontal flip at the same time	Allowable for all sub-tasks
Shift, Wrap	Non-allowable for all sub-tasks

The basic operations over images were studied and their capabilities for the data augmentation were determined.

Operations like Rotate and Scale are allowable for certain data samples, however their usage assumes enlargement of image palette to prevent the loss of fonts features. Enlargement of image palette will cause the increasing of required power supply, that is not appropriate for this type of tasks when computer resources are quite limited.

Number of fonts that were collected and classified is as follows: 826 fonts were classified by style, 664 – by weight, 1128 – by slope. The result of image generation and applying operations for image number augmentation and data balancing is: 12754 images were classified by style (using 3 types of mirroring and letter reordering); 12074 images were classified by weight (also with use of 3 types of mirroring and letter reordering); 4628 images were classified by slope (using letter reordering and size modification).

The example of neural network training is given in Fig. 5. Figure shows that network has correct training, with validation loss value is close to training loss value (i.e. there is no retraining effect). Also, from plot the stochastic gradient descent appliance can be seen, with validation loss curve that seems to roll down, hence it may be concluded that configuration is advantageous. Values of Loss and Accuracy functions for every data samples are given in table 2.

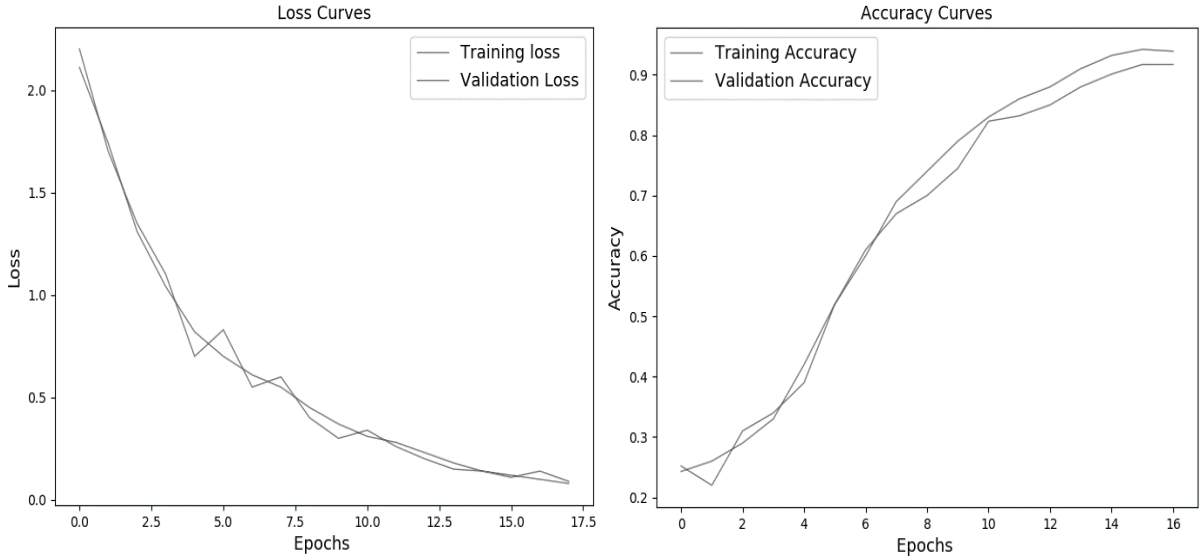


Fig. 5 – Plot of Loss and Accuracy functions during the training of classification by style

Visualization method called Gradient-weighted Class Activation Mapping was used to analyze and understand on what basis neural networks establish the association of the font with one or the other class [6]. It allows to represent the areas that attract neural network attention and the attention intensity with the heat map.

Table 2

Amount of data in samples and the result of network training

Training type	Training images	Test images	loss_train	acc_train	loss_test	acc_test
By style	12274	480	0.09	0.924	0.12	0.909
By weight	11594	480	0.1	0.937	0.13	0.91
By slope	4168	460	0.08	0.946	0.1	0.938

Fig. 6 – Heat map of class activation that is responsible for Decorative style recognition

Fig. 7 – Heat map of class activation that is responsible for Serif style recognition

Fig. 6 shows the neural network focuses attention on unusual FasterOne font lines, that indicate the font belongs to Decorative style. Activation in serif location areas that is typical for Serif class is shown in fig. 7.

This method has allowed to examine activation for each class. Examples of arguable points, where neural network wasn't confident if the font belongs to one or the other style, are presented below.

Table 3

Analyzing of IndieFlower Script font from Guided Backpropagation

Style	Confidence	Neural network activation
Script	0.54	
Decorative	0.46	
Serif or Sans-serif	0.0	

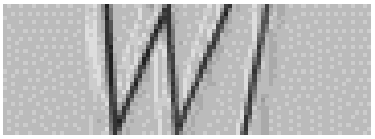
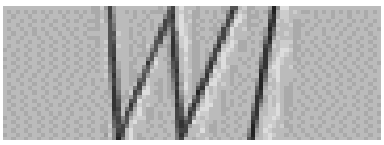
Table 4

Analyzing WireOne Sans-serif without Guided Backpropagation

Style	Confidence	Neural network activation
Serif	0.02	
Sans-serif	0.44	
Decorative	0.22	
Script	0.33	

Table 5

Analyzing Overpass Thin Italic font without Guided Backpropagation

Style	Confidence	Neural network activation
Italic	0.85	
Non-italic	0.15	

To check the accuracy of classification the Accuracy-Checker module that assesses the percentage of correctly classified fonts was developed. 100 fonts were collected for each classification by style, weight and slope. Module classifies the font using neural network and then compares its classification with the correct answer, then counts and displays the percentage of the right answers. The result of module execution is given in table 3.5. Comparison of network training metric with conducted accuracy check is shown in Fig. 8.

Table 3.5

The result of classification accuracy check

Classification	Test fonts	Classes	Accuracy
By slope	100	2	96%
By weight	100	9	91%
By style	100	4	92%

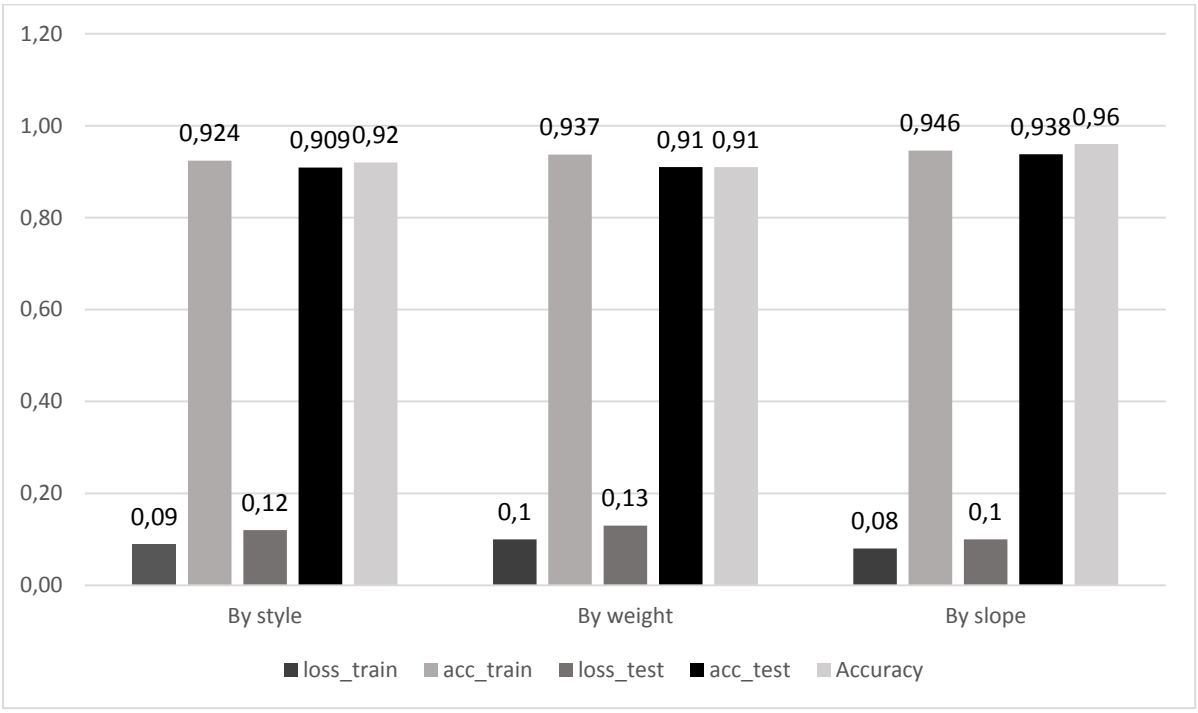


Fig. 8 – Comparison of networks training metric with their classification accuracy

Main results and conclusions. The main problem of fonts classification consists in fuzziness of features that allow to classify the font, and their strong variation. In this paper the basic approaches of fonts classification with relevant advantages and disadvantages were described. After analyzing the approaches, it was decided to apply neural network that takes the images with font symbols as input. Neural network selects patterns (filters, features maps), to be considered in classification process based on the teacher's correct answers. Possible use of alternative fonts classification techniques was suggested, and the main related problems were described.

Computer fonts classification system driven by convolutional neural networks, that allows to classify fonts by slope, basic style and weight according to their graphical representation, was developed. Percentage of fonts that were correctly classified by the system is: in determining slope – 96%, in determining basic style – 92%, in determining weight – 91%.The developed system can be applied to solving fonts classification tasks as an assistance tool for determination of digital documents structure, and as font selection system for design creation.

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СИСТЕМА КЛАСИФІКАЦІЇ ШРИФТІВ ЗА ДОПОМОГОЮ НЕЙРОННИХ МЕРЕЖ

Анотація. Актуальність та мета статті. Метою даної статті є дослідження та розробка системи візуальної класифікації шрифтів, що дасть змогу користувачам ефективніше працювати з шрифтами, а саме: обирати необхідні шрифти використовуючи попередній перегляд, застосовувати різноманітні фільтри та засоби організації шрифтів. Завдяки системі класифікації користувачі зможуть шукати шрифти за нахилом, базовим стилем і вагою, відповідно до їх дійсного відображення, цим самим уникаючи проблему некоректно вказаних стилів.

Методи дослідження. В даній статті розглянуто основні підходи класифікації шрифтів, їх переваги та недоліки. Зваживши розглянуті підходи, було вирішено застосувати нейронну мережу, на вхід якої надходять зображення з символами шрифтів. Нейронна мережа підбирає патерни (фільтри, карти ознак), на які слід звертати увагу при класифікації, зважаючи на правильні відповіді вчителя. Запропоновано можливе використання альтернативних методів класифікації шрифтів з описом їх проблемних місць.

Результати. Створено систему класифікації комп'ютерних шрифтів на основі згорткових нейронних мереж, що дозволяє класифікувати шрифти за нахилом, базовим стилем і вагою, відповідно до їх графічного відображення. Відсоток коректно класифікованих шрифтів системи: в визначенні нахилу – 96%; в визначенні базового стилю – 92%, в визначенні ваги – 91%. Розроблена система може застосовуватись для вирішення задач класифікації шрифтів як допоміжний інструмент визначення структури оцифрованих документів, а також у якості системи підбору шрифтів для створення дизайну. Виходячи з результату, можна судити про успішне застосування нейронних мереж для вирішення задач класифікації шрифтів.

Наукова новизна та практична значимість. В роботі були досліджені основні підходи до класифікації шрифтів, проаналізовані їх недоліки та переваги. Була перевірена ефективність застосування багатошарових перцептронів та згорткових нейронних мереж. Експериментальним шляхом виявлені найбільш оптимальні параметри моделей нейронних мереж. Була розроблена та інтегрована в органайзер система візуальної класифікації шрифтів, що

працює на згорткових нейронних мережах. Проведені контрольні тести, що підвердили високу точність класифікації розроблених моделей нейронних мереж.

Ключові слова: *машинне навчання, згорткова нейронна мережа, класифікація шрифтів, класифікація зображень.*

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СИСТЕМА КЛАССИФИКАЦИИ ШРИФТОВ С ПОМОЩЬЮ НЕЙРОННЫХ СЕТЕЙ

Аннотация. Актуальность и цель статьи. Целью данной статьи является исследование и разработка системы визуальной классификации шрифтов, что позволит пользователям эффективно работать со шрифтами, а именно: выбирать необходимые шрифты, используя предварительный просмотр, применять различные фильтры и средства организации шрифтов. Благодаря системе классификации пользователи смогут искать шрифты по наклону, базовым стилем и весом, в соответствии с их действительным отображением, тем самым избегая проблему некорректно указанных стилей.

Методы исследования. В данной статье рассмотрены основные подходы классификации шрифтов, их преимущества и недостатки. Взвесив рассмотреные подходы, было решено применить нейронную сеть, на вход которой поступают изображения с символами шрифтов. Нейронная сеть подбирает паттерны (фильтры, карты признаков), на которые следует обращать внимание при классификации, учитывая правильные ответы учителя. Предложено возможно использование альтернативных методов классификации шрифтов с описанием их проблемных мест.

Результаты. Созданная система классификации компьютерных шрифтов на основе сверточных нейронных сетей, позволяет классифицировать шрифты по наклону, базовым стилям и весам, в соответствии с их графическим отображением. Процент корректно классифицированных шрифтов системы: в определении наклона - 96%; в определении базового стиля – 92%, в определении веса – 91%. Разработанная система может применяться для решения задач классификации шрифтов как вспомогательный инструмент определения структуры оцифрованных документов, а также в качестве системы подбора шрифтов для создания дизайна. Исходя из результата, можно судить об успешном применении нейронных сетей для решения задач классификации шрифтов.

Научная новизна и практическая значимость. В работе были исследованы основные подходы к классификации шрифтов, проанализированы их недостатки и преимущества. Была проверена эффективность применения многослойных перцептронов и сверточных нейронных сетей. Экспериментальным путем выявлены наиболее оптимальные параметры моделей нейронных сетей. Была разработана и интегрирована в органайзер система визуальной классификации шрифтов, работающий на нейронных сетях. Проведенные контрольные тесты подтвердили высокую точность классификации разработанных моделей нейронных сетей.

Ключевые слова: *машинное обучение, сверточная нейронная сеть, классификация шрифтов, классификация изображений.*

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INTEROPERABILITY OF DISTRIBUTED MULTIPLE SYSTEM FOR MALWARE DETECTION BASED ON COMPONENTS LEVELS OF SAFETY

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Abstract. The work out the developed method of interaction of components of distributed multi-level system of detection of malicious software on the basis of decentralized and self-organized architecture in local networks. Its feature is the synthesis of its requirements of distribution, decentralization, multilevel and self-organization. This allows you to use it autonomously. The basis of the distributed distributed system is its structural components, which are represented by autonomous software modules that can be in different states. The transition between module states is based on a defined set of transitions. Interaction and communication between autonomous software modules is based on their presence in certain states during operation and is determined by the rules of the developed method. Distributed system is a responsive system that will monitor selected events. Each program module places a resident mechanism, the motive mechanisms for the transition between states, the transitions between which are given by subsets of transitions, the data for which will be formed using the technologies of artificial intelligence. In addition, the feature of the components of the system is the same organization, which allows the exchange of knowledge in the middle of the system, which, unlike the known systems, allows us to use the knowledge gained by separate parts of our system in other parts. The developed system allows to fill it with subsystems of detection of various types of malicious software in local area networks. The method of interaction of components of a distributed multilevel detection system of malicious software provides a procedure for communication between parts of the system and the exchange of knowledge between them. It will be used to organize the interaction of system components and maintain its integrity. In order to solve the problem of the direct detection of malicious software in local area networks, methods will be applied that will be applied to the lower level of the system, which will include the architectural features of the distributed system and the technology of detecting the malicious software-based software. However, the developed method of interaction includes the ability to determine the state of a distributed multi-level system, depending on the states of individual modules, and on its basis, in accordance with it will be decided on the further operation of the system as a whole and its configuration. The method regulates the actions of the part of the system that relates to the bundling software of the distributed system. The conducted experiments on the use of the developed distributed system showed the possibility of attracting to the detection of the malicious software of computing power of

other hosts of the local network. The obtained results of experiments show an increase in the reliability of the detection of malicious software.

Keywords*: malware, distributed multi-level system, decentralized system, computer systems, local area network.*

Formulation of the problem. The growth of the number of computer systems and the spread of information technology in various industries and spheres, their integration into the global Internet network, as well as the growing opportunities for obtaining financial returns that appear at the same time, motivate malware developers to increase and spread them [1, 2]. Trends in the development of technology for the creation and spread of malware-many of the security demonstrate an active expansion of the technical capabilities of such tools. Modern malware is a complex, multi-functional software system and complex that is built using effective methods to create software and malicious code spreading methods.

Distribution of malware in the information systems of lo cial networks creates problems for users. Available means of its appearance today do not meet the needs of users. This is especially true of the task of detecting malware prior to it, at the stage of its direct distribution. As a rule, detection of malware comes from already after it was spread over a period of time and was carrying out destructive actions. A variety of antivirus tools that detect malicious software at different stages of its operation are known to prevent its full detection [1]. A special place is occupied by antivirus products [3-7] that detect malware in local area networks. They allow you to take advantage of an organization with more computing power than individual computer systems. They are mainly used in corporative networks of organizations and enterprises. Such network detection systems have a centralized architecture used by malicious people to block them, after detecting and blocking their centers.

Distribution of malware creates problems for users of computer systems. Existing detection systems do not provide full detection. Therefore, the problem of developing new methods and systems for detecting malicious software is relevant.

Analysis of recent research and publications. For network detection systems, methods have been developed, which are possible mainly on the server or on corporate or local networks. Most of these techniques are developed using technologies and components of artificial intelligence. As a rule, modern malware detection systems contain sets of many methods and their combinations. This is influenced by the growth of malicious software varieties. Let's consider more well-known systems and methods for detecting malicious software.

The known implementation of such detection systems mainly has a single control center with a certain level of centralization. These include: ESET Endpoint Security for Windows Endpoint Protection in corporate networks [1], Dr.Web CureNet! [2], Symantec Endpoint Protection [3], Malwarebytes Endpoint Security [5], "Cisco® Network Admission Control (NAC)»[6]. Kaspersky Administration Kit [6] has implemented the principle of autonomous decision-making in the network-based detection system. But in the future, the administrator controls the decisions taken. This indicates the presence of partial centralization in the architecture of this network detection system.

Known malware detection tools are built on top-notch methods that do not sufficiently take into account all the stages of operation and possible structures, which reduces the authenticity of the detection.

The authors of the paper [8] proposed a system of identification and classification for megye cyber attacks. To implement the system, a combination of different methods of artificial machine learning, namely neural networks, the immune system, neuro-physical classifiers and the method of reference vectors, is proposed. A distinctive feature of the proposed system is the multi-level analysis of network traffic, which makes it possible to detect signature attacks and combine a set of adaptive detectors based on machine learning techniques.

The system for detecting cyberattacks on the basis of the involvement of neural network immune detectors is presented in [9]. The decision on the possible impact of the malicious software is carried out with the involvement of a system of neural network detectors based on the algorithm of Mamdani.

The system of detection based on the selection of characteristic features of the flow of the program is presented in [10]. The proposed system involves building a

graph of the flow of malware control, and then converting it into a vector pro-stripe.

In [11], the authors identify a coordinated form of organized cyber attacks in botnet components, in which they conduct synchronized attacks in the form of groups. The similarity of the activities of cooperative groups is used as an effective measure for distinguishing bots from ordinary users. In this paper an approach is proposed for the analysis of behavior based on the histogram. To determine the number of web requests and their diversity over time using HTTP bots. As a result, the detection method is based on the correlation analysis of communication histograms designed to detect HTTP Botnets based on the similarity and correlation of their group activity.

The development of methods without taking into account the fundamental features of bot network architectures, allows attackers to bypass the tools that use typical representations. Sys-theme of modeling agents of various architectures of botnets, taking into account the various mechanisms of their functioning, is presented in [12]. It is based on the need to take into account the specialties of construction and structure. This is important for gathering the characteristics of botnets.

The botnet detection system presented in [12] is based on the analysis of traffic, and tac-toe modifications of the methods are oriented on comparing the results of the analysis of traffic with templates of the base of anomalies. The disadvantage is the need for a constant analysis of traffic and the allocation of important characteristics that may vary by intruders. This does not take into account the architecture of the botnet and packet blocking in the future does not guarantee their repetition.

In [13-14], detection methods are based on signatures. The results are applicable to known bots. They provide for control of each package and compare them with pre-configured signatures and attack patterns in the database. The common disadvantage of these methods is the need to update templates, which affects the system's failure to display new botnets or their nodes.

The analysis showed that for detecting malware, known systems carry out analysis of network traffic, audit files, packets transmitted over the network, checking the configuration of open network services. To establish the fact of a violation of the work of the systems, various methods of motor training are used, namely, neural networks, artificial immune systems, the method of reference vectors, Bayesian networks, and fuzzy clustering [8-14]. The main disadvantage of known systems is their host-oriented approach to detecting malicious software, and for network detection systems, the presence of centralization in decision-making or maintenance.

Therefore, further development of the theory and practice of creating distributed systems for detecting malware is a topical scientific and technical problem.

The aim of the study. In order to effectively apply malware detection methods and means, it is necessary to develop a system that includes a sufficient number of implemented effective methods in the form of appropriate subsystems, has a potential for upgrading and takes into account future development trends as antivirus agents, and malware.

The purpose of the work is to develop the theory and practice of creating distributed multilevel detection systems to increase the reliability of malware detection in computer systems of local networks based on decentralization and self-management. Multilevelness involves the inclusion in the system of different detection methods and their placement at different levels. Self-organization serves as the basis for the functioning of a rolled-up system with decentralized architecture.

The need for distributed multi-level detection systems for malware-malware detection in local computer systems is needed to attract other local area network hosts for the detection process. This will increase the reliability of its detection.

Presentation of research material. In order to increase the authenticity of the detection of malicious software, it is proposed to use decentralization of the system in distributed systems in local networks and to apply the developed method of interaction of the components of the distributed detection system of the malicious software to coordinate the components of the system. It establishes the order of communication between the components of the system and the exchange of knowledge between them based on the security levels of the system. They are dynamically determined at certain moments of time. It will be used to solve top-level tasks of the interaction organization. Only for the organization of the interaction of components of the system and the presentation of its integrity. To solve the problem of

directly detecting malicious software on local networks, methods will be applied that will apply to the lower level of the system. They will include the architectural features of the distributed system and the technology of detecting malicious software. The generalized scheme of the main components of the distributed system in local computer networks is shown in Fig. 1/ Architecture of the distributed multilevel detection system of the malicious software is presented in [16].

The architecture of a distributed multi-level system based on decentralization and self-organization to detect malware. Taking into account that the malware detection process will be conducted on local networks, the choice of the model of the system's operation should involve the inclusion of information from all computer systems of the local network, that is, placement in all computer systems of the system. This is necessary to increase the efficiency and reliability of detection by taking into account information on the state of other computer systems for decision-making in a particular computer system. These basic requirements that a system should be placed on the network in each computer system, affect the choice of model of its architecture. Also important for such systems is that the center of decision-making of the system is not presented and identified unambiguously, since its detection will lead to an attack on it to remove the entire system from the working state. The system should be constructed so that its components in the computer systems of the local network communicate effectively with each other for the exchange of information about the state of the computer systems in order to provide additional information for decision-making. In addition, the malware detection system must be structured accordingly in order to be able to grow and increase it should not slow down the detection process.

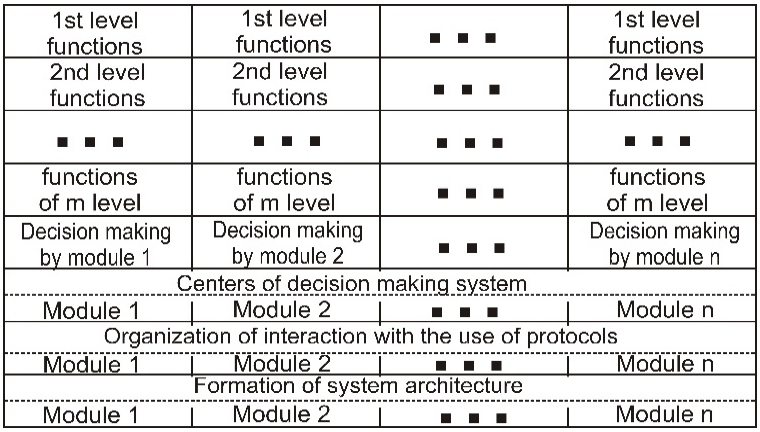

Fig.1 The generalized scheme of the main components of the distributed system

Structural components of the built-in distributed system appear as autonomous software modules. They can be in different states. The transition between module states is based on a defined set of transitions. Interaction between standalone software modules. It is based on their presence in certain states during operation. Distributed system is a responsive system that will monitor certain events. Each program module contains a resident mechanism, moving mechanisms for the transition between states.

Since the detection system is distributed, multilevel, decentralized and self-organized, then it is necessary to establish rules for its functioning and its components.

Method of interaction of components of distributed multi-level system of detection of malicious software on the basis of decentralization and self-organization. The method of component interaction supports the integrity of the system, changes its configurations, establishes the order of communication between the components of the system and the exchange of knowledge between them. It will be used to solve the tasks of organizing the interaction of components of the system. To solve the problem of the direct detection of malware, software will apply methods that are related to the lower level of the system, which will include the

architectural peculiarities of the distributed system and the technology of detecting the malicious software.

Initial conditions for work The distributed system according to the method of interaction of its components are as follows: the launch of the software module in a specific host is successful but successful; no less than in the two systems of the network, the start function was successful; programm module has already been preinstalled successfully. Then, the following protocols that occur on the network that are related to the functioning of the system, will be presented by some steps:

1) determining the states of program modules;

2) processing responses from the software module to the sent packages;

3) software uncertainty processing associated with the absence of responses to sent packages;

4) scanning a given port computer systems;

5) assessment of the status of the software module and its verification between the rest of the software module distributed multi-level system at the stage of the exchange of messages;

6) determining the state of a decentralized distributed system;

7) making a decision on the further work. distributed multi-level system in general on the basis of studying its state by software modules;

8) the removal of the active software module from the distributed multi-level system as a result of switching off the software module;

9) events that activate methods for detecting malicious software, affect the state of the state of the software module distributed by the distributed multi-level system; to carry out research of other computer systems for the presence of similar activities and exchange of received results;

10) processing and optimization of statistical data accumulated in the system by each module separately;

11) knowledge sharing in the middle of a decentralized distributed system;

12) joint execution of tasks with components distributed multi-level system;

13) the work is distributed by the basis system, consisting of only one component of system;

14) additional work of the distributed multi-level system with new software module.

Determination of the states of program modules distributed multi-level system. Determination of the status of each software module in the computer systems , in which the distributed multi-level system at the stages of the start of the software module during its initial installation, with daily loading of the computer systems, during the functioning of the computer systems and at the completion of the computer systems. Determination of the status of the program module in the computer systems includes verification of the computer systems, its software and directly the level of activity of the software module itself. Inclusion of information in the internal bases of each software module of the system. Comparing the results of scanning the computer systems with the previous scan results for a certain period stored in the scan database. If the scan results do not match the previous, then the computer systems is blocked and a corresponding message is displayed. If the basic scan settings match, then the software module continues to work. Preparation and formation of the message about your condition by each module of the system. Entering a package message into the software module (sent and received). Sending message packets about your condition to all other parts. distributed multi-level system in accordance with the specified registry of software modules of the system and computer systems in which they are located. Saving information about events by the numbers and addresses of program modules distributed multi-level system, which are included in the database of software modules of the remaining computer systems during installation.

Processing responses from the software modules computer systems to the sent packages. Receive responses to the sent message about the status of the software module. If the submitted package was delivered successfully, then the corresponding response is sent, and it will necessarily be received separately after the first packet sent from all components of the system. Expecting a response by the program module of the system occurs at a given time interval, which is calculated at the initial installation of the system and takes into account the technical capabilities of the network at the speed of packet transmission, and also certain criteria can be entered, the execution of which indicates the need to wait for the message on the sent package, rather than switching to next step. Taking into account the disabled computer systems

that contain the software modules distributed multi-level system and in which the software modules are not active, to assess the state of integrity the system is distributed and its structure at certain moments of time. Receiving responses from everyone registered in the distributed multi-level system, a software module from the rest of the computer systems on the successful receipt of their package with a statement of their status from all software modules distributed multi-level system. Conduct analysis of received answers from the software modules of the remaining computer systems and analysis from which the computer systems received replies, but not received. Processing of the response to the successful receipt of the package with the message about the status of the program module, which sent this message to all the rest of the software modules with distributed multi-level system, from a certain number of software modules and determination of those from which no response was received. Processing of the event, which consists in not receiving the response from anysoftware modules in the established time requirements. Adding the received information to the module's message base. Formation or confirmation of integrity distributed multi-level system with active program modules. For each package, which is formed after the computer systems is turned on and sent to the rest of the computer systems, it is mandatory to receive the application and to include the software modules in the register of the active software modules distributed multi-level system.

Processing by the program module of uncertainties associated with the lack of responses to sent packages. If the response to the sent packet from a given software module of a particular computer systems is not received within a specified time interval or the definition of such a fact by other criteria, then scan the required port of a given computer system. If the answer is received that the packet was not delivered due to crashes in the transfer system, then retry sending the packet to the specified computer systems.

Scan a given port computer systems . The port number through which the exchange of messages between program modules is defined during configuration when the software module is installed in the computer systems. Additionally, several more ports can be installed as backup to improve system durability. If the port scan is successful, that is, the port is accessible, then the mark in the database of sent and received messages is made and the software modules for this computer systems goes into the packet waiting state from it. Otherwise, that is, if the scan is unsuccessful and indicates that the port is unavailable, that is, the port is closed, then a mark is made in the database of sent and received messages and the software modules on this computer systems goes into the standby state of the packet from it. If the explored computer systems is off, in this case, make a backup of ports in turn. If the scan response is negative, then the software modules goes into the state of waiting for results from such a computer systems; otherwise, a result of such a result is being tested with other active software modules that have already been generated by the distributed multi-level system.

Evaluation of the status of the software module and its verification between the rest of the software module distributed multi-level system at the stage of the exchange of messages. Processing of events for the software module, which sent packets to all computer systems: for the sent packet the response was not received; After the port is scanned, the response in the form of a result is not received or received, which is open. Then the software module monitors its result with the results of the rest of the computer systems. For this purpose, a request is made in the form of a package of the rest of the software modules, besides the subject, who must send a confirmation of their work, on the state of the program module under study. In order to carry out the research on the instructions of one selected software module, the software module is distributed, the rest of the software module sends him one packet of his condition and processes the replies from him. Submit the research results of the selected software module to the requested module. Processing the results of the study of the selected software module. If the software modules received the same response from the module under study as the software module that activated this validation event, then all the software module of the distributed multi-level system consider that the module under study is not yet active and continue to wait for the packet from it when the computer systems is turned on. The explored computer systems can be excluded, then all the software module will receive the same response. If program modules received different responses from the study module or received a certain part and the other received no other answers, as well as the software module

that activated this validation event, then all program modules notify the administrator about this event, issue a message to their computer systems screen, write in their registry of extraordinary situations and reduce the distributed multi-level system for one software module.

Determine the state of a distributed multi-level system. After a certain time set by the administrator, program modules determine the state of the distributed multi-level system with a certain periodicity in time or upon occurrence of critical events in the *computer systems*. The software module is distributed by the state-of-the-art system by its level of security. Each software module individually after the start determines its own state and in subsequent work it changes depending on the functions performed. Preparation and formation of a package with the notification of its status to each software module system and sending it from each software module to the remaining active software module. Conduct confirmation of the successful delivery of the package to each software module from the rest of the software module.

To determine the state of safety, distributed multi-level system, we use the data at the current time from its software modules: the state of each software module from the beginning of the current start, the time spent in each state of the same software module, the levels of security in each state of each software module. Calculation by the formulas (1) and (2) of the state is allowed by the distributed multi-level system by each software module on the basis of the received data from all active software module. The division into the system is carried out in two stages. At the first stage, the level of defecation will be distributed by the state-of-the-art system by the formula 1:

$$R_{b,\text{РБС},1} = \frac{\sum_{l=1}^{n}(1-\sum_{s=1}^{m} k_{s,l} * p_{s,l})}{n}, \qquad (1)$$

where $R_{b,\text{РБС},1}$- the level of security distributed multi-level system, defined in the first stage, b - security designation, l - the number of the software module, n - number of software modules, distributed multi-level system, $k_{s,l}$ - the threat factor to be affected by the software modules, s - the status of the software modules, $[0;1]$ - the value of which is determined from the segment, depending on which functional imposition is laid down in a certain state, $p_{s,l}$ - the probability of being affected, m - number of states of the software modules.

By the formula 2 distributed multi-level system determines its center at the moment, as well as, based on this value, the allocation of critical software modules.

$$\mathrm{g}\left(\mathrm{R}_{\mathrm{b,РБС,1}}, \mathrm{k}, \mathrm{s}, \mathrm{s}_{\mathrm{c,РБС}}\right) = \begin{cases} 0, & \text{if the condition is fulfilled 1} \\ 1, & \text{if the condition is fulfilled 2}, \\ 2, & \text{if the condition is fulfilled 3} \end{cases} \qquad (2)$$

where $g\left(R_{b,\text{РБС},1}, k, s, s_{\text{c,РБС}}\right)$ - the function of determining the further steps for distributed multi-level system, $R_{b,\text{РБС},1}$ - security level distributed multi-level system , received in the first stage by the formula 1, k - number of active software modules from the total number n, s - state number, $s = 1, 2, \ldots, m$, m - number of states of the software modules, $s_{\text{c,РБС}}$ - average value for distributed multi-level system based on a set of states of its software modules. The conditions for specifying the function g are presented in the table. The total number of such cases can be 64, since there are four cases for the level of security, two cases for the number of software modules, which are included in the center distributed multi-level system at the current time, eight for attributing the center to one of the states due to the study of its deviation.

Under condition 1, if $g\left(R_{b,\text{РБС},1}, k, s, s_{\text{c,РБС}}\right) = 0$, then distributed multi-level system continues to work in the mode when its software modules works in the states in which they were. In this case, no action is taken on the handling of situations in certain selected computer systems.

When the condition 2 is fulfilled, if $g\left(R_{b,\text{РБС},1}, k, s, s_{\text{c,РБС}}\right) = 1$, then distributed multi-level system continues to work in the mode when its software modules works in the states in which they were. And also, the distributed multi-level system immediately notices program modules for which additional clarification is required regarding the tasks that are performed at the current time.

When the condition 3 is fulfilled, if $g(R_{b,\text{РБС},1}, k, s, s_{\text{с,РБС}}) = 2$, then distributed multi-level system goes to the second stage of refinement of its state based on the involvement of the time characteristics of the states of all the software modules.

If the likelihood of being affected by the malicious software will affect not only the software modules or their impact on these modules is insignificant, it does not allow you to determine the state of the distributed multi-level system as critical. Such a case is possible when the study in the first stage, due to the definition of the average value and its subsequent use, was low due to the short time from the last launch of the software modules or the need for its averaging into eight states. But it may turn out that many software modules have been or were in the same state for a long time, but the use of criteria of the first phase does not distinguish them. Therefore, to take into account such boundary features, we select the probability of being affected by the malicious software for the distributed multi-level system in certain specified states and we evaluate the such cases at the second stage of the study. For the second stage of the determination of the state distributed multi-level system, the general formula 3 of the definition of the level of security will look like:

$$R_{b,\text{РБС},2} = \frac{1}{4} * \left(\sum_{s=1}^{m} \left(1 - \prod_{\substack{j=1, \\ p_{s,j}<1}}^{n} (1 - p_{s,j}) \right) * k_s + \sum_{j=1}^{n} \sum_{\substack{s=1, \\ t_{s,j}>0, \\ w_{s,j}>0}}^{m} \left(\frac{t_{s,j}}{\sum_{s=1}^{m} t_{s,j}} * \frac{w_{s,j}}{\sum_{s=1}^{m} w_{s,j}} \right) + \sum_{s=1}^{m} \left((1 + k_s) * \frac{\sum_{j=1}^{n} w_{s,j}}{\sum_{s=1}^{m} \sum_{j=1}^{n} w_{s,j}} * \frac{\sum_{j=1}^{n} t_{s,j}}{\sum_{s=1}^{m} \sum_{j=1}^{n} t_{s,j}} \right) \right), \quad (3)$$

where $R_{b,\text{РБС},2}$ - the level of security distributed multi-level system determined at the second stage, b - refer to safety, s - the number of software modules of distributed multi-level system, n - the number of software modules distributed multi-level system, m - the number of states of software modules, k_s - rate risk of being infected with malware, s that state software modules, the value of which is determined from the segment, depending on $[0; 1]$ which functional load is laid in a certain state, $p_{s,j}$ - the probability of being affected malicious software, $w_{s,j}$ - number stays with the number of software modules j in the state s, $i = 1, 2, \ldots, n$, $t_{s,j}$ - the total time spent with the number of software modules in the state. Values $p_{s,j}$ are obtained on the basis of the results of the operation of the installed in the program modules of the subsystems of the detection of certain types of malicious software.

Pinging status message distributed multi-level system of each software module with the rest of the system software modules. Analysis and processing of results each software modules of distributed multilevel system. If all software modules calculate state distributed multi-level system the same, then the system continues to work. Results of checking on the status of a distributed multi-level system match, then sent a message of each software module to all other modules. This information is stored in the internal register of events. If you find that at least one of the software modules will respond to all the rest that he received from a module result is different from his, and their, then it indicates a message for all program modules number of the software module and its result, which is different from the general results. In this situation, all the software modules, in addition to which different from other results, the team sent him to lock the computer systems and output messages cause the lock on the screen, and they block the flow of any packages from it and withdraw it from the registry system. distributed multi-level system continue to operate, but each program module will display on the screen computer systems message number and status of software modules, which removed. If you find that a software module received from all the same value of the system, but it does not match the calculated it while he sent all its value, while the software module blocks and issues outlet computer systems situations message on the screen. If parts of software modules distributed multi-level

system received packets to then start the implementation of procedures to determine the reasons for not receiving messages. After processing these events continue the work program modules.

The decision on the future work of the distributed multi-level system as a whole based on a study of the state of software modules. Determining the level of each system based on levels of software modules, their distribution by groups at risk of being affected, that is defined levels of threats and a decision on further work-based system results in function 3 and Figure 4. If the state distributed multi-level system, defined as such that the degree of safety is 0-30%, while blocking software modules to implement all of the computer systems and notify the administrator. This event may also occur upon availability in the system of a large number of software modules, which are at levels 2 or 3 for a long time. If the state distributed multi-level system, defined as having security level is 30-75%, while blocking only those make computer systems, program modules which indicates the classification of the computer systems to the level of 0-30%, to inform the administrator and transfer system status on the amount of computer systems remaining. If the state distributed multi-level system, defined as having security level is 75-100%, while they explore the computer systems, in which the security level is less than 75% for a long time. If you exceed the time limit expired to combat the threat, then make blocking software modules of the computer systems, inform the administrator and proceed without remote software modules. If the state distributed multi-level system, defined as having security level is 75-100% and after study of the computer systems, in which the security level is less than 75% for a long time, they are not found, then continue.

Removing the active software from distributed multi-level system as a result of disabling the computer systems. If one of the computer systems turns off, then its program module tells the rest of the modules and only then there is a shutdown.

Events that activate methods for detecting malware affect the state of the state of the software modules distributed multi-level system. Investigating other computer systems for the presence of similar activities and sharing the results. When switching to the software modules level 2, the method of detecting file malware based on the agent approach and the fuzzy conclusion and the method is based on the distribution of access in the network and the attraction of additional computing components of the network. When switching the software module to level 3, the method of detecting botnets or the method of detecting exploits is used.

Processing and optimization of statistical data accumulated in the system by each module separately. With a small load of computer systems and the absence of other tasks that are related to the need to stay program module at level 2 or 3, and long-term in the state of 1, the software modules goes to level 4 and researches the accumulated statistical data. In particular, it monitors and analyzes the launch procedure of the software modules in comparison with other computer systems programs and the time it starts for a certain period of time. Processing such data includes the calculation of the main statistical parameters: the definition of the average value, the variance and the mean square deviation. Implementation of optimization of accumulated statistical data in the bases of software modules. If there is a calculation and a significant deviation is detected, data optimization is not performed, the computer systems is blocked and the administrator notifies.

Knowledge sharing in the middle of a distributed multilevel system. The results obtained by one software module distributed multi-level system, which relate to the detection and localization of the malicious software, are generated in a package and sent to other software modules on the network that use these results to verify their computer systems.

Compatible completion of the match problems distributed multi-level system. Collective execution of the tasks related to the detection of the malicious software by increasing the computational resources for the software module by sending a part of the tasks to other computer systems for the investigation of the malicious software, in which there are suspicious behaviors. In particular, the involvement of other computer systemsprocessors in the software modules of the processor's work to encourage the manifestation of the malicious software. Preparation and submission to other software modules of the results obtained.

The work is distributed multi-level system, consisting of only one software module. If the distributed multi-level system remains in one of the software modules, due to the

correct completion of the work of the other software modules, then it goes to the limited use of its capabilities and can move from the first level to the other, with limited capabilities. After the next new launch, the system is in this software modules, it is compulsory to check its status, provided it goes to level 2, remaining one in the system. Thus, every last running software modules during a new run is distributed by the host system so is checked.

Replacement distributed multi-level system with new modules. Computer systems that will turn on later will rebuild the system by expanding it. Each software module of the computer systems will mail packets to other software modules.

The use of the developed method allows organizing the maintenance of the integrity of the system and the transfer of knowledge received by separate structural components of a decentralized distributed system software modules to other components. The developed method is the basis for developing a bundle of software for a decentralized distributed detection system for malicious software in local computer networks based on its security level.

The developed method of interaction of components of the system allows to support the work of distributed multi-level systems and their integrity in local area networks. Based on it, a distributed, multilevel system is developed that allows it to be filled with the implementation of various methods for detecting malicious software and apply a network component to them when detected.

Experiments. A developed method for the interaction of components distributed multi-level system and implemented methods for detecting file malicious software was tested experimentally. The experiment was conducted on a local network. The results of the system have been saved to log files. To carry out the experiment, a network of 20 computer systems was involved. Each computer system was equipped with a virtual environment based on Qemu, which was activated by the software module of the developed system for investigating allegedly malicious behavior and receiving API functions calls. The study of executable programs was carried out in three stages of their functioning: access to the computer systems, activation and implementation of the established functions. Each software module has used the database of behavioral models of the malicious software program at its various stages of operation. In order to calculate the authenticity of the malware file detection, the following experiment was conducted with different types of file malware: file (simple) viruses, polymorphic viruses, metamorphic viruses, and Trojan horses. There were generated 600 software objects with the functional load of the four types of files under consideration, each containing 150 malicious software. Each of the generated variations of metamorphic viruses used the main techniques of confusing the code: inserting garbage commands, using equivalent instructions, and moving the instruction blocks. Signatures of the generated file malicious software are absent in the databases of the signal round. All program objects were divided into groups for specifying how they would enter the computer systems to take into account all possible ways of penetration into the computer systems:

1) program objects copied to the hard disk of each computer systems;

2) program objects loaded on flash drives and connected to each computer systems;

3) program objects downloaded to a pre-created web site;

4) program objects archived and sent to previously created electronic addresses;

5) program objects are downloaded to pre-created ftp-servers of all computer systems.

The launch of the generated program objects was carried out by a special program, which was installed in each computer systems and launched one software object from the malicious software in each computer systems at a time. Then everything was repeated to select another software object. Running useful programs in all computer systems was not performed. After turning on all the computer systems, the operation systems and all the programs that are scheduled to start automatically are loaded. All computer systems contained the same hardware and software.

The results of the conducted experiment and the assessment of the authenticity of the malware detection Distributed Multilevel System [16], in which the methods are implemented, is presented in Table 1. In addition, according to the results of the experiment, the number of software module that were involved in the study throughout the experiment and the number of software module that were blocked by the rest of the software module of the developed system during the detection were

also determined. This confirms the use of the rest of the components of the distributed system in the process of detecting the malicious software of individual software module.

Table 1

Experiment results for malicious software misleading the software

Software objects with explicit inside malicious software		Number of programs detected as suspicious	Percent detection,%	The number of software modules that were involved in the study of the whole experiment	Number of software modules that were blocked by the rest of the software modules of the developed system during the detection
File viruses	150	146	97,3%	0	2
Polymorphic viruses	150	134	89,3%	57	7
Metamorphic viruses	150	138	92,3%	24	3
Trojan programs	150	128	85,3%	2	5
Total	600	546	90,9	20,75	5,7

The following known anti-virus tools were selected for benchmarking: ESET Smart Security (version 10.1.204.0), Avast (version 17.5.2303), Comodo Antivirus (version 8.2.0.4674), Kaspersky (version 17.0.0.61), McAfee Internet Security (version 10.1.0), Dr.Web (version 11.0), Microsoft Security Essentials (version 4.11.15063.446), Avira Antivirus (version 10.0). The results of the developed Distributed Multilevel System for detecting malicious software are presented in the diagram in Fig. 2.

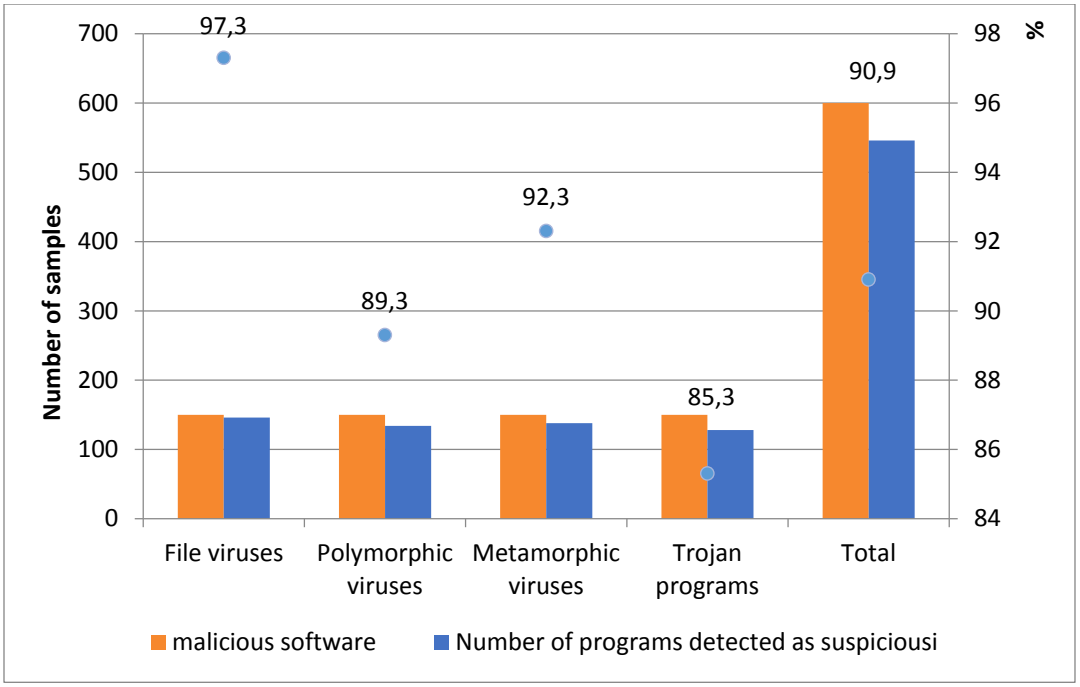

Fig. 2. Experiment results

The results of experimental studies using the developed Distributed Multilevel System based on the method of organizing the interaction of its components are confirmed by the fidelity of the scientific principles of the developed methods and the efficiency of the architecture of the distributed multilevel system. Its implementation increases the authenticity of the detection by 5-12% in the network representation compared to the host, and by 2-4% compared with the existing network firewall detecting the file new malware.

Conclusions. Using the developed method of interaction of components of the system allows organizing the support for the integrity of the distributed multi-level system and the transfer of knowledge acquired by the individual structural components of the system software modules of the remaining components. The developed method is the basis for developing a bundle of software distributed multi-level decentralized system of detection of malicious software.

The direction of further research is the development of new models of malicious software, the detailed structure of the distributed multi-level system, its states and filling subsystems of detection of various types of malware.

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ОРГАНІЗАЦІЯ ВЗАЄМОДІЇ КОМПОНЕНТІВ РОЗПОДІЛЕНОЇ БАГАТОРІВНЕВОЇ СИСТЕМИ ВИЯВЛЕННЯ ЗЛОВМИСНОГО ПРОГРАМНОГО ЗАБЕЗПЕЧЕННЯ НА ОСНОВІ РІВНІВ ЇХ БЕЗПЕКИ

У роботі представлено розроблений метод взаємодії компонентів розподіленої багаторівневої системи виявлення зловмисного програмного забезпечення (ЗПЗ) на основі децентралізованої та самоорганізованої архітектури в локальних мережах. Її особливістю є синтез в ній вимог розподіленості, децентралізованості, багаторівневості та самоорганізованості. Це дозволяє використовувати її автономно. Основою побудованої розподіленої системи є її структурні компоненти, які представляються автономними програмними модулями, що можуть перебувати в різних станах. Перехід між станами модулів здійснюється на основі визначеної множини переходів. Взаємодія та спілкування між автономними програмними модулями базується на основі їх перебування в певних станах під час експлуатації та встановлюється правилами розробленого методу. Розподілена система є реагуючою системою, яка здійснюватиме моніторинг визначених подій. Кожен програмний модуль містить резидентний механізм, рушійні механізми для переходу між станами, переходи між якими задаються підмножинами переходів, данні для яких формуватимуться з використанням технологій штучного інтелекту. Крім того, особливістю компонентів системи є така самоорганізація, що дає змогу здійснювати обмін знаннями в середині системи, яка на відміну від відомих систем дозволяє використовувати знання отримані окремими частинами системи в інших частинах. Розроблена система дозволяє здійснювати її наповнення підсистемами виявлення різного типу зловмисного програмного забезпечення в локальних обчислювальних мережах. Метод взаємодії компонентів розподіленої багаторівневої системи виявлення ЗПЗ встановлює порядок здійснення комунікації між частинами системи та обміну знаннями між ними. Він застосовуватиметься для організації взаємодії компонент системи і підтримки її цілісності. Для вирішення проблеми з безпосереднього виявлення ЗПЗ в локальних обчислювальних мережах застосовуватимуться методи, які відноситимуться до нижчого рівня системи, що включатимуть архітектурні особливості розподіленої системи і технології виявлення ЗПЗ. Проте розроблений метод взаємодії включає можливість визначення стану розподіленої багаторівневої системи в залежності від станів окремих модулів та на його основі згідно нього прийматимуться рішення про подальшу роботу системи в цілому і її конфігурацію. Метод регламентує дії тієї частини системи, яка відноситься до зв'язуючого програмного забезпечення розподіленої системи. Проведені експерименти з використання розробленої розподіленої системи показали можливість залучення до виявлення ЗПЗ обчислювальних потужностей інших КС локальної мережі. Отримані результати експериментів показують підвищення достовірності виявлення ЗПЗ.

Ключові слова: *зловмисне програмне забезпечення, розподілена багаторівнева система, децентралізована система, комп'ютерні системи, локальна мережа*

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ОРГАНИЗАЦИЯ ВЗАИМОДЕЙСТВИЯ КОМПОНЕНТОВ РАСПРЕДЕЛЕННОЙ МНОГОУРОВНЕВОЙ СИСТЕМЫ ОБНАРУЖЕНИЯ ВРЕДОНОСНОГО ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ НА ОСНОВЕ УРОВНЕЙ ИХ БЕЗОПАСНОТИ

В работе представлен разработанный метод взаимодействия компонентов распределенной многоуровневой системы обнаружения вредоносного программного обеспечения (ВПО) на основе децентрализованной и самоорганизующейся архитектуры в локальных сетях. Ее особенностью является синтез в ней требований распределенности, децентрализованости, многоуровневости и самоорганизованности. Это позволяет использовать ее автономно. Основой построенной распределенной системы является ее структурные компоненты, которые представляются автономными программными модулями, которые могут находиться в разных состояниях. Переход между состояниями модулей осуществляется на основе определенной множества переходов. Взаимодействие и общение между автономными программными модулями базируется на основе их пребывания в определенных состояниях при эксплуатации и устанавливается правилами разработанного метода. Распределенная система является реагирующей системой, которая будет осуществлять мониторинг определенных событий. Каждый программный модуль содержит резидентный механизм, движущие механизмы для перехода между состояниями, переходы между которыми задаются подмножествами переходов, данные для которых будут формироваться с использованием технологий искусственного интеллекта. Кроме того, особенностью компонентов системы есть такая самоорганизация, что позволяет осуществлять обмен знаниями внутри системы, которая в отличие от известных систем позволяет использовать знания, полученные отдельными частями системы в других частях. Разработанная система позволяет осуществлять ее наполнения подсистемами обнаружения различного типа вредоносных программ в локальных вычислительных сетях. Метод взаимодействия компонентов распределенной многоуровневой системы обнаружения ВПО устанавливает порядок осуществления коммуникации между частями системы и обмена знаниями между ними. Он будет применяться для организации взаимодействия компонент системы и поддержания ее целостности. Для решения проблемы с непосредственного обнаружения ВПО в локальных вычислительных сетях применяться методы, которые будут относиться к более низкому уровню системы, включающие архитектурные особенности распределенной системы и технологии обнаружения ВПО. Однако разработанный метод взаимодействия включает возможность определения состояния распределенной многоуровневой системы в зависимости от состояний отдельных модулей и на его основе по нему будут приниматься решения о дальнейшей работе системы в целом и ее конфигурации. Метод регламентирует действия той части системы, которая относится к связующему программному обеспечению распределенной системы. Проведенные эксперименты по использованию разработанной распределенной системы показали возможность привлечения к выявлению ВПО вычислительных мощностей других КС локальной сети. Полученные результаты экспериментов показывают повышение достоверности обнаружения ВПО.

Ключевые слова: *вредоносное программное обеспечение, распределенная многоуровневая система, децентрализированная система, компьютерные системы, локальная сеть*

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POSINGTHE PROBLEMOF IDENTIFYING UNAUTHORISED ALARM MESSAGES IN THE AUTOMATED SYSTEMS OF EARLY DETECTION OF EMERGENT SITUATIONS

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Abstract. The goal of the paper is to analyze the problem of creating an automated system for early detecting the threat of emergencies of anthropogenic nature and preventing the transmission of unauthorized alarms. The research methods of system analysis, graph theory, information theory were used to achieve this goal. Main results of the research. In most cases the reason for emergencies is a disruption of the technological process. An integral part of the systems of early detection of emergent situations are alarm systems. It's purpose is to notify operators about abnormal or emergent situations through sending alarm signals. In the conditions of real industrial enterprises, most abnormal accidents of alarm, including false and missed alarms, always hinder the judgments of operators. This leads to an errors in the assessment of the situation and critical consequences finally. We can make a conclusion that the problem of improving resistance to interruption to signal processing and recognizing false signals is actual for the effective operation of enterprises and preventing emergencies.

The primary signals and transmission channels may be affected by external and internal interference. It leads to distortion of the signal and transmission of a false information. The problem of identifying false signals as the results of atmospheric agents, human factors and failures are solved "manually" today and that is not rational. Therefore, the problem of converting group of signals into one signal, its further transmission through a communication line and separation of signal for detecting the source of the false message. This approach will provide an opportunity to improve the quality of data transmission and the efficiency of automated systems of early detection of emergent situations on the whole.

Scientific novelty. The classic methods of digital discrimination discriminate when applied to identifying false alarms. The transmitted signals should be known for correct identification. Under real conditions, signals may be distorted due to

interference with communication channels. Another limitation on the use of classical methods is the condition for perfect synchronization of signals.

Thus, it is necessary to develop methods for processing signals and detecting false signals without existing restrictions and taking into account incompleteness of data. This approach will improve the quality of data transmission and the effectiveness of automated early detection systems in general.

Practical significance. Solving of the defined problem will give opportunity to increase the accuracy and reliability of the parameters of the emergent situations monitoring systems. Early detection of such emergent situations is a guarantee of prevention of man-made disasters at different levels.

Keywords*: emergency situations, unauthorized alarm messages, automated systems.*

Formulation of the problem. An analysis of the current state of technogenic safety in Ukraine indicates that a lot of objects with an accidents risk are present. These accidents could lead to emergencies of a different nature. There is a high risk of emergencies connected with accidents with release or threat of release of hazardous chemicals in Ukraine. It relates to the operation of 711 facilities. Mentioned above facilities store or use in the production activity more than 285 thousand tons of hazardous chemicals, including 3 thousand tons of chlorine, 183 thousand tons of ammonia and about 99 thousand tons of other hazardous chemicals [1]. Among the objects that store or use chemicals in their activities, the most potentially dangerous are:

- production of explosives and disposal of unsuitable ammunition;
- large-scale production of inorganic substances (mineral fertilizers, chlorine, ammonia, acids);
- oil and gas refineries;
- production of organic synthesis products;
- production using chlorine and ammonia;
- Warehouses with reserves of pesticides for agriculture;
- main ammonia and ethylene pipelines.

Considering the importance of protecting the population and the environment from the emergencies at the dangerous objects, the Cabinet of Ministers of Ukraine developed and approved the Methodology for determining the risks and their permitted levels for making statement of being safe about dangerous objects, and also the thresholds of hazardous substances [2] .

The automated systems for early detection of emergencies and for alarms in the cases of emergencies are installed at the dangerous enterprises. In the case of a threat or emergency, the automated system should automatically inform responsible persons about identified threat. The responsible persons have to carry out certain actions to prevent the emergency or minimize the negative consequences in case of its occurrence [3].

Taking into consideration the state of technogenic safety and significant number of dangerous objects in Ukraine, preventing emergencies and timely informing the responsible persons about the threats of their occurrence is an urgent problem. The guarantee of preventing man-made disasters at all levels is the accuracy and reliability of monitoring systems parameters, as well as their early detection.

An integral part of mentioned systems of early detection of emergencies are the alarm systems. Their purpose is to inform responsible persons by sending alarm signals about abnormal or emergent situations. The most of abnormal alarms, including false alarms and missed alarms, always hinder the judgments of operators in real conditions at the industrial enterprises [4]. This leads to errors in the assessment of the situation and can lead to critical consequences. Thus the problem of improving resistance to interruption to signal processing and recognizing false signals is actual for the effective operation of enterprises and preventing emergencies.

Analysis of recent research and publications. The reason for the occurrence of emergencies is mostly a violation of the technological process. The problem of recognizing false alarms is relevant for most of automated systems. Particularly for security systems, fire safety systems, detection systems, radar systems in the military sphere, and others [5-6]. False alarms are associated with information exchange technologies and occur as a side effect of system technologies and the process of notification [7].

The authors of paper [5] listed such causes of false alarms as incorrect installation of sensors, improper setting

of electronic blocks, etc. They propose to use the probabilistic approach to determine the sensor's resistance to interruption based on statistical data.

Signals are transferred from primary information source in the form of GSM messages or radio signals both by means of electrical signals or wireless communication channel. The problem of signal transform and protection from interference occurs.

Depending on the subject area, where the problem of detecting and eliminating false alarms occurs and depending on the type of signal, it can be processed by different methods. For example, in the paper [8] author proposed to use conditional probabilities taking into account the levels of false alarms and reliability in the framework of creating a reliable engineering system.

There are adaptive, non-parametric, adaptively-nonparametric and robust methods of resistant detection and stabilization of false alarms level. In general they can be divided into pre-detecting and after-detecting methods for stabilizing false alarms [9].

In paper [10] author gives an algorithm to achieve consistent probability of false alarms. It is based on the calculation of threshold value, which is a quantile of the distribution of maximum values.

Due to conducting an analysis of research papers devoted to the problem of detecting false alarms, we can make a conclusion that the developing methods for recognizing false alarms is an actual problem and its solution depends on the field of subject.

The aim of the study. The purpose of this research is to analyze the problem of creating an automated system for early detection of the threat of emergencies of anthropogenic nature and prevent the transmission of unauthorized alarms.

In order to solve the problem we have to investigate the scheme of signals transmission from the sources to the responsible person; characteristics of transmitted signals; requirements for the system of message transmission and requirements for data being processed.

Setting the problem of detecting unauthorized alarms. The alert is made by transmitting signals from measuring sensors to its respondents. The storage of data from sources of primary information should include:

- Receiving data in the form of analog, discrete or coded signals that include information about the current value of controlled parameters and its reaching critical values, as well as information related to the tripping of manual detectors;

- Receiving information from primary information sources about their performance loss;

- Determining the ability of communication channels to transmit signals from the sources of primary information (sensors), depending on the source interface controlling the lines of communication for breakage or closure, deviations of the defined parameters, the presence of confirmation from the DPI on the exchange of data, the reliability of the data received from primary information source.

Recognition of discrete messages in the presence of interference for coherent signal receiving is carried out under the following conditions [10]:

1) the transmitted signals $s_i(x)$, $i = 1, ..., m$ is completely known;

2) the communication channel has known parameters;

3) the interference n(x) has an additive character, has a Gaussian probability density and a known spectral density G_N;

4) Synchronization of signals is ideal.

Then the real signal can be described by the model:

$$\xi(x) = s_i(x) + n(x) \quad (1)$$

where $\xi(x)$ -measured vector that includes all possible transmitted signals $s_i(x)$ (for a each signal $s_i(x)$ (m-1) components of the vector $\xi(x)$ are zero). It is necessary to provide the optimal difference of the signals $s_i(x)$.

Analog signal processing can take place by making them discrete.

Let's introduce the following designation

SU – a switching unit

UNU – Universal notification unit

LS – a loudspeaker

IE – inputs Extender

RD – reconciliation device

MA – manual alert

RF – radio feeder

PTN – a public telecommunication network

AA – an additional amplifier

Thus the signal transfer process can schematically be described as it shown at the Fig. 1

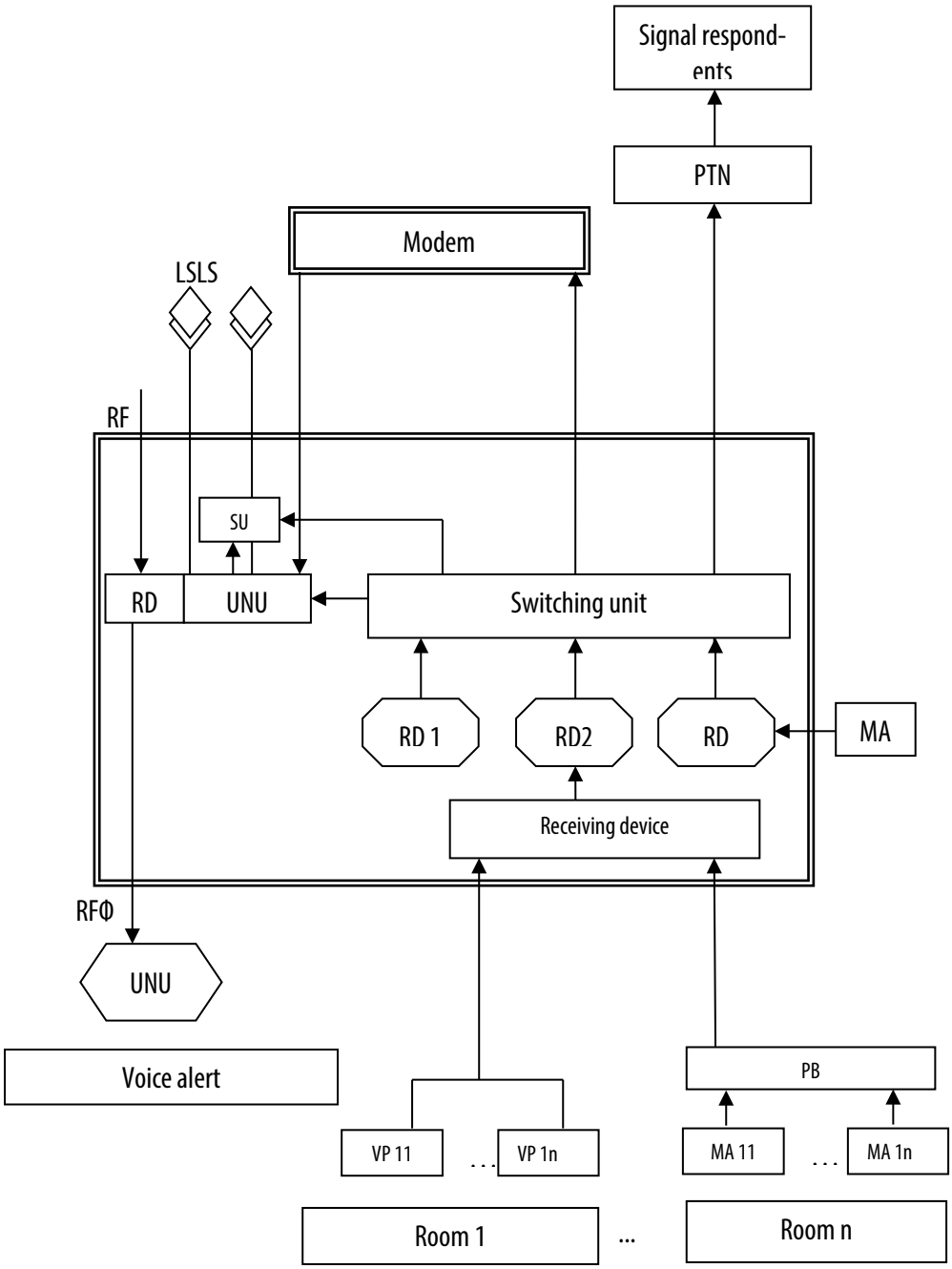

Fig. 1. Signal transfer process

In the process of collecting data concerning the current state of sources of man-caused hazards and natural hazards from the primary information sources further stages iscarried out:

- Creating appropriate notifications in case of violations of the capacity of technical means of the system,

- Comparison of the current values of parameters received from the primary information sources with defined thresholds and creating appropriate messages in the case of excess,

- Creating corresponding messages in case of violation (restoration) of communication with primary information

sources, refusal (restoration) of primary information sources performance,

- prohibiting the creation of a message in case of refusal of the primary information sources or a violation of the connection with it.

The primary information source signal is transmitted to the receiving device, which processes the signals and transmits information to the modem device from which the data is transmitted to the central monitoring panel. The primary signals and lines of communication may be affected by external and internal interference, which results in distortion of the signal and transmission of a false message. The problem of identifying false signals as the results of atmospheric agents, human factors and failures are solved "manually" today and that is not rational. The distance between the primary information source and the remote control can reach several kilometers in the conditions of real industrial enterprises. Therefore, the problem of converting group of signals into one signal, its further transmission through a communication line and separation of signal for detecting the source of the false message. This approach will provide an opportunity to improve the quality of data transmission and the efficiency of automated systems of early detection of emergent situations on the whole.

Let's formulate the statement of the problem. Let N sources (UNU, MA) transmit signals $x_1, x_2, ..., x_n$ to the device (gas analyzer). It is necessary to convert the set of signals $\{x_i\}$ into a group signal $S_\Sigma(t)$. The group signal are transmitted through condensed channel to a device with an additive interference $n(t)$ and the receiver gets the message from the device in separated form

$$U_\Sigma(t) = S_\Sigma(t) + n(t) \qquad (2)$$

The task of the separation device is to divide the group signal $U_Y(t)$ and convert it into a set of messages $y_1, y_2, ..., y_n$.

For this purpose device has to select a system of the functions $\{S_i\}$ with will provide recovery of x_i through y_i due to received signal group $U_Y(t)$.

As a result, the problem is to combine and separate signals.

It is necessary to use orthogonal signals in order to exclude the possible influence of individual signals on each other [10]. That is, for any pair of signals S_i, S_j, $i \neq j$ one of the conditions must be fulfilled:

$$\int_{-T/2}^{T/2} S_i(\varpi, \Theta, t) \cdot S_j(\varpi, \Theta, t) dt = 0 \qquad (3)$$

where T is the duration of the signal element, ω - the signal frequency, Θ is the spatial angle of signal observation.

Discrete signals can be represented by a N-dimensional vector $X = (x_0, x_1, ..., x_i, ...x_{N-1})$, where x_i– the numerical value of the signal at the point i of the discrete frame. The methods of transformation that allow reproducing the output signals with sufficient accuracy with a smaller number of readings could be used in this case [13].

Conclusions:

1. An analysis of the current state of technogenic safety in Ukraine shows that preventing emergencies and timely informing the responsible persons about the threats of their occurrence is an urgent problem.

2. Due to conducting an analysis of research papers devoted to the problem of detecting false alarms we have made a conclusion that the main causes of false alarms as incorrect installation of sensors, improper setting of electronic blocks, etc.

3. The purpose of analyzing the problem of creating an automated system of early detecting emergencies of anthropogenic nature and preventing the transmission of unauthorized alarms is set. Classical methods for recognizing discrete messages applied to the recognition of false alarms have a lot of shortcomings. The transmitted signals must be known. In real conditions, taking into account the noises influencing the communication channels, transmitted signals could be distorted or not transmitted. Restriction in application of classical methods is also a condition of perfect synchronization of signals.

4. The problem of detecting unauthorized alert messages where informing is conducted by transmitting signals from measuring sensors to the respondents of the notification were set.

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Аннотация. Целью данной работы является анализ проблемы создания автоматизированной системы раннего обнаружения угрозы чрезвычайных ситуаций антропогенного характера и предотвращения передачи несанкционированных сигналов тревоги. Для достижения этой цели использовались методы исследования системного анализа, теории графов, теории информации. Основные результаты исследования. В большинстве случаев причиной аварийных ситуаций является нарушение технологического процесса. Неотъемлемой частью систем раннего обнаружения нештатных ситуаций являются системы сигнализации. Целью таких систем является оповещение операторов об аномальных или аварийных ситуациях посредством отправки сигналов тревоги. В условиях реальных промышленных предприятий ложные и пропущенные сигналы препятствуют правильным суждениям операторов. Это приводит к ошибкам в оценке ситуации и критическим последствиям в конечном итоге. Можно сделать вывод, что проблема повышения устойчивости к прерыванию обработки сигналов и распознавание ложных сигналов актуальна для эффективной работы предприятий и предотвращения аварийных ситуаций.

На первичные сигналы и каналы передачи могут влиять внешние и внутренние помехи. Это приводит к искажению сигнала и передаче ложной информации. Проблема выявления ложных сигналов как результат воздействия атмосферных факторов, человеческих факторов и отказов решается сегодня «вручную», что не рационально. Поэтому возникает проблема преобразования группового сигнала в один сигнал, дальнейшей его передачи по линии связи и разделения сигнала для обнаружения источника ложного сообщения. Такой подход даст возмож-

ность повысить качество передачи данных и эффективность автоматизированных систем раннего обнаружения нештатных ситуаций в целом.

Научная новизна. Классические методы распознавания цифровых сообщений имеют недостатки при применении к идентификации ложных тревог. Передаваемые сигналы для правильной идентификации должны быть известны. С учетом помех, влияющих на каналы связи, в реальных условиях сигналы могут быть искажены. Еще одним ограничением применения классических методов является условие идеальной синхронизации сигналов.

Таким образом, необходимо разработать методы обработки сигналов и обнаружения ложных сигналов, которые бы снимали ограничения, присущие классическим методам и учитывали неполноту данных. Такой подход даст возможность повысить качество передачи данных и эффективность автоматизированных систем раннего обнаружения нештатных ситуаций в целом.

Практическое значение. Решение поставленной задачи позволит повысить точность и достоверность параметров систем мониторинга чрезвычайных ситуаций. Раннее выявление таких возникающих ситуаций является гарантией предотвращения техногенных катастроф на разных уровнях.

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Анотація. Метою статті є аналіз проблеми створення автоматизованої системи раннього виявлення загрози надзвичайних ситуацій антропогенного характеру та запобігання передачі несанкціонованих тривожних повідомлень. Для досягнення цієї мети були використані методи дослідження системного аналізу, теорії графів, теорії інформації. Основні результати дослідження. У більшості випадків причиною надзвичайних ситуацій є порушення технологічного процесу. Невід'ємною частиною систем раннього виявлення надзвичайних ситуацій є системи сигналізації. Призначення зазначених систем є сповіщення операторів про аномальні або надзвичайні ситуації шляхом надсилання сигналів тривоги. В умовах реальних промислових підприємств помилкові та пропущені сигнали тривоги перешкоджають правильним судженням операторів. Це призводить до помилок в оцінці ситуації та критичних наслідків. Можна зробити висновок, що проблема підвищення стійкості до переривання обробки сигналів і розпізнавання помилкових сигналів є актуальною для ефективної роботи підприємств і запобігання надзвичайним ситуаціям.

На первинні сигнали і канали передачі можуть впливати зовнішні та внутрішні перешкоди. Це призводить до спотворення сигналу і передачі хибної інформації. Проблема виявлення помилкових сигналів як результат впливу атмосферних явищ, людських факторів та відмов вирішується сьогодні "вручну", що не раціонально. Тому виникає проблема перетворення групового сигналу в один сигнал, його подальша передача по лінії зв'язку і поділ сигналу для виявлення джерела помилкового повідомлення. Такий підхід дасть можливість поліпшити якість передачі даних та ефективність автоматизованих систем раннього виявлення надзвичайних ситуацій в цілому.

Наукова новизна. Класичні методи дискримінації цифрових повідомлень мають недоліки при застосуванні до ідентифікації помилкових тривог. Передані сигнали повинні бути відомі для правильної ідентифікації. У реальних умовах сигнали можуть бути спотворені унаслідок перешкод, що впливають на канали зв'язку. Іншим обмеженням на застосування класичних методів є умова досконалої синхронізації сигналів.

Таким чином, необхідно розробити методи обробки сигналів та виявлення хибних сигналів без існуючих обмежень та враховували неповноту даних. Такий підхід дасть можливість поліпшити якість передачі даних та ефективність автоматизованих систем раннього виявлення надзвичайних ситуацій в цілому.

Практичне значення. Вирішення поставленої задачі дасть можливість підвищити точність і достовірність параметрів систем моніторингу на ситуацій. Раннє виявлення виникнення надзвичайних ситуацій є запорукою запобігання техногенних катастроф на різних рівнях.

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THE USE OF THE FUZZY GAME MODEL IN MANUFACTURE PLANNING AT THE AGROENTERPRISE

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Abstract. The market orientation of the agrarian sector is increasingly requiring agricultural managers not only to be able to see the prospects of their industry, but also to take effective managerial decisions in the given risky, crisis economic conditions. The manager, who takes decisions at a modern agroenterprise, must solve the problems of forming the product range and product yield, must evaluate the existing and expected market needs in this product, that is, solve the tasks of strategic management. To do this, he must have at his disposal mathematical methods and information technologies adapted to this subject area.

The purpose of the study is to use fuzzy game models of decision making when planning production at an agrarian enterprise. The issue of taking managerial decisions in agriculture requires more detailed mathematical processing and working out the principles and conditions for improving their efficiency. The methods of fuzzy set theory and game theory are used to create a manufacture planning model.

Research methods. The article considers the possibility of using fuzzy game models of decision making in manufacture planning at an agroenterprise. In order to improve the accuracy of manufacture planning forecasts, a production planning

model based on the data from previous sales has been proposed relying on the joint application of game theory and fuzzy mathematics.

The main results of research. The use of the proposed model will allow increasing the efficiency and quality of management decisions due to the integrated usage of mathematical models and methods.

Scientific novelty. To confirm the obtained results practically, the risk matrix, matrix of gain and criteria for decision making under conditions of uncertainty and risk were assessed, a set of fuzzy rules, which form together with the accepted conditions Wang-Mendel's fuzzy inference model, was given, and the value of gain for choosing a manufacture strategy based on a fuzzy game mode was calculated. The joint application of the game theory and fuzzy mathematics is determined, firstly by the conditions of uncertainty, and secondly by the refusal from the probabilistic approach applied in the theory of games. The proposed model allows carrying out calculations using modern information technologies.

Practical significance. The use of mathematical models and modern information technologies for agroenterprises will allow using the enterprise resources in a more efficient way; optimizing work; minimizing risks; analyzing thoroughly and accelerating the process of making managerial decisions. To take and implement decisions is the most important function of management, which successful execution ensures the enterprise to achieve its goals.

Keywords*: optimal manufacture planning, games with "nature", decision making criteria, Wang-Mendel's fuzzy inference model, fuzzy game model.*

Problem Statement. To take and implement decisions is the most important function of management, which successful execution ensures the enterprise to achieve its goals. The most well-developed subject is the construction of a mathematical model for optimizing a production programme. A large number of models of different completeness and complexity have been developed. However, there is a certain space for new investigations, especially in the area of adaptation of existing models and methods of optimizing the production programme to the peculiarities of a particular type of enterprises and a specific enterprise as well [5, 8, 11].

The issue of taking managerial decisions in agriculture requires more detailed mathematical processing and working out the principles and conditions for improving their efficiency [5, 11].

The need to consider the significant sources of uncertainty in planning at an agrarian enterprise, as well as to minimize their negative economic consequences, is nowadays obvious and widely recognized.

Review of the Literature. Problems of using the theory of games for the managing socio-economic facilities were considered in the works of D. Blackwell, V. Burkov, E. Ventsel, M. M. Girshik, M. Gubko, M. Dresher, G. Dyubin, Y. Zaychenko, M. Intriligator, S. Karlin, R. Keeney, P. Konyukhovsky, N. Kremer, O. Larichev, D. McKinsey, O.Morgenstern, J. Neumann, S. Orlovsky, D. Pospelov, V. Suzdal, E. Trakhthengerts, D. Shapiro, D. Judin and others.

Despite the developed character of the theory of games and the diversity of its models and methods, in order to support decision-making in the matter of choosing a strategy there exist certain problems of their adaptation to a particular enterprise, because in most cases the task of choosing a strategy has a unique, individual character.

An overview of literary sources [5, 11, 14] meanwhile shows that the given difficulties can be eliminated when using the apparatus of fuzzy logical conclusions in game models [7, 8, 20, 33], with the help of which both wins and losses, and possible players' strategies are expressed in terms of fuzzy sets [7, 8, 12, 15].

The works of O. Altunin, V. Borisov, A. Kofmann A., V. Kruglov, S. Orlovsky, D. Pospelov, L. Wang, J. Mendel and other scholars are devoted to using the methods of the theory of fuzzy sets for solving the tasks of mathematical modeling.

The aim of the paper is to study the use of fuzzy game models of decision making in manufacture planning at an agrarian enterprise.

Presentation of research material. The problem of risk and profit is one of the crucial problems in economic activity, in particular in production and finance management. Risk is defined as the probability (threat) of loss by a person or organization of part of their resources, lack of income or the emergence of additional costs as a result of the implementation of certain production and financial policies [5, 11, 14].

One of the most common methods of strategic analysis, planning and management of agricultural enterprises are the methods of economic-mathematical modeling. These methods give an opportunity to conduct a comprehensive research of the structure of agricultural enterprises. At the same time, the methods of economic-mathematical modeling are used to make operative and strategic plans for the activity of agricultural enterprises. This is primarily due to the fact that these methods allow solving a number of issues related to the development of alternative ways of the activity of an enterprise, optimization of the structure of agricultural enterprises, optimization of production costs and sales of agricultural products [11, 14].

The use of methods of economic-mathematical modeling is firstly related to understanding of production processes and restrictions that operate in the manufacturing and sales of products. These restrictions form the structure of the economic-mathematical model of enterprise's activity and provide the basis for solving the given task. The restrictions of the economic-mathematical model are by their nature a mathematical interpretation of the statement of strategic management at agricultural enterprises.

The optimization economic-mathematical model is based on the restrictions of the activity of an agricultural enterprise. At the same time, these restrictions are divided into two groups: inequalities and equations. The first group of restrictions is the largest. A group of restrictions that consists of inequalities describes the process of manufacturing and sales of products. A group of restrictions that consist of equations most often describe the requirements to a task, but this group is rather rarely used in solving the optimization problem, since "hard" restrictions of the task do not allow conducting the modeling process using alternative solutions of the tasks [5, 11].

It is important that economic-mathematical modeling provides the opportunity to conduct a strategic analysis at all stages of agricultural production. In this case, the use of economic-mathematical modeling is possible for the analysis of the development of the activity of an enterprise in future periods, provided that the restrictions of the task will be established. Therefore, the most important factor influencing the quality of the carried out strategic analysis in agriculture is defining the restrictions of the enterprise's activity and being correctly reflected in the form of equations and inequalities.

One of the main advantages of using these methods is that economic-mathematical modeling provides an opportunity to investigate the effect of changing the certain restrictions of the task on forming the final result, thereby increasing the number of strategic alternatives without using a repeated full solution of the problem and finding the factors that have the largest influence on the final result of the task. The disadvantage of conducting economic-mathematical modeling is the lack of a clear mechanism that would take into account the restrictions of the modeling tasks of the activity of an enterprise, coming from the external environment of an agricultural enterprise [5, 11].

It is possible to optimize the manufacture of agricultural products of a particular enterprise with the help of methods of economic-mathematical modeling. The solution to the problem is to find the maximum yield from the sale of products in the conditions of limited amounts of manufacturing resources.

The structural model of the task has the form:

$$\begin{cases} F_{\max} = \sum_{j=1}^{n} c\ x \\ \sum_{i=1}^{m} a_i x \le V_i \\ x \ge 0;\ \mathrm{i} = \overline{1, \mathrm{m}} \end{cases}$$

where F – the income from sales of agricultural products (wheat) (thousand UAH);

c – the selling price of wheat (UAH);

x – the amount of agricultural products (wheat) (t);

a_{ij} – the norms of expenses of the i-type of resource for the production of 1 tonne of wheat (UAH / t);

V_i – the actual volume of the i-type of resource (UAH);

m – the number of available resources involved in the production process.

In order to make decisions in conditions of uncertainty and risk using the game model, the input information is presented in the form of a matrix, the lines of which are possible alternative solutions, and the columns are the states of the system (environment) [12-13, 15].

The matrix of possible wins (obtaining a conditionally net profit) - $\|V_{ji}\|$ is based on the data of Table 1 and Table 2. The set of managerial decisions is a finite number - R_j (j = 380,67; 1818,92 – from the minimum production to the possible maximum), S_i is the state of "nature" (in this case, production volumes for the previous periods). Implementation of the R_j solution in conditions when the "nature" is in a state will lead to a definite result in a quantitative terms.

The element of the matrix $\|V_{ji}\|$:

$$V_{ji} = \begin{cases} V_{prod_i} \cdot P - V_{vyrob_j} \cdot C, & V_{prod_i} \le V_{vyrob_j} \\ V_{vyrob_j} \cdot P - V_{prod_i} \cdot C, & V_{prod_i} > V_{vyrob_j} \end{cases}$$

where V_{prod_i} –sales for the first year;

$i = 1,8$;

C – the purchase price of wheat;

P – the selling prices of wheat;

V_{vyrob_j} – the production volume;

j=380,67; 1818,92.

The volume of production is adjusted taking into account the balances of wheat:

$$V_{vyrob_j} = \begin{cases} V_{vyrob_{j+1}} + (V_{vyrob_j} - V_{prod_i}), & V_{vyrob_j} \ge V_{prod_i} \\ V_{vyrob_j}, & V_{vyrob_j} < V_{prod_i} \end{cases}$$

Several criteria are used to make decisions under the conditions of uncertainty: Wald's, Laplace's, Savage's, Hurwitz's. The decision-making criterion is a function that expresses the benefits of the decision maker (DMP) and defines the rule according to which the acceptable or optimal solution is chosen [2, 3, 12, 13, 15].

Of course, choosing a decision-making criterion under the conditions of uncertainty is the most complicated and responsible step in the study of operations. There are no general tips or recommendations. The choice of the criterion should be developed by DMP, taking into account the specific character of the problem to be solved and in accordance with their goals, and also based on past experience and own intuition.

In order to select the strategies more precisely, we should consider the same task but only from the standpoint of risk. Uncertainty predetermines the emergence of situations that do not have an unambiguous result (decision). Among the various types of situations faced by enterprises in the process of production, risk situations stand out.

The situation of risk should be understood as a combination, a set of different circumstances and conditions that create the situation of a particular type of activity. It is accompanied by three conditions:

- the presence of uncertainty;
- the need to choose an alternative (the refusal to choose such ones is a kind of alternative);
- a possibility to evaluate the probability of oncoming of the chosen alternatives.

Thus, if there is a possibility to determine the degree of probability of one or another option quantitatively or qualitatively, then this will be a situation of risk.

In order to exclude the risk situation, business managers are forced to make decisions and seek to implement them. The risk for decision-making processes under conditions of uncertainty and risk (under information deficiency or uncertainty in the reliability of the information) will be defined as purposeful actions, during which there is an opportunity to estimate quantitatively and qualitatively the probability of achieving the desired result, failure and deviation from the goal (positive or negative properties) [15].

The matrix of possible risks (the underdrawal of conventionally net profit) - $\|r_{ji}\|$ is based on the data of Table 1 and Table 2. The risk matrix gives a more vivid picture of an uncertain situation than the matrix of wins. The risk, therefore, is the difference between the result that can be obtained if you know the real state of "nature" and the result obtained with the j-strategy.

The matrix element $\|r_{ji}\|$:

$$r_{ji} = \begin{cases} (V_{vyrob_j} - V_{prod_i}) \cdot P - (V_{vyrob_j} - V_{prod_i}) \cdot C, & V_{vyrob_j} > V_{prod_i} \\ (V_{prod_i} - V_{vyrob_j}) \cdot P - (V_{prod_i} - V_{vyrob_j}) \cdot C, & V_{vyrob_j} \le V_{prod_i} \end{cases}$$

In case when the situation is not the same, it is suggested to solve each of the payment matrices with the help of the apparatus of game theory and to obtain a solution.

The games will be final, because each player has a finite number of strategies. The game is classified as a game with "nature" because there is uncertainty caused by the lack of information about the conditions in which the action (demand) is carried out [12, 13, 15].

After selecting the optimal strategies (with the maximum received conditionally net profit and the minimum underdrawn conditionally net profit), the decision-making task is considered according to the chosen strategy based on the fuzzy game model. Classical matrix game models are used ss models that represent risk, with looking for solutions in the class of mixed strategies, that is, based on the probabilistic approach [12, 13, 15].

We use the proposed approach [14] to justify the correct choice of manufacture planning strategy.

This strategy may be: 1) the minimum or average production strategy (defined expertly) that can bring losses (because the potential of the enterprise is not fully used) or income – d_1 can be chosen; 2) the optimal strategy (based on the choice of several criteria of optimality) is fully implemented and will bring a certain income – d_2; 3) the maximum production strategy (determined by the optimization task) can be chosen, which will also bring losses (since not all manufactured products can be fully sold) or income – d_3. The value of income is counted with a "+" sign, losses are counted with a "-" sign. The numerical values d_1, d_2 and d_3 are known (or at least their estimates are known).

Whereas the project is unique. DMP can choose one of the two behaviour strategies: 1) to adopt an optimal production strategy; 2) not to adopt this strategy.

It is necessary to choose the strategy of DMP behavior in which their gain would, at least, be inseparable, and in the worst case, the losses would be zero. This situation is described by the player's A gain matrix A (DMP) of the matrix game between two players (Table 1).

Next the matrix model becomes fuzzy [1, 4, 6]. Expertly we can determine the degree of belonging to the alternatives of "nature" γ_j - the degree of certainty that the nature will choose the variant *Bj*. Expert assessments are selected according to E. Harrington's scale for formalizing heuristic information.

Table 1

The matrix of DMP wins

	B_1 (minimum or average production strategy)	B_2 (optimal strategy)	B_3 (maximum production strategy)
A_1 (DMP accepts the strategy)	d_1	d_2	d_3
A_2 (DMP does not accept the strategy)	0*	0*	0*

* - DMP does not lose or gain anything.

The interpretation of the model in case the player A chooses the alternative A1 is reflected in this case by a set of fuzzy production rules:

R_1: if x is B_1, then y is d_1,

R_2: if x is B_2, then y is d_2,

R_3: if x is B_3 then y is d_3.

Here the variable x represents the player's B state (the state of "nature"), and y is the player's A (DMP) gain (loss). The degree of truth of the premise of the first rule (R1) is obviously γ_1 , the second - γ_2 and the third - γ_3 .

At the same time the set of the given fuzzy rules together with the accepted conditions build Wang-Mendel's fuzzy inference model [4, 10], according to which the exact value of the output variable (in this case, the value of the gain *Q1*) is determined by the formula:

$$Q_j = \frac{\sum_{j=1}^{3} a_j \cdot \gamma_j}{\sum_{j=1}^{3} \gamma_j} \qquad (1)$$

If player *A* selects the strategy *A2*, the wins (losses) of DMP obviously are zero $Q_2 = 0$.

The question of choosing a strategy is now solved by checking inequality: $_1 > Q_2$ or $Q_1 > 0$ [14]. If this inequality is fulfilled, then the strategy should be accepted, if it is not fulfilled, the strategy should be rejected.

In our case the wins and losses, as well as the degree of confidence for the "nature" alternatives (set by the experts) are given in Table 4 (the sum of alternatives are not necessary equal 1 [14]).

According to the output data of Table 2 and Table 3, the income matrix was determined and established according to the criteria:

- even without taking into account the choice of strategies, only at the expense of defining the conventionally received income (at the average price of sales in 2018), the chosen strategy - the production of 1818,29 thousand tons of wheat, then the income will reach its maximum (1181,89 thousand UAH). For most DMPs in practice in such cases solutions based on the criterion of maximizing the average expected income (or minimizing the expected expenses) are sufficient. Additional recommendations may be ambiguous, depending on the susceptibility to DMP risk;

- according to Laplace's criterion it is the highest expected gain, according to Wald's criterion – "pessimistic", the best of the worst strategies, according to Savage's criterion – the least value in the most unfavourable situation – the strategy of production of 380,67 thousand tons of wheat is recommended (income – 247,44 thousand UAH);

- according to Hurwitz's criterion – when the decision maker tends to pessimism and optimism at 0.5 – the strategy of production is recommended when the chosen strategy is the production of 1818,29 thousand tons of wheat, then the income will reach its maximum (1181,89 thousand UAH) .

Table 2.

Production of agricultural crops – wheat in Kherson region (according to the website of the Main Department of Statistics in the Kherson region http://ks.ukrstat.gov.ua)

Year	2011	2012	2013	2014	2015	2016	2017	2018
Thousand tons	1589,97	380,67	900,78	1424,94	1818,29	1300,44	1696,24	1531,63

Table 3.

Sales of wheat at agricultural enterprises, except small ones (January-September) (according to the website of the Main Department of Statistics in the Kherson region http://ks.ukrstat.gov.ua)

Year	2011	2012	2013	2014	2015	2016	2017	2018
Thousand tons	493,8	162,2	196,1	506,0	650,3	617,8	525,3	535,3

Evaluating the matrix of risks:

- by the size of minimum average risk, according to Laplace's, Wald's, Savage's and Hurwitz's criteria the optimal production of 380,67 thousand tons of wheat (2352,22 thousand UAH – minimal losses) is determined.

In such a way, 380,67 thousand tons of wheat match the strategy of production: the highest expected gain and the smallest of the biggest risks. This solution will be optimal because there are signs that this solution is the best than all the rest.

Table 4.

Output data for determining strategy adoption

	B_1 (The average strategy production - the production of 1330,37 thousand tons of wheat)	B_2 (The optimal strategy production – the production of 380,67 thousand tons of wheat)	B_3 (The maximum strategy production – the production of 1818,29 thousand tons of wheat)
A_1 (DMP accepts the strategy)	The underdrawal of conventionally net profit (thousand UAH) - 118,56	The conventionally net profit (thousand UAH) – 245,50	The underdrawal of conventionally net profit (thousand UAH) - 183,72
A_2 (DMP does not accept the strategy)	0	0	0
the degree of confidence for the "nature" alternatives	0,2	0,5	0,5

After selecting the optimal strategies (the maximum of conditionally net profit and the minimum of conditionally underdrawn net profit), the task of decision-making on the chosen strategy is considered and is based on the fuzzy game model. The wins and losses, as well as the degree of confidence of experts for the "nature" alternatives are given in Table 4 (the sum of which is not necessary equal to 1). The decision should be taken if the value of the winning is bigger than zero.

If the values of the conditionally net profit and the conditionally underdrawn net profit have the value indicated in Table 4, then the value of the wins according to the formula will be (1):

$$Q_1 = \frac{-118{,}56 \cdot 0{,}2 + 245{,}50 \cdot 0{,}5 - 183{,}72 \cdot 0{,}5}{0{,}2 + 0{,}5 + 0{,}5} \approx 5{,}982$$

thousand UAH – the value is positive, therefore it is possible to accept the strategy. 5,982 thousand UAH is a value which sign determines the choice of one or another alternative.

This decision was made only as for wheat. On the basis of the proposed model, all selected strategies should be considered for reasoning. This scheme should be applied in the context of each type of agricultural production. After that the optimization actions in manufacturing all types of products should be carried out.

The proposed information technology of modeling the strategy choice for manufacture planning on the basis of a fuzzy game model, which uses fuzzy set theory and game theory tools, that allows us to determine the optimal strategy for manufacture planning, has the following algorithm:

1) determination of the maximum possible volume of production within the scope of the enterprise;

2) the formation of matrices of conditionally net profit or underdrawal of conditionally net profit (with different production variants and data from previous sales);

3) selection of manufacture planning strategy according to the criteria;

4) in the case the strategies coincide according to different criteria – the winning matrix of DMP is built (the list of the "nature" strategies is formed, the degrees of belong-

ing to the "nature" alternatives are expertly determined, the values of gain / loss for each "nature" strategy are determined), otherwise, the winning matrices of DMP for all selected strategies are built or the strategies based on matrix game solutions and on a fuzzy game model are selected;

5) a decision on the choice of manufacture planning strategy is made.

rik	2011			2012			2013			2014			2015			
tys.t	493,8			162,2			196,1			506,0			650,3			
zakupivel`na cina	6500 grn/t															zakupivel`na cina
serednya cina realizaciyi	7150 grn/t															serednya cina realizaci
OTRYMANYJ PRYBUTOK																
popyt / vyrobnycztvo	493,8	zalyshky vyrobnycztva pry prodazhi 493,8	koreguvannya vyrobnycztva za rahunok zalyshkiv vyrobnycztva	162,2	zalyshky vyrobnycztva pry prodazhi 162,2	koreguvannya vyrobnycztva za rahunok zalyshkiv vyrobnycztva	196,1	zalyshky vyrobnycztva pry prodazhi 196,1	koreguvannya vyrobnycztva za rahunok zalyshkiv vyrobnycztva	506,0	zalyshky vyrobnycztva pry prodazhi 506,0	koreguvannya vyrobnycztva za rahunok zalyshkiv vyrobnycztva	650,3	zalyshky vyrobnycztva pry prodazhi 650,3	koreguvannya vyrobnycztva za rahunok zalyshkiv vyrobnycztva	
1589,97	1033480,50	0,00	1589,97	-9175075,00	1427,77	3017,74	-8932690,00	2821,64	4411,61	2867546,50	0,00	1589,97	-5685160,00	939,67	2529,64	
380,67	247435,50	0,00	380,67	-1314625,00	218,47	599,14	-1072240,00	403,04	783,71	509411,50	0,00	380,67	247435,50	0,00	380,67	
900,78	585507,00	0,00	900,78	-4695340,00	738,58	1639,36	-4452955,00	1443,26	2344,04	1523626,00	0,00	900,78	-1205425,00	250,48	1151,26	
1424,94	926211,00	0,00	1424,94	-8102380,00	1262,74	2687,68	-7859995,00	2491,58	3916,52	2545738,00	0,00	1424,94	-4612465,00	774,64	2199,58	
1818,29	1181888,50	0,00	1818,29	-10659155,00	1656,09	3474,38	-10416770,00	3278,28	5096,57	3312770,50	0,00	1818,29	-7169240,00	1167,99	2986,28	optymal`ne vyrobnycz
1300,44	845286,00	0,00	1300,44	-7293130,00	1138,24	2438,68	-7050745,00	2242,58	3543,02	2302963,00	0,00	1300,44	-3803215,00	650,14	1950,58	
1696,24	1102556,00	0,00	1696,24	-9865830,00	1534,04	3230,28	-9623445,00	3034,18	4730,42	3074773,00	0,00	1696,24	-6375915,00	1045,94	2742,18	
1531,63	995559,50	0,00	1531,63	-8795865,00	1369,43	2901,06	-8553480,00	2704,96	4236,59	2753783,50	0,00	1531,63	-5305950,00	881,33	2412,96	

Fig. 1. A fragment of building the winning matrix and the calculating the criteria for the selection and implementation of specific decision options during the planning of wheat production (according to the data of production and sale of wheat in Kherson region from the site of the Main Department of Statistics in the Kherson region http://ks.ukrstat.gov.ua)

rik	2011	2012	2013	2014	2015	2016	2017	2018				
тис.т	493,80	162,20	196,10	506,00	650,30	617,80	525,30	535,30				
zakupivel`na cina	6500 grn/t									zakupivel`na cina	6500,00	
serednya cina realizaciyi	7150 grn/t									serednya cina realizaciyi	7150,00	
nedootrymannya umovno chystogo prybutku												
popyt / vyrobnycztvo	493,80	162,20	196,10	506,00	650,30	617,80	525,30	535,30	serednye znachennya nedootrymannya umovno chystogo prybutku			kryteryj Laplasa
1589,97	712510,50	928050,50	906015,50	704580,50	610785,50	631910,50	692035,50	685535,50	733928,00			489285,3333
380,67	73534,50	142005,50	119970,50	81464,50	175259,50	154134,50	94009,50	100509,50	117611,00	optymalne vyrobnycztvo		78407,33333 optymalno
900,78	264537,00	480077,00	458042,00	256607,00	162812,00	183937,00	244062,00	237562,00	285954,50			190636,3333
1424,94	605241,00	820781,00	798746,00	597311,00	503516,00	524641,00	584766,00	578266,00	626658,50			417772,3333
1818,29	860918,50	1076458,50	1054423,50	852988,50	759193,50	780318,50	840443,50	833943,50	882336,00			588224
1300,44	524316,00	739856,00	717821,00	516386,00	422591,00	443716,00	503841,00	497341,00	545733,50			363822,3333
1696,24	781586,00	997126,00	975091,00	773656,00	679861,00	700986,00	761111,00	754611,00	803003,50			535335,6667
1531,63	674589,50	890129,50	868094,50	666659,50	572864,50	593989,50	654114,50	647614,50	696007,00			464004,6667

Fig. 2. A fragment of building the risk matrix and the calculating the criteria for the selection and implementation of specific decision options for wheat production (according to the data of production and sale of wheat in Kherson region from the site of the Main Department of Statistics in the Kherson region http://ks.ukrstat.gov.ua).

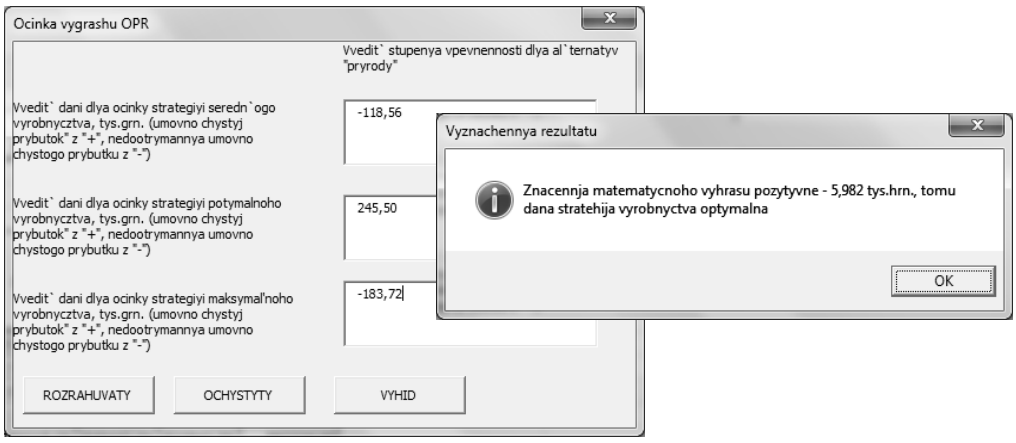

Fig. 3. The screen forms of the results of the program calculation of the DMP's winning value

The software implementation of the prototype of information technology (Fig. 1 - Fig. 3) is carried out on the data of a particular enterprise using MS Excel and VBA for MS Excel.

Conclusions. Manufacture planning on the basis of data from the previous sales, with the help of the joint application of the theory of games and fuzzy mathematics allows us to choose the strategy of enterprise development. The joint application of the theory of games and fuzzy mathematics is determined, firstly, by the conditions of uncertainty, and secondly, the refusal from the probabilistic approach applied in the theory of games. The use of the proposed model will increase the efficiency and quality of management decisions due to the multipurpose use of mathematical models and methods. The approach is realized on the data of the particular enterprise, the proposed model allows carrying out calculations using modern information technologies.

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ВИКОРИСТАННЯ НЕЧІТКОЇ ІГРОВОЇ МОДЕЛІ ПРИ ПЛАНУВАННІ ВИРОБНИЦТВА НА АГРОПІДПРИЄМСТВІ

Анотація. Ринкова орієнтація аграрного сектора все більше вимагає від керівників сільськогосподарських підприємств не тільки вміння бачити перспективи своєї галузі, а й приймати ефективні управлінські рішення в сформованих ризикованих, кризових умовах господарювання. Керівник, який приймає рішення на сучасному сільськогосподарському об'єкті, повинен вирішувати проблеми формування номенклатури і обсягів продукції, що випускається, оцінювати існуючі та очікувані в перспективі потреби ринку в цій продукції, тобто вирішувати задачі стратегічного управління. Для цього він повинен мати в своєму розпорядженні математичні методи та інформаційні технології, адаптовані до даної предметної області.

Метою дослідження є використання нечітких ігрових моделей прийняття рішень при плануванні виробництва на аграрному підприємстві. Питання прийняття управлінських рішень в сільському господарстві потребують більш детальної математичної обробці та вироблення принципів і умов щодо підвищення їх ефективності. Для створення моделі планування виробництва використано методи теорії нечітких множин та теорії ігор.

Методи дослідження. У статті розглянуто можливість використання нечітких ігрових моделей прийняття рішень при плануванні виробництва на агропідприємстві. Для підвищення точність прогнозів планування виробництва запропоновано модель планування виробництва на основі даних попередніх продаж на базі спільного застосування теорії ігор і нечіткої математики.

Основні результати дослідження. Використання запропонованої моделі дозволить підвищити ефективність і якість прийняття управлінських рішень за рахунок комплексного використання математичний моделей та методів.

Наукова новизна. Для практичного підтвердження отриманих результатів були проведені оцінки матриці ризиків, матриці виграшів та критеріїв для прийняття рішень в умовах невизначеності та ризику, приведено набір нечітких правил, які разом з прийнятими умовами утворюють модель нечіткого логічного висновку Ванга-Менделя та розраховано значення виграш для вибору стратегії виробництва на основі нечіткої ігрової моделі. Спільне застосування теорії ігор і нечіткої математики обумовлено, по-перше, умовами невизначеності, по-друге, відмовою від імовірнісного підходу, застосовуваного в теорії ігор. Запропонована модель дозволяє виконувати розрахунки із застосуванням сучасних інформаційних технологій.

Практична значимість. Використання математичних моделей та сучасних інформаційних технологій для агропідприємств дозволить ефективніше використовувати ресурси підприємства; оптимізувати роботу; мінімізувати ризики; ґрунтовно аналізувати та пришвидшити процес прийняття управлінських рішень. Прийняття та реалізація рішень є найважливішою функцією управління, успішне здійснення якої забезпечує досягнення підприємством його цілей.

***Ключові слова**: планування оптимального виробництва, ігри з «природою», критерії прийняття рішень, модель нечіткого логічного висновку Ванга - Менделя, нечітка ігрова модель.*

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ИСПОЛЬЗОВАНИЕ НЕЧЕТКОЙ ИГРОВОЙ МОДЕЛИ ПРИ ПЛАНИРОВАНИИ ПРОИЗВОДСТВА НА АГРОПРЕДПРИЯТИИ

Аннотация. Рыночная ориентация аграрного сектора все больше требует от руководителей сельскохозяйственных предприятий не только умения видеть перспективы своей отрасли, но и принимать эффективные управленческие решения в сложившихся рискованных, кризисных условиях хозяйствования. Руководитель, принимающий решения на современном сельскохозяйственном объекте, должен решать проблемы формирования номенклатуры и объемов выпускаемой продукции, оценивать существующие и ожидаемые в перспективе потребности рынка в этой продукции, то есть решать задачи стратегического управления. Для этого он должен иметь в своем распоряжении математические методы и информационные технологии, адаптированные к данной предметной области. Целью исследования является использование нечетких игровых моделей принятия решений при планировании производства на аграрном предприятии. Вопрос принятия управленческих решений в сельском хозяйстве требуют более детальной математической обработки и выработки принципов и условий по повышению их эффективности. Для создания модели планирования производства использованы методы теории нечетких множеств и теории игр. Методы исследования. В статье рассмотрена возможность использования нечетких игровых моделей принятия решений при планировании производства на агропредприятии. Для повышения точности прогнозов планирования производства предложена модель планирования производства на основе данных предыдущих продаж на базе совместного использования теории игр и нечеткой математики. Основные результаты исследования. Использование предложенной модели позволит повысить эффективность и качество принятия управленческих решений за счет комплексного использования математических моделей и методов. Научная новизна. Для практического подтверждения полученных результатов были проведены оценки матрицы рисков, матрицы выигрышей и критериев для принятия решений в условиях неопределенности и риска, приведены набор нечетких правил, которые вместе с принятыми условиями образуют модель нечеткого логического вывода Ванга-Менделя и рассчитано значение выигрыш для выбора стратегии производства на основе нечеткой игровой модели. Совместное применение теории игр и нечеткой математики обусловлено, во-первых, условиями неопределенности, во-вторых, отказом от вероятностного подхода, применяемого в теории игр. Предложенная модель позволяет выполнять расчеты с применением современных информационных технологий. Практическая значимость. Использование математических моделей и современных информационных технологий для агропредприятий позволит эффективнее использовать ресурсы предприятия; оптимизировать работу; минимизировать риски; основательно анализировать и ускорить процесс принятия управленческих решений. Принятие и реализация решений является

важнейшей функцией управления, успешное осуществление которой обеспечивает достижение предприятием его целей.

***Ключевые слова**: планирование оптимального производства, игры с «природой», критерии принятия решений, модель нечеткого логического вывода Ванга - Менделя, нечеткая игровая модель.*

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RESEARCH IN COMPUTERIZED INFORMATION TECHNOLOGIES AS BASES OF TRAINING AND EDUCATIONAL SYSTEMS

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Abstract. The objective of the article is to improve the methodological apparatus in computerized information technology of training to optimize education systems in the context of globalization based on the identification and formalization in new links for technological components of learning information processes with elements of information theory and information systems control theory. Research methods. The basis of the research is the theory of information, information systems, and processes, control, optimization. Main research results. The specificity of the education systems globalization on the basis of the training computerized information technology and the adaptation of information theory to the interaction and control in training information systems is revealed. In this context, we obtained: the norm over the event space as a functional dependence on information for evaluating causal relationships, the producing differential equation, the analytical expression for information evaluating; the concept of normalized metric information space; the information processes types in learning systems; the entropy determination functions based on the mathematical expectations of norms and metrics for information transfer processes evaluating; the information processing operator; the sets of information objects; the scheme of the learning information system operation as a control with optimization feedback for information perception errors minimizing; the procedures for decisions making in the conformity of perception models to information flows, analysis of the information objects structures; the concept in the informational essence of learning processes with adaptation to the requirements and limitations; the formalized descriptions of information perception in learning; an algorithms on the perception and advancement of infor-

mation flows; an elaboration in the optimization task of the training information systems control; the concept of modern information learning environments improving with information theory and information systems theory using. Scientific novelty. The new concepts, algorithms, and models have been developed, which allowed formalizing the identified interrelations for the components of learning information processes with elements of theories in information and information systems optimization control, achieving improvements in computerized information training technologies, taking into account the globalization of education systems.

Practical`s significance. The introduction of the obtained theoretical developments on the improvement of control in training information systems based on computerized information technologies in the practice of education systems in the context of globalization can significantly improve the effectiveness of learning information processes.

Keywords: *information technology, computer, network, system, process, training, education.*

Problem's statement. Information processes of information perception, accumulation, and storage form the basis of learning in the animate and inanimate nature, human society. Features of the learning information processes implementation are displayed in educational practice in teaching methods. The methodological foundations of training are based on the theoretical basis of information processes, technologies, and systems. Control of learning information processes requires the formation of goals and the identification of learning actions sequences that ensure the successful achievement of the goals. The tasks of training control, viewed from the point of view of information aspects, are solved by education systems. The defining theoretical basis for learning is the theory of information`s systems, and for educational systems is the theory of control. In the long evolution process, learning paradigms were formed, containing in its composition the processes of information perception, accumulation, and storage. However, the constant strengthening of globalization trends requires the adjustment in existing theories of learning information technology in order to ensure the optimal development of education systems.

Analysis of recent research and publications. The value of progressive education systems, as well as effective processes and quality learning outcomes in the modern world, is constantly increasing. Education is the primary resource that precedes the use of economic resources, is able to awaken the economy and make it more dynamic, can provide a breakthrough in the development of production and agriculture; thus, education acts as a generator, the main productive force of society, the basis of the triad "education–science–production", the cornerstone for solving the foundations of the state life [1-10]. A significant part (40-70%) of the increase in national income activates the growth of the population knowledge and level of education, there is an intellectualization of all society productive forces. Education plays the role of the main factor for the emergence of changes in economic development. Each country has its own specific requirements, recommendations and wishes for education, the prerequisites of which can be attributed to the following two large groups: climatic conditions, characteristics of the countries territories, communication routes, borders, etc.; the globalization aspects of the society and the economy. Improvement of education systems activates the development of technologies, which, in turn, stimulates the emergence of new industries (Table 1).

Table 1

The technology impact on the emergence of new industries

The developed technology (the university where the development was carried out)	The industry that emerged on the basis of a new technology
Electronic calculator (University of Pennsylvania)	Computer manufacturing
Optical fibers (Massachusetts Technology Institute)	Telecommunications
Vegetative reproduction (DNA cloning) (Stanford University)	Biotechnology
Supercomputer (University of Illinois)	Internet

Along with the acquisition of knowledge, the essential point is the preservation of knowledge. A reliable way to obtain and preserve knowledge is the learning process. To reveal the essence of learning, consider a number of definitions [2-4, 6, 11-16, 33-46]. First of all, learning acts as a type of learning activity in which the quantity and quality of the trainee knowledge and skills elements are brought to the proper level by the trainer [13, 41, 33-46]. The training activity is considered completed if the quantity and quality of educational material in the trainee's replicated product correspond to the training objectives and represent the proper level. The learning process is a set of consecutive interrelated actions of the trainer and the trainees, aimed at obtaining the following achievements: a solid assimilation of the scientific knowledge and skills system and the formation of the ability to use them in life; the development of such cognitive trainees abilities as independent thinking, observation, etc.; mastering the elements of the mental labor culture; the formation of the foundations of the world view. Analyzing the sources [2, 3, 6, 11-13], it is possible to trace the global trends in changes of the time intervals values for training specialists in the direction of the training duration increasing. The analysis of materials [1-16, 33-46] leads to the following conclusions: the higher the indicator of the years number allotted for education, the faster the economy develops, and countries with accelerated rates of improvement in higher education have increased economic growth rates; the importance of education as a factor of development is associated with its effect on human capital (as the main resource) and production technologies; education has a positive effect on investment in human capital, contributing to economic growth.

Considering the education importance in the modern world from the point of view of analyzing the development and modern achievements evolution in the computerized information technology training field, it is necessary to note an even greater increase in its capabilities and advantages. The training implementation with the use of high-tech, progressive, continuously improving information and communication technologies allows increasing the education effectiveness at a rapid pace. In the period of globalization, education, viewed from the perspective of modern information processes, systems, and technologies for the accumulation and preservation of knowledge, has an even stronger impact on the society`s economic development.

Within the framework of the information approach, teaching methods play an important role. In Ukraine, the system of division into education levels is defined as a set of educational institutions, complexes, methodological recommendations and relevant educational programs [2, 3, 6, 11-13]. There is a tendency to increase the share of full higher education and reduce the number of people with primary education. In the works [3, 7, 12-13] the scheme of training is presented within the framework of the Ukraine educational system structure and the assessment of degrees. The essential point in the education system is the teaching model adopted by the pedagogical community. The basic model of education is the unity of the three teaching methods: passive; active; interactive [2, 4, 6, 14-16, 33-40, 42-26]. On the way of teaching methods improving, it is necessary to note the following current trends: the desire to develop structurally complete models of knowledge formation processes []; the increase in the value of the evaluating knowledge problem as a result of learning [2, 4, 6, 14-16, 33-40, 42-26]. Based on the analysis of the source [2, 4, 6, 14-16, 33-40, 42-26], a more detailed classification system can be distinguished. Active methods are used, which are divided into the following types: various modeling (game, social, imitational); business games; concretized situations analysis (case studies); method of active sociological tested analysis and control, close to real life situations. Modern teaching methods use information and computer technology [28-37] based on the use of advanced high-tech tools for information processing and transmitting. The difference in modern computer technology of education is interactivity, which is achieved on the basis of situations modeling and ensuring the possibility of rapid feedback for the student with the system of information support from the trainer. The principle of feedback in pedagogy and the presentation of teaching scientific methods is presented in [2, 4, 6, 14-16, 33-40, 42-26], where: training is viewed as a process of knowledge and skills transferring from the teacher to the learner; allocated negative feedback in the learning system.

Let us further characterize the features of globalization for information processes in education. The use of computer technics in the educational process made it possible to talk about computer education, the effectiveness of which has been dramatically increased due to the wide and easy access to a large number of diverse educational materials. According

to [2, 3, 6, 11-13], computer-based education is global, and globalization is seen as a process of international economic, political, and cultural integration. The process of globalization is a global trend covering all levels of education. In foreign pedagogy [2, 4, 6, 14-16, 33-40, 42-26], the following opposing paradigms for the implementation of the global education concept can be distinguished: global interdependence and international understanding; global economic competition. The development of information technology has led to the introduction of the information society concept, where the majority of workers are engaged in informational production, storage, processing, and sale. Prospects for the education development associated with the use of training information technology in the global information space of the network Internet, World Wide Web. Globalization necessitates an increase in the value of the education fundamental nature [2, 3, 6, 11-13], by which we understand the consolidated use of the following types of knowledge: the versatile humanitarian and natural-science knowledge of the relevant areas of science; specialized vocational-oriented knowledge; general education disciplines that form intelligence in a person. The fundamental nature of higher education is a combination of scientific knowledge and the educational process. Globalization contributes to increasing risks, namely, increasing their number and expanding their diversity. In order to compensate for the phenomena generated by globalization, education should be organized taking into account many factors, namely: to strive for compensation and to counter risks; be fundamental; provide the ability to work in the information environment of the Worldwide network; function in the global information space; expand international understanding and use of international languages (above all, English); strive to reach all education levels.

The objective of the study. The main purpose of the work is to identify the interrelationships of methods and techniques for the learning information processes implementation with the theoretical foundations of information technologies that provide the possibility of education systems further development based on the information systems theory application. Speaking about the theoretical foundations of information processes, first of all, the theory of information is meant as a mathematical discipline, allowing formalizing descriptions of information processes, in particular, in the education field.

Research findings. We begin our consideration by analyzing the features of the fundamental theoretical foundations in education and training problems solving. The education task is posed as a typical optimal control problem, in which [47-54] for the system *W*, given its description, the goal is formed as a function or functional *J*(**u**, **x**, **β**), depending on the control vectors **u**, the learning trajectory **x,** and the parameters **β**:

$$\begin{aligned} &\mathbf{u}^*, \mathbf{x}^* \rightarrow optJ(\mathbf{u}, \mathbf{x}, \boldsymbol{\beta}); \\ &W = W((\mathbf{u}, \mathbf{x}, \boldsymbol{\beta}, t). \end{aligned} \quad (1)$$

The education task, formulated in the above statement, is often seen as rather vague and it defines restrictions, such as funding, various conditions, etc. As a rule, the goal in the stated problem formulation is not unique, which leads to the formulation of a vector (multi-criteria) optimization problem:

$$\begin{aligned} &\mathbf{u}^*, \mathbf{x}^* \rightarrow opt\mathbf{J}(\mathbf{u}, \mathbf{x}, \boldsymbol{\beta}); \\ &\mathbf{W} = \mathbf{W}((\mathbf{u}, \mathbf{x}, \boldsymbol{\beta}, t). \end{aligned} \quad (2)$$

A problem modified in this way is posed easier, but it is more difficult to solve [47-54]. At the same time, attempts are being made to construct models of objects and use methods of control theory.

Since information objects, processes and technologies are the most relevant in learning tasks, it is necessary to talk about the tasks of information systems control [17-28, 41, 47-54]. Accordingly, we will continue the question presentation from the point of view of the information and information system concepts. Each branch of science uses an established mathematical apparatus and methods for constructing models of objects and processes. The basis of information systems is natural to see information theory [17-28, 41]. However, perfectly describing the tasks of communication, the theory of information as such, without additional study, is of little use for the tasks of information systems control and training. In this paper, steps have been taken towards the expedient use of information theory elements in learning tasks, which consider information as a fundamental concept and are explored from the point of

view of information objects, processes, technologies, and systems conceptual categories.

As a basis, an assumption is made about the analytical dependence of information on the norm, which is defined over the event space. Information is considered as an assessment for the degree of a causal relationship in the event space. In this case, the function is the norm over the event space, and the function argument is information *I*. For a probability space with probability *P*, as the norm over the event space, we obtain $P = P(I)$. The main thing is the possibility of representing the function $P(I)$ by a power series and obtaining, in a linear approximation, the generating differential equation $DP / DI = f(P, I, a)$. The solution of the generating equation allows, taking into account the initial conditions, to obtain an estimate of the information in the form $I = P^{-1}(I)$. For different processes, we will have different methods for information evaluating [17-28, 41, 47-54]. This conclusion is confirmed by the existence of a methods variety for information evaluating. Using elements of information theory, one can choose the generating equation. For example, the organic growth equation corresponds to the Hartley measure; at the same time, for the case of collecting information from a variety of incompetent and unrelated sources, by virtue of the central limit theorem, the confidence value estimate will be an estimate of the information content. Thus, it is possible to measure information as the degree of causation. Having determined the method for estimating the informational proximity of events (metric), we obtain the normalized metric information space induced over the event space. The information space corresponds to simple mathematical construction. For processes of different nature, norms and metrics will vary. Since events, evaluations of informational links between events and the distance between events must be considered in the information space, it is impossible to build an information model outside the information space. As a rule, when modeling information systems, first of all, the following are required: physical models (like aerodynamic and hydrodynamic systems); operators (like control systems).

Using block *A* (for processing information I_A) and block *B* (for processing information I_B), which are interconnected by information flow lines, you can define an elementary information flow as a sequence of events associated with the information transfer. Since the elementary information flow is unidirectional, the information processes in the elementary information system are reduced to the information transfer (Figure 1) and comparison (Figure 2). Based on the evaluation of the flow $I\varepsilon$, can be non-trivial solutions and build complex algorithms. However, elementary systems, consider only those options of information flows formation, which were shown in figures 1, 2. The fact that the process in the blocks of information processing can be varied, does not affect the structure of links.

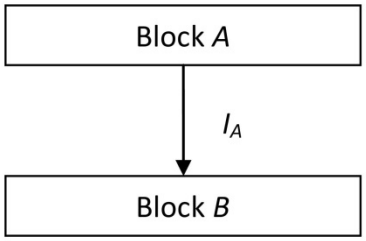

Figure1 – Possible information stream in the elementary information system: information transfer

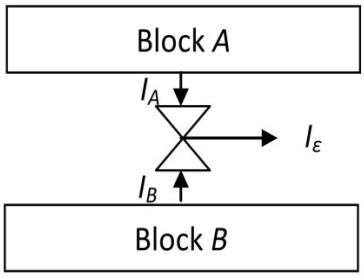

Figure 2 – Possible information streams in the elementary information system: information comparison and producing differential information flow Iε

The information transfer process is evaluated by the information space norm, and the information flows comparison related to the metric notion. During the transition to expected assessments, practically there is a transition to the mathematical expectation of the norm and metric (entropy estimates):

$$H_A = M\{\|I_A\|\};$$
$$H_\varepsilon = M\{a(I_A, I_B)\}. \quad (3)$$

The question of information processing in blocks of the system is more complicated since it affects processes in the event space, calculations of transformations, and so on. However, ideas about the elementary information system and the elementary information flow are quite sufficient for building complex models of information systems.

Consider as a visual example the task of translating from one natural language to another, where the elementary information system from the source (source text *A*) and the receiver (translation text *B*) is subject to consideration. With proper translation, the accuracy (or error) criterion is that the return receiver flow must compensate for the source forward flow. The problem is solved in its own coordinates. An algorithm is generated that represents the information system model, but you also need to deal with the operations in the blocks.

Information processing, which is carried out as a change in the magnitude of cause-effect relationships, occurs due to processes in the event space.

The simplest flow is formed by an ordered set elements sequence, and the simplest operation that is performed at the receiver is the mapping of the vector **x** by operator *A*:

$$\mathbf{y} = A\mathbf{x}. \tag{4}$$

An ordered set is transformed into a set that is represented by definition, by virtue of operator *A*.

In the future, you can make a decision regarding the set of perceived objects Ω by going to the set specified by the enumeration:

$$\mathbf{y} \in \omega_i \quad if \quad = \left\langle (a_{i1}, a_{i2}, \ldots a_{in}), \mathbf{x} \right\rangle = y_i \to extr. \tag{5}$$

Thus, we obtain the perception model of the first level in the form of an algorithm for the information system functioning, presented in Figure 3.

The trainer forms the information flow I_A, perceived by the trainee as an image of y_i. Since the learning process requires the student to achieve the correct response, based on operator *A*, an inversion of model A^{-1} is formed, which allows the information flow of the student I_B to be generated. Comparison of the flows of the trainer and the learner generates a differential information flow I_ε, which creates the basis for building an optimization procedure of finding the optimal operator (Block 4 of Figure 3). The stream of ordered sets generates an optimal operator that allows for minimizing errors. We have the process of elementary skills and concepts learner obtaining.

The compensation degree of input and return flows determines the training quality. The growth of the accumulated information causes an increase in the dimension of the operator matrix. The error occurs in the following cases: before training; in the event of additional information flows due to disturbances that were not taken into account during training.

The direct (immediate) transformation of an ordered set into a set specified by enumeration makes errors. If fuzzy sets are used in the input sets stream represented by definition, then conversion to sets specified by enumeration requires the definition of a proximity measure and the construction of a membership rule, that is, a model, which in this case is defined on a set of images and membership rules. Memorization is associated with the optimization procedure for changing the fixed part of the image and the corresponding membership rule. In this case, the error is obtained after finding the optimal solution.

The transformation of a set, which is set by description, to a set, which is set by enumeration, is an algorithm for describing an image, which is set by the description in its name.

Training involves the formation of an algorithm that is optimal with respect to the minimum error, which allows us to speak about the optimal solution of the training problem.

That is, with perception, a sequential transformation of the set, which represents the signal (M_D), into sets that are represented by definition (M_F) and by enumeration (M_L) occurs. At each stage, its own model is formed: at the stage of transition from the signal to the image, the model is implemented with the help of an operator; at the stage of transition from the image that is specified by description to the name, to the set that is specified by enumeration, the procedure for deciding whether the model corresponds to the input stream is applied; when working with a set of object names, the procedure for analyzing the structure of an object is applied. Thus: an ordered set is transformed into a set by definition using an operator; the set is by definition converted into a set by specifying using an optimization procedure for

finding the best description; the set by enumeration allows you to build algorithms that describe the organization (structure, building) of the input stream. In this case: the first stage requires significant amounts of data memory; the second stage assumes the presence of images bases and proximity measures, which requires a smaller memory amount, but more time; the last stage involves the storage of algorithms where a small memory amount is required, but it takes a long time to optimize.

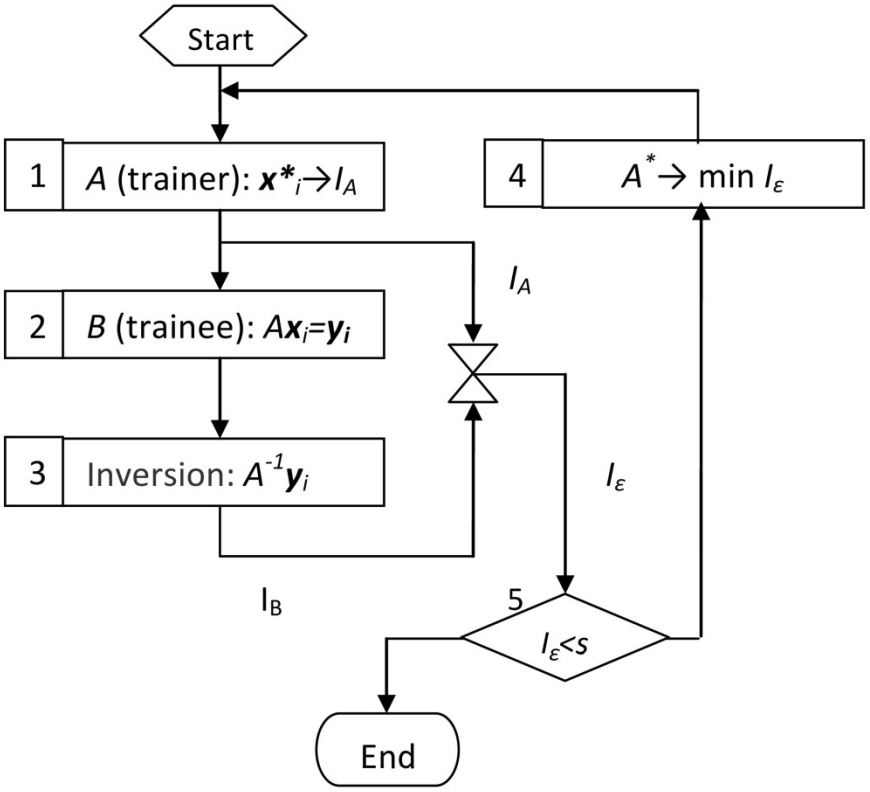

Figure 3 – Information model of the first level perception

It should be noted that statements about the existence of two possible elementary information interactions (transmission and comparison of information flows) and three possible elementary structures for information perception and accumulation are in the nature of limitations. Of the above fundamental elements, you can build a system. Thus, learning is an informational process where adjustment to the requirements and constraints is necessary. We characterize the specifics of learning as an information process. The first thing to consider is the importance of repetition in order to eliminate errors and form reflex operators. Further, it is important to form images, which also requires repetition. In turn, the construction of algorithms and logic circuits is perceived almost immediately. With perception, the following happens: the operator and the base of the images are compressed, leaving only what is expected; algorithms and logic circuits are compressed, eliminating repetition. Therefore, you need to submit the material without overloading it with unnecessary information.

We will analyze the concept and informational essence of the learning paradigm (following [2, 4, 6, 14-46], we will assume that the paradigm is an accepted model, standard, or sample). Within the framework of the above concepts, we will have the following: a teacher is a source of information; a learner is an object; the model of the student is determined only with respect to the formal accumulation of knowledge.

Consider perception as an objective process. The information process of perception consists of the processes of

receiving, processing and storing the information that is created by the source of information. Due to the one-sided orientation of the information flow, there are only two possible forms of information interaction, transmission, and comparison of information. Naturally, the above determines the formation of algorithms for information perception. Moreover, the existence of three methods for defining sets, sufficient to form models of the external world, determines the existence of three perception levels.

Here it is necessary to dwell on the principle of optimality. Given the limitations of the sets specifying, we can distinguish three tasks of informational perception. The first task of information perception is analogous to the Wiener problem, where for ordered sets it is required to find an operator that minimizes the difference *Iε* between the trainer message I_A and the student response I_B:

$$\begin{aligned} &I_\varepsilon = a(I_A, I_B); \\ &A^* \to \min \varepsilon. \end{aligned} \quad (6)$$

Actually, we have the task of forming reactions and habits, and the reaction will be the more correct, the more correct the operator will be. Training is reduced to finding the optimal operator. Errors are corrected only after their completion. At this stage, the operator determines the need for static memory. The model is formed long, stored completely.

The second task of information perception is determined by the formation of the external world model *W*, which allows to model it using the inversion model. This task is similar to the Bellman problem, where the optimal sequence *X** and the optimal control of the *U** model, which delivers the minimum expected error, are sought:

$$\begin{aligned} M\{I_\varepsilon\} = H_\varepsilon = M\{a(I_A, I_B)\}; \\ W = W(X, U); \\ U^*, X^* \to \min H_\varepsilon. \end{aligned} \quad (7)$$

In this case, the model describes elements that are represented by definition, that is, elements that have nonrandom components and rules for determining membership (in fact, they are fuzzy sets or images). To store these models, a dynamic memory organization similar to the database is required. The elements of the image are saved here. This task requires figurative thinking, which generates teaching methods using demonstration material. A decision making error occurs after the process of modeling an external situation, which is time-consuming but is a more efficient technique. Information comes from the outside world as an ordered set and is transmitted for its presentation by the image and model only after being processed by the operator.

The third task of perception is associated with the processing of logical structures – model building algorithms. Here we look for an optimal algorithm for constructing a model, which allows us to find a minimal general description of the methods for models constructing. Operations are defined on the elements of sets by enumeration. We have an algorithm for searching the algorithm for models constructing, which are described by logical functions and the task of finding the best model representation:

$$\begin{aligned} M\{I_\varepsilon\} = H_\varepsilon = M\{a(I_A, I_B)\}; \\ \xi^* \to W^*. \end{aligned} \quad (8)$$

Let us proceed to the consideration in the issue of information perception levels and models. Received three options for objective problems to be solved in the information perception process. The first level is information processing at the first stage of perception. The second level of information perception is associated with the formation of models and the determination of their proximity to reality, which allows us to obtain a different truth criterion – the attainability of the distance минимальности. We have a level of images and situations analysis. This level requires clarity and imaginative of information presentation. The third level operates with logical structures and algorithms for constructing models at the set level, which are given by enumeration. Here the problem of building models is solved and the algorithms for building images are formed. We have a level of logical thinking.

Thus, the algorithm of information perception (Figure 4, Figure 5) is quite simple. When perceiving information (Figure 4), a signal is always defined as an ordered set. To check the correctness of information perception (Figure 5), it is necessary to compare the message of the teacher with the message that the student creates on the basis of his

knowledge. Here the reverse process is performed, namely: based on the description, a set of elements is built and an internal image is formed, which is compared with the external image. Differential information flow, which is generated when comparing, allows you to adjust the knowledge gained. When forming the student's message flow, at each step they turn to the model, getting the following: for the operator – just a quasi-appeal; for the level of image processing – image recovery from its fragments; for the hypothesis formation – the list and image fragments link`s formation.

Let us dwell on the question analysis in the educational systems theoretical foundations. Based on the preceding, we can talk about the main principles of learning, such as the formation of exclusively true, concise and completed images that should be reproduced. Moving from the problem of information perception to the theory of educational systems, one can see that the control task is set, in which the formation of goals is of top priority. The principle of optimality is the fundamental principle of learning: we form the information flow of the trainer so as to minimize the student's error. Next, measures are identified that ensure the best achievement of the goal, which is a classic optimization problem. The most difficult is the construction of a student model [2, 4, 6, 14-46]. The models of the information perception dynamics are built and the time for training is predicted. The information systems theory assumes knowledge in the dynamic models of the student and the teacher, and the teacher is the central figure of the educational process.

The first specific feature of the modern information environment is that the teacher ceases to be the main source of knowledge since all knowledge is available on the computer network. The second feature of the modern computerized network information environment is noise, which is primarily created by: empty websites, Internet echoes from reposts, various informational nonsense; oversaturation with literature, which naturally arises due to the availability of access to virtually all existing technical and fiction literature in the absence of a proper unified organization for such an electronic information fund. A rather complicated question arises: how exactly to choose among the numerous information noise that which is necessary and useful?

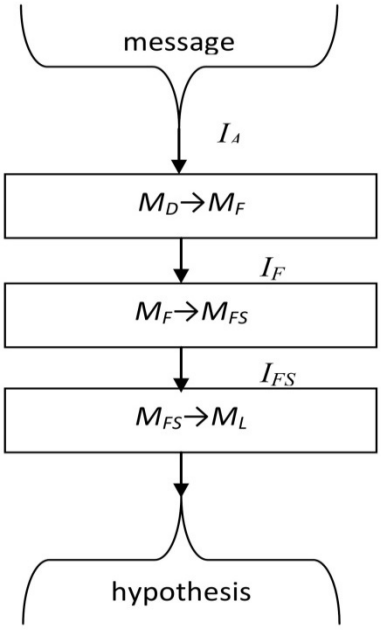

Figure 4 – Information flows in the message perception

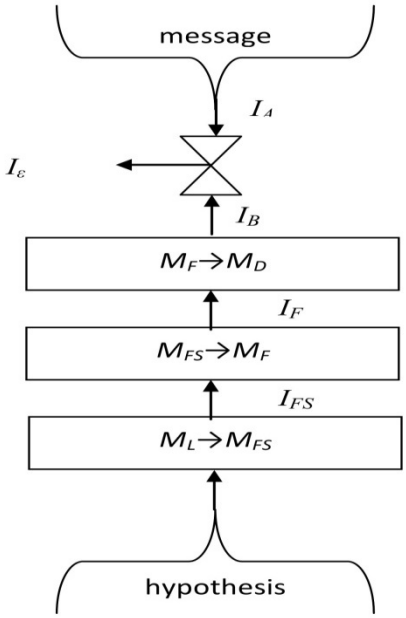

Figure 5 – Information flows when checking the put forward hypothesis correctness

Since the network is a sets union of weakly correlating sources, we get the information space with the norm in the form of trust information. The above provides an opportunity to build strategies for selecting information according to the method, which is based on taking into account the ratio of the information saved number to the information calls number, which allows us to single out the

expected useful information. Using the Hartley measure, you can choose the information that has a minimum of hits and therefore can potentially be new. Further, it is useful to use information systems theory. The following actual properties are required: logical connectivity, which is achieved by the interactive organization; the truth that can be achieved by the above method of information sampling; general accessibility provided by an open, non-commercial project. Attention should be paid to the fact that this exists (for example, in the format of Wikipedia and other similar network information resources), is a logical consequence of the global information system development. It remains only to ensure the availability and overcoming of language barriers, which is also solved. Returning to normal, it should be noted that the trainer becomes a mentor not only in the world of knowledge as such, but also in the computer network, where he offers his (most often, encyclopedic) knowledge in a format adapted for computerized network information interaction.

In general, as a result of the study, the following conclusions can be formulated. Learning processes are basically information processes, subject to the objective laws of the information systems functioning. The task of creating an education system is the control task, and the theoretical foundations of education systems building are based on control theory. Principles and methods of training, formed over a long period of practice, reflect the objective laws of the information systems functioning. The theorem of the information flow one-sided orientation and the limited types of sets, together with the principle of optimality, limits the number of information perception levels in the learning process to three levels. The development of the global information network leads to the unified knowledge system formation in the electronic encyclopedia`s form, which is the result of an objective process on the global network information flow compressing.

Conclusions. The study was aimed at further improving the methodological apparatus of computerized information training technology to ensure the optimal development of education systems in the context of the continuous strengthening for the socio-economic globalization trends, carried out by identifying those links for the composite technological components of modern computerized information learning processes with elements of the information technologies theoretical foundation that allow perfection develop learning and education systems in general based on information, information processes, and information systems theories. The basis for the processes of conducting and processing the results in scientific research was the methodological toolkit of theories in information and coding, probabilities and mathematical statistics, information processes, information technologies, feedback control, multi-criteria optimization, information systems, expert assessment.

As a result of the analysis in the features of the information processes globalization in the education systems based on modern computerized information and communication training technologies, its advantages, problematic aspects and factors of negative manifestations compensating were revealed. The study in the theoretical foundation of the education and training tasks showed the following dominants: typical problems of optimal control for systems, given descriptions, where functional dependencies of goals on control vectors, learning trajectories and parameters are formed; problem statements are vague, have numerous limitations and goals, requiring multi-criteria optimization; to solve problems, build models of objects and apply methods of control theory.

The results on monitoring the increasing relevance for conceptual categories of information, information objects, processes, technologies and systems in the training and education tasks in the globalization context have shown the desirability of increasing attention to their consideration as tasks of information systems control. Since information theory, as the basis of information systems, requires adaptation to the information systems control and training tasks, the article explores the feasibility for appropriately using elements of information theory in learning tasks as tasks of interacting with information systems and control of them.

In the context of the problem`s category to be solved, an analytical (functional) dependence on information for the norm defined above the event space is adopted in order to assess the degree of causal relationships. In probabilistic space, it is possible to represent the norm by a power series and to obtain, using a linear approximation, a generating differential equation, the solution of which allows, given initial conditions, to obtain an informational estimate based on the inverse functional dependence. A generalized formalized form is proposed: the probabilistic functional

dependence of the norm over the probabilistic event space on information; generating differential equation; an analytical expression for estimating information based on the solution of the indicated equation. By applying elements of information theory, processes of different essence can be put into correspondence with different types of methods for evaluating information and producing equations, measuring information as the degree of causal relationships. Determining the method for estimating the informational proximity of events (metrics) allows us to obtain a normalized metric information space induced over the event space, which is described by a simple mathematical construction. Events, information connections evaluations, and distances between events, the construction of information models should be considered in the information space. When modeling information systems, first of all, physical models and operators are needed.

The types of information processes (flows) in the elementary training information system, on the basis of which, it is possible to obtain complex information systems and control solutions, are defined. For the expected estimates of information transfer processes based on the norms of information spaces and comparisons of information flows using metrics, functional dependencies are obtained to determine the entropy based on the mathematical expectations of norms and metrics. Information processing is represented by a change in the values of causal relationships by the processes of the event space; formal definitions of the information processing operator and sets of perceived information objects are given.

Received a generalized block diagram of the algorithm for the training information system functioning as a control system with an informative input signal, feedback and an optimization procedure for finding the optimal operator to transform an ordered set into a set by definition with the aim of minimizing for information image perceptual errors, which displays a formalized perception information model at the level of elementary skills and concepts formation, given the characteristic features of the algorithm. For the subsequent stages of perception, the features of the models are also formed and analyzed: when moving from an image given by description by name (set by definition), to the set specified by enumeration (set by specifying by the optimization procedure of finding the best description), a characteristic procedure for deciding whether the input model corresponds to input flow; when working with a set of objects names, the characteristic procedure for analyzing the structure of the object (the set of enumeration allows you to build algorithms for describing the input stream organization).

Training is an informational process with the need to adapt to the requirements and limitations, statements about possible elementary interactions of information flows and structures for perception and accumulation of information are limitations, the information training system is built on the basis of selected fundamental elements, an important role in eliminating errors and the formation of operators-reflexes and images plays information non-redundant repetition.

The result of the analysis in the concept and informational essence of the learning paradigm is the following: the model of the learner as an object is determined relative to the formal knowledge accumulation; information perception process consists of receiving, processing and storing information created by the trainer as an information source; one-sided orientation of the information flow determines two possible forms of information interaction, transmission, and comparison of information; the above determines the formation of algorithms for the information perception; a limited number of methods for specifying specialized sets sufficient to form models of the external world determines the number for levels and tasks of information perception; the cornerstone is the principle of optimality.

The features are analyzed and formalized (analytical, algorithmic) descriptions are obtained for the main tasks of informational perception in training: for the formation of reactions and habits – a model for finding an operator that minimizes differences in the information of the trainer and the trainees; for the formation and determination of realism for the external world models on the basis of figurative and situational thinking – a model for finding the optimal sequence of informational influences and control, minimizing the expected perception error; for processing logical structures and algorithms for models constructing at the level of sets specified by enumeration, based on logical thinking – the optimal algorithm for finding algorithms of constructing models and images described by logical functions and problems of finding the best representations of models, which finds the minimum general description of methods for models constructing. An algorithm for infor-

mation perception has been developed, which takes into account information flows in perceiving messages and checking the correctness of hypotheses. The generalized structural schemes for formalized algorithms of information promotion between the message and the hypothesis are presented, taking into account the passage of perception levels models.

The analysis of the information perception tasks together with the theoretical foundations of educational systems allowed: to identify the main principles of information learning processes, based on the requirement to form true, concise and complete information images to be reproduced; to set the task of information training systems control as a classical optimization task, in which the fundamental are the goals formation and the optimality principle, which requires minimizing the error of the learner and measures to ensure the best achievement of the goal. To build a student model, the models of the information perception dynamics are built and the time of training is predicted. The information systems theory assumes knowledge of the dynamic models for the student and the teacher (the central figure of the educational process).

Highlighted current features and necessary properties of modern computerized network learning information environment, analyzed the sources and proposed ways to resolve their problem aspects and further improve on the basis of the developed information sampling techniques using the information systems theory.

In general, new concepts, algorithms, and models were developed that made it possible to formalize the identified interrelations of the learning information processes components with elements of the theories in information and information systems optimization control, achieving on this basis improvements in computerized information training technologies taking into account the features of the education systems globalization.

The obtained theoretical developments regarding the improvement of control in information training systems based on computerized information technologies make it possible, when introducing them into the practice of education systems in the context of globalization, to significantly improve the effectiveness of learning information processes.

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ДОСЛІДЖЕННЯ КОМП'ЮТЕРИЗОВАНИХ ІНФОРМАЦІЙНИХ ТЕХНОЛОГІЙ ЯК ОСНОВ НАВЧАННЯ ТА СИСТЕМ ОСВІТИ

Анотація. Мета статті полягає в удосконаленні методологічного апарату комп'ютеризованих інформаційних технологій навчання для оптимізації систем освіти в умовах глобалізації на основі виявлення і формалізації нових зв'язків технологічних компонентів інформаційних процесів навчання з елементами теорій інформації та управління інформаційними системами. Методи дослідження. Основою досліджень є теорії інформації, інформаційних систем та процесів, управління, оптимізації. Основні результати дослідження. Виявлено специфіку глобалізації систем освіти на базі комп'ютеризованих інформаційних технологій навчання, адаптації теорії інформації до взаємодії і управління в інформаційних системах навчання. В даному контексті, отримані: норма над простором подій як функціональна залежність від інформації для оцінки причинно-наслідкових зв'язків, що виробляє диференціальне рівняння, аналітичний вираз для оцінки інформації; концепція нормованого метричного інформаційного простору; види інформаційних процесів систем навчання; функції визначення ентропії на основі математичних очікувань норм і метрик для оцінок процесів передачі інформації; оператор обробки інформації; безлічі інформаційних об'єктів; схема дії інформаційної системи навчання як управління з оптимизационной зворотним зв'язком для мінімізації помилок інформаційного сприйняття; процедури прийняття рішень про відповідність моделей сприйняття інформаційних потоків, аналізу структур інформаційних об'єктів; концепція інформаційної суті процесів навчання з адаптацією до вимог і обмежень; формалізовані описи інформаційного сприйняття в навчанні; алгоритми сприйняття і просування інформаційних потоків; опрацювання оптимізаційної задачі управління інформаційними системами навчання; концепція вдосконалення сучасних інформаційних середовищ навчання із

застосуванням теорій інформації, інформаційних систем. Наукова новизна. Розроблено нові концепції, алгоритми і моделі, що дозволили формалізувати виявлені взаємозв'язку складових компонентів інформаційних процесів навчання з елементами теорій інформації та оптимізаційного управління інформаційними системами, досягаючи вдосконалення комп'ютеризованих інформаційних технологій навчання з урахуванням глобалізації систем освіти. Практична значимість. Впровадження отриманих теоретичних напрацювань щодо вдосконалення управління в інформаційних системах навчання на основі комп'ютеризованих інформаційних технологій в практику систем освіти в умовах глобалізації дозволяє істотно підвищувати ефективність інформаційних процесів навчання.

Ключові слова: *інформаційна технологія, комп'ютер, мережа, система, процес, навчання, освіта.*

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ИССЛЕДОВАНИЕ КОМПЬЮТЕРИЗИРОВАННЫХ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ КАК ОСНОВ ОБУЧЕНИЯ И СИСТЕМ ОБРАЗОВАНИЯ

Аннотация. Цель статьи состоит в совершенствовании методологического аппарата компьютеризированных информационных технологий обучения для оптимизации систем образования в условиях глобализации на основе выявления и формализации новых связей технологических компонентов информационных процессов обучения с элементами теорий информации и управления информационными системами. Методы исследования. Основой исследований являются теории информации, информационных систем и процессов, управления, оптимизации. Основные результаты исследования. Выявлена специфика глобализации систем образования на базе компьютеризированных информационных технологий обучения, адаптации теории информации к взаимодействию и управлению в информационных системах обучения. В данном контексте, получены: норма над пространством событий как функциональная зависимость от информации для оценки причинно-следственных связей, производящее дифференциальное уравнение, аналитическое выражение для оценки информации; концепция нормированного метрического информационного пространства; виды информационных процессов систем обучения; функции определения энтропии на основе математических ожиданий норм и метрик для оценок процессов передачи информации; оператор обработки информации; множества информационных объектов; схема действия информационной системы обучения как управления с оптимизационной обратной связью для минимизации ошибок информационного восприятия; процедуры принятия решений о соответствии моделей восприятия информационным потокам, анализа структур информационных объектов; концепция информационной сути процессов обучения с адаптацией к требованиям и ограничениям; формализованные описания информационного восприятия в обучении; алгоритмы восприятия и продвижения информационных потоков; проработка оптимизационной задачи управления информационными системами обучения; концепция совершенствования современных информационных сред обучения с применением теорий информации, информационных систем. Научная новизна. Разработаны новые концепции,

алгоритмы и модели, позволившие формализовать выявленные взаимосвязи составных компонентов информационных процессов обучения с элементами теорий информации и оптимизационного управления информационными системами, достигая совершенствования компьютеризированных информационных технологий обучения с учетом глобализации систем образования. Практическая значимость. Внедрение полученных теоретических наработок по совершенствованию управления в информационных системах обучения на основе компьютеризированных информационных технологий в практику систем образования в условиях глобализации позволяет существенно повышать эффективность информационных процессов обучения.

Ключевые слова: *информационная технология, компьютер, сеть, система, процесс, обучение, образование.*

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АВТОРИ

ВИМОГИ ДО ОФОРМЛЕННЯ СТАТЕЙ
в журналі «Проблеми інформаційних технологій»

Журнал «Проблеми інформаційних технологій» є періодичним науковим журналом, який включено до переліку наукових фахових видань України з технічних наук (Наказ Міністерства освіти і науки України № 820 від 11.07.2016 р.).

Журнал публікує статті з новими науковими результатами в області теоретичних і прикладних проблем сучасних інформаційних технологій, системного аналізу і моделювання за такими групами спеціальностей:

121 Інженерія програмного забезпечення.
122 Комп'ютерні науки.
123 Комп'ютерна інженерія.
124 Системний аналіз.
125 Кібербезпека.
126 Інформаційні системи і технології.
151 Автоматизація та комп'ютерно-інтегровані технології.

Мінімальний обсяг статті – 8 сторінок. Максимальний – 20 сторінок. Література та анотації також входять до загальної кількості сторінок публікації.

Журнал видається українською, англійською та російською мовами.

Публікація статей здійснюється на платній основі. Розмір внеску за публікацію статті становить 45 грн. за кожну (повну чи неповну) сторінку поданих матеріалів.

Журнал включено до науково-метричних баз даних, цифрових архівів та бібліотек з безкоштовним on-line-доступом: Index Copernicus, CrossRef, Google Scholar, Directory of Open Access Journals (DOAJ), Research Bible, Open Academic Journals Index (OAJI), РІНЦ (Російський індекс наукового цитування), AcademicKeys, National Library of Ukraine (Vernadsky).

ВИМОГИ ДО ЗМІСТУ Й ОФОРМЛЕННЯ НАУКОВИХ СТАТЕЙ

Наукова стаття в журналі «Проблеми інформаційних технологій» повинна відповідати вимогам п. 3 Постанови ВАК України № 7-05 / 1 від 15.01.2003 року та враховувати вимоги міжнародних наукометричних баз даних (Scopus / Elsevier database, Clarivate Analytics / former Thomson Reuters, Web of Knowledge, CrossRef / Digital Object Identified та ін.) до наукових статей.

Редакційна колегія рекомендує авторам дотримуватися такої структури наукової статті:

1. **Постановка проблеми.** Необхідно розкрити сутність і стан наукової проблеми у загальному вигляді, її теоретичну та (або) практичну значущість, обґрунтувати актуальність дослідження.

2. **Аналіз останніх досліджень і публікацій.** Необхідно проаналізувати основні положення останніх досліджень і публікацій, що безпосередньо стосуються порушеної проблеми, виокремити невирішені раніше частини загальної проблеми, яким присвячено статтю.

3. **Мета дослідження.** Необхідно висловити основну ідею публікації. Мета дослідження має випливати з постановки проблеми й аналізу останніх досліджень і публікацій, у ній повинно бути чітко визначено кінцевий науковий результат.

4. **Виклад матеріалу дослідження.** Необхідно висвітлити основні положення і результати наукового дослідження.

5. **Висновки.** Необхідно висвітлити найбільш важливі результати дослідження, які містять наукову новизну і мають теоретичне та (або) практичне значення.

6. **Список літератури.** Список літератури повинен бути оформлений у двох варіантах:

1. відповідно до міжнародного бібліографічного стандарту APA: https:/www.apastyle.org.

2. відповідно до ДСТУ 8302.2015 «Інформація та документація. Бібліографічні посилання. Загальні положення та правила складання.».

У списку літератури обов'язково повинні бути присутні джерела з досліджуваної проблеми не більше ніж 3-4-річної давності. Не слід обмежуватися цитуванням робіт, які належать тільки одному колективу авторів або дослідницькій групі.

Необхідними є посилання на сучасні міжнародні публікації. Статті, які не містять посилань на роботи, опубліковані протягом останнього десятиліття, автоматично вважаються такими, що не відповідають редакційним вимогам.

СТРУКТУРНІ ЕЛЕМЕНТИ НАУКОВОЇ СТАТТІ

Індекс УДК у верхньому лівому куті сторінки (Times New Roman, 12 пт.).

Інформація про авторів (співавторів) статті (ім'я та прізвище мовою статті, науковий ступінь, вчене звання, посада, місце роботи, населений пункт, країна, адреса електронної пошти, ORCID ID) (Times New Roman, 12 пт., вирівнювання – по лівому краю).

Назва статті. Назву статті потрібно подавати напівжирним шрифтом великими літерами з вирівнюванням по центру, без скорочень, зокрема літерних абревіатур. Назва статті повинна відображати зміст дослідження та відповідати його меті, науковим результатам і висновкам. (Times New Roman, 14 пт., напівжирний шрифт).

Анотація мовою статті. Обсяг анотації має становити 2–3 тис. знаків разом із ключовими словами (4–8 слів). (Times New Roman, 12 пт.).

Анотація має містити такі структурні елементи:

1) мета статті;

2) методи дослідження;

3) основні результати дослідження;

4) наукова новизна;

5) практична значимість.

Перелік ключових слів, який починається зі слів: «Ключові слова:» (Times New Roman, 12 пт., курсив).

Постановка проблеми

Аналіз останніх досліджень і публікацій

Мета дослідження

Виклад матеріалу дослідження

Висновки

Список літератури

У тексті статті можна подавати ілюстрації. Підпис під ілюстрацією має складатися з чотирьох основних елементів: найменування, що позначається скороченим словом «Рис.»; порядкового номера ілюстрації, який вказується без знаку номера арабськими цифрами; тематичного заголовка ілюстрації, що містить текст зі стислою характеристикою зображення.

Ілюстрації потрібно оформлювати окремими файлами у форматах jpg, tiff, png належної якості. Роздільна здатність має бути не менш як 300 dpi, а розмір зображення – не менш як 1060 x 1410 pixel.

Таблиці необхідно виконувати у текстовому редакторі MS Word 2016.

Кожна таблиця повинна мати порядковий номер і тематичний заголовок, які необхідно розмістити над нею симетрично до тексту.

Формули потрібно подавати за допомогою редактора формул MS Equation 3.0, Math Type.

Також мають бути анотації українською та російською мовами, які за змістом цілком відповідають анотації англійською мовою. Кожна анотація також повинна містити інформацію про авторів, відповідною мовою.

Редакційна колегія не обов'язково поділяє позицію, висловлену авторами у статтях, та не несе відповідальності за достовірність наведених даних, цитат, фактів та посилань.

Редакційна колегія залишає за собою право відхиляти матеріали, що не відповідають редакційним вимогам, мають низький науковий рівень та не пройшли процедуру рецензування.

ВИМОГИ ДО ПОДАННЯ НАУКОВОЇ СТАТТІ

Для опублікування наукової статті на адресу електронної пошти журналу (magazinepit@ukr.net) необхідно надіслати її електронну версію разом із ілюстраціями, оформленими окремими файлами у відповідних форматах.

Звертаємо увагу!

Автору (співавторам) не потрібно надсилати рецензію, оскільки кожна подана для опублікування наукова стаття проходить анонімне рецензування та перевірку на наявність плагіату.

Вимоги до оформлення файлу:

Текст наукової статті повинен бути надрукований у текстовому редакторі MS Word 2016 (у форматі docx); формат паперу: А4 (210 х 297мм); орієнтація сторінок: книжкова із вирівнюванням по ширині з відступом від лівого краю – 1,25 мм; поля: верхнє, нижнє, праве – 2 см, ліве – 2,5 см; шрифт: Times New Roman (розмір шрифту – 12 pt); міжрядковий інтервал – 1.

У тексті не повинно бути переносів і макросів. У тексті статті виділяються лише назви розділів статті, відповідно до її структури. Інших виділень не має бути.

Формули потрібно подавати за допомогою редактора формул MS Equation 3.0, Math Type. Всі формули вставляються в таблицю з не окресленим контуром, що складається з двох колонок: у першій знаходиться формула без абзацу та вирівняна по центру, в другій - номер формули (якщо такий є) теж без абзацу та з вирівнюванням по правому краю. Кордон між колонками таблиці встановлюється на позначці 14 см. У тексті формули повинні бути виділені зверху і знизу порожнім рядком. Нижче наведено приклад вставки формули:

$\lim_{t \to 0} \int_0^t P dt = \pi \cdot 0$.	(1)

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Прохання до авторів суворо дотримуватися вимог редколегії. В іншому випадку Вашу статтю буде відхилено.

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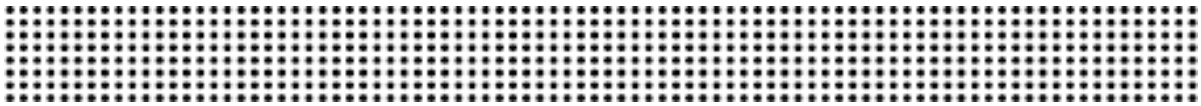

НОТАТКИ

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