

SUMMARY

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INFORMATION SYSTEMS, NETWORKS AND TECHNOLOGY

1. Ковалишин О. С. Нейронечіткий генетичний алгоритм оптимізації планів відновлювальної терапії

NEURO-FUZZY GENETIC ALGORITHM OF OPTIMIZATION OF REHABILITATION THERAPY PLANS

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According to 178 countries, 20-50 million people get injured every year. More than 250 thousand people a year suffer from the injuries leading to disability.

The high level and complexity of domestic injuries are associated with an increase in the number of road injuries and the usage of modern mechanisms in domestic conditions, non-compliance with safety rules.

Modern injuries have a poly structured character, which causes their severe consequences and difficulties in the different stages of rehabilitation.

In this regard, in the process of rehabilitation, special attention is given to the issue of individually oriented rehabilitation services, since at present plans for rehabilitation therapy rarely cover the interests of patients themselves, which directly affects the quality of treatment.

In order to solve the problem, it is necessary to take into account the set of restrictions imposed on the process – the need to consolidate schedules of the medical equipment usage, the availability of qualified medical personnel for each specific procedure at a certain time, the availability of off-the-shelf equipment, etc.

In fact, to solve this problem, it is necessary to construct a full functioning schedule of the medical institution, which is superimposed on the set of hard restrictions – the conditions that must necessarily be fulfilled to ensure the correctness of the schedule, and soft requirements – the implementation of which is desirable – the actual interests of patients.

The following methods are used to solve the problem of constructing a schedule for medical institutions: full selection, method of branches and boundaries, logical programming with constraints, graph coloring, simulated annealing, simulation modeling, genetic algorithm, etc.

Regarding other methods, genetic algorithms have several advantages, such as: simultaneous usage of several points of the search space, the usage of probabilistic and deterministic rules for the transition between solutions, the absence of the need to use an external extra data and operations. Therefore, it is proposed to use genetic algorithms to solve the problem of multi-criteria optimization of rehabilitation therapy plans.

In the process of the method, the following actions are performed:

1. Each individual of the current population is evaluated using a fuzzy logic controller.
2. The best variants are copied to the new population unchanged.
3. On the basis of proportional selection from the current population, chromosomes that are subject to recombination are selected.
4. If a new population is formed then the old one is deleted. After that we turn to item 5, and in the opposite case – to item 3.
5. If the criterion for stopping the optimization process is not met, the transition to p.1 is performed.

To assess the progress of optimization, a mechanism for evaluating alternatives generated during the work of evolution operators has been constructed. To this end, a fuzzy logic controller, the T-Controller, has several advantages over classical methods: high accuracy of computations, zero methodological error, high speed of operation.

Indicators based on fines imposed for violation of a certain criterion are used as input arguments of the controller.

For the organization of the optimization process, the mechanisms of population development – crossover and mutation operators have been developed.

In particular the following operators are used:

- 1) the change of the time of the procedure, which represents transferring of a certain procedure from one time interval to another arbitrary time period during the same day;

- 2) the change of the date of the procedure represents transferring of a certain procedure from one time interval to another available time interval of another day;
- 3) the patient exchange of procedures represents the interchange of patients of two identical procedures;
- 4) the exchange of medical personnel consists of the partial interchange of qualified personnel, carrying out two procedures of the same type.

Each of the above operators with a certain probability are applied to each iteration of the optimization process.

Method stoppage occurs if, for a certain number of generations of optimization, there is no improvement in the chromosome with the highest level of evaluation.

The conducted analysis and the developed method allow to perform construction and multi-criteria optimization of plans for restorative therapy in the context of the schedules of medical institutions. Taking into account the interests of patients as restrictions makes it possible to increase the individualization of the services provided and, as a consequence, contributes to the improvement of the efficiency of the activities of medical institutions.

Key words: multicriteria optimization, genetic algorithms, fuzzy logic, restorative therapy.

1. Хобзей М. К. Аналіз сучасного стану реабілітації інвалідів в Україні/ Хобзей М. К., Іпатов А. В., Коробкін Ю. І., Мороз О. М. // *Медичні перспективи*. 2010. № 4. 2. Іпатов А.В. Професійна реабілітація інвалідів / Іпатов А. В., Сергієні, Т. Г. Войтчак О. В.; за ред. В.В.Маруніча. – Д.: Пороги, 2005. – 227 с. 3. Іпатов. А. В. Основні показники інвалідності та діяльності медико-соціальних експертних комісій України за 2014 рік. / А. В. Іпатов, О. М. Мороз, В. А. Голик, Р. Я. Перепелична, І. Я. Ханюкова, Ю. І. Коробкін, Р. М. Молчанов, Г. М. Маловичко, Н. О. Гондуленко, Н. А. Саніна // *Основні показники інвалідності та діяльності медико-соціальних експертних комісій України за 2014 рік: Аналітико-інформаційний довідник* / за ред. С. І. Черняка. – Дніпропетровськ: Роял-Принт, 2015. – 167 с. 4. Коффман Э.Г. Теория расписаний и вычислительные машины / Коффман Э. Г. М.: Наука, 1984. – 335 с. 5. Глибовец Н.Н. Генетические алгоритмы и их использование для решения задачи составления расписания / Медвідь С. А., Глибовец Н. Н // *Кибернетика и системный анализ*. – 2003. – No 1. – С. 95–108. 6. Tkachenko R. O. Method of making up clinic schedule with use of finite-state automaton / Tkachenko R. O., Kovalyshyn O. S. // *Econtechmod. An international quarterly journal*. – 2016. Vol. 5. No. 3, 131–134. 7. Hosny M. A Survey of Genetic Algorithms for the University Timetabling Problem/ Hosny M., Shameem F.// *International Conference on Future Information Technology*. – Singapore. – 2011. – Vol. 13. – pp. 34–39. 8. Дорошенко А.В. Нейроподобні структури машини геометричних перетворень у завданнях інтелектуального аналізу даних/ Дорошенко А.В, Ткаченко Р. О. // Міжнародна наукова конференція «Інтелектуальні системи прийняття рішень і проблеми обчислювального інтелекту» ISDMCI'2009: зб. наук. пр. у 2 т., 18-22 трав. 2009 р., Євпаторія, Україна. – Х. ; Херсон, 2009. – Т. 2. – С. 309–314. 9. Tkachenko O., Tkachenko R., Hirniak Yu., Mushenyk P. Rule based Fuzzy system of Improved accuracy // *Proceeding of the 56-th international Colloquium: Innovation of Mechanical Engineering – Shaping the Future*. – Ilmenau University of Technology. – pp. 1–6. 10. I.Verbenko, R. Tkachenko. Fuzzy Methods and Tools for Grane Management System Based on T-Controller // *Journal of Global Research in Computer Science*. – March 2013. – Vol. 4, No. 3, P. 1–4. 11. T-Controller Workshop [Електронний ресурс]. – Режим доступу: <http://tkatchenko.com/t-controller/about-t-controller/> (станом на 21.05.2018).

2. Дудикевич В. Б., Микитин Г. В., Ребець А. І. До проблеми управління комплексною системою безпеки кіберфізичних систем

ON THE PROBLEM OF COMPLEX SECURITY SYSTEM MANAGEMENT OF CYBER-PHYSICAL SYSTEMS

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The paper focuses on the analysis of the models of information security (IS) management of cyber-physical systems (CPS) in accordance with ISO / IEC TR 13335 and ISO / IEC 27001 standards. As the basis of the development of the complex security system (CSS) management methodology, the concepts of information technology security management are considered based on principles of security, assets, threats, vulnerabilities,

exposure, risk, protective measures and restrictions. For a thorough and multidimensional study of the problem, we use the models of information security management, in particular the model of interrelations of security elements, which shows how assets can be exposed to several threats, one of which is fundamental to this model; a model of safety and risk communication that shows the effectiveness of some protective measures to reduce risk; a model of the hierarchy of corporate security policies, the basic principles of which are the hierarchy of relations between technical and managerial policies that form the basis of the IS policy of the cyber-physics system; the existence of protection principles and directives for the whole organization as well as those relating to the protection of information that is vulnerable to threats or which is very valuable or has special significance for the organization; availability of basic safety principles in the CFS field and indications of the correct usage of guarantees to ensure proper security.

The authors propose an approach of planning and management of the CPS protection in accordance with the general structure formed on the basis of the CPS corporate safety methodology principles, the organizational aspects of the CPS security, the methods of CPS protection in accordance with the safety recommendations, the CPS safety projects for the protection means on the basis of approved IT protection methods, a general strategy for risk management and a mechanism for refining of the protection process. This approach takes into account the requirements and guarantees of security and is oriented on the dynamic environment and processes.

The article deals with the methods and approaches to control the IS of the cyber-physics system in order to analyze the risk and reduce it to an acceptable level. Depending on the specific organization and conditions, basic, informal, detailed and combined approaches to risk analysis are offered. To further manage the CPS security, the authors propose the application of one or more methods, including the usage of a security plan for information technology, maintaining the personnel competence regarding security and personnel training, as well as maintaining a security system that includes security checking, monitoring and incident handling.

To organize the cycle of security management system processes, the model “plan – do – check – act” is analyzed, which provides the necessary list of actions and processes concerning the IS management and guarantees compliance with the requirements and expectations of the interested parties.

In the article, the structure of CPS information security management was created at the level of the information lifecycle and CPS multi-level model on the basis of the conception “object – threat – protection”. This structure takes into account accidental and deliberate threats, methods and means of protection at the stages of input (collection / selection), storage, processing and transmission of data in the cyber-physical system, as well as accidental and deliberate threats, methods and means of protection for the CPS components – information resources, information systems, information processes, communication environment and physical space. This approach provides comprehensive information security management of the cyber-physics system, since it takes into account not only aspects of the structure, but also the stages of the CPS information lifecycle.

Key words: information security, models and methods of management, cyber-physical system, information lifecycle, complex security system, conception of “object – threat – protection”.

1. *Proekt Stratehii kibernetychnoi bezpeky Ukrainy. Elektronnyi resurs. – Rezhym dostupu: http://www.niss.gov.ua/public/File/2013_nauk_an_rozrobku/kiberstrateg.pdf*. 2. Mykytyn G.V. *Security of Cyber-Physical Systems from Concept to Complex Information Security System/ Dudykevych V., Mykytyn G., Kret T., Rebets A. // Advances in Cyber-Physical Systems. – Volume 1, Number 2 (2016). – S. 67–75.* 3. *Informatsiini tekhnolohii. Nastanovy z keruvannia bezpekoiu informatsiinykh tekhnolohii (IT). Chastyna 1. Kontseptsii y modeli bezpeky IT (ISO/IEC TR 13335-1: 1996, IDT): DSTU ISO/IEC TR 13335-1-2003. – [Chynnyi vid 2004-10-01]. – K.: Derzhspozhyvstandart Ukrainy, 2004. – 23 s.* 4. *Informatsiini tekhnolohii. Nastanovy z keruvannia bezpekoiu informatsiinykh tekhnolohii (IT). Chastyna 2. Keruvannia ta planuvannia bezpeky IT (ISO/IEC TR 13335- 2: 1997, IDT): DSTU ISO/IEC TR 13335-2-2003. – [Chynnyi vid 2004-10-01]. – K.: Derzhspozhyvstandart Ukrainy, 2004. – 20 s.* 5. *Informatsiini tekhnolohii. Nastanovy z keruvannia bezpekoiu informatsiinykh tekhnolohii (IT). Chastyna 3. Metody keruvannia zakhystom IT (ISO/IEC TR 13335-3: 1998, IDT): DSTU ISO/IEC TR 13335-3-2003. – [Chynnyi vid 2004-10-01]. – K.: Derzhspozhyvstandart Ukrainy, 2004. – 48 s.* 6. *Informatsiini tekhnolohii. Metody zakhystu. Systema upravlinnia informatsiinoiu bezpekoiu. Vymohy: HSTU SUIB 1.0 / ISO/IEC 27001: 2010. – [Chynnyi vid 2010-01-01]. – K.: Natsionalnyi bank Ukrainy, 2010. – 49 s.* 7. *Informatsiini tekhnolohii. Metody zakhystu. Systema upravlinnia informatsiinoiu bezpekoiu. Zvid pravyl dlia upravlinnia informatsiinoiu bezpekoiu: HSTU SUIB 2.0 / ISO/IEC 27002: 2010. – [Chynnyi vid 2010-01-01]. – K.: Natsionalnyi bank Ukrainy, 2010. – 149 s.*

3. Литвин В. В., Висоцька В. А., Кучковський В. В., Дуткевич С. Ю., Наум О. М. Метод інтеграції та управління контентом мережі інформаційних ресурсів туризму згідно потреб кінцевого користувача

CONTENT INTEGRATION AND MANAGEMENT METHOD OF INFORMATION RESOURCES NETWORK OF THE CITY ACCORDING TO THE END-USER NEEDS

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Today there are a lot of information resources that provide diverse content. However, a lot of their parts are quite inconvenient in terms of usability and the others are not filled with information and not always timely updated. For example, the actual content for the user with the bus schedule of a certain time period and with bus numbers need to be updated each week and to add comfortable search filters for the user. Then the reliable information and user-friendly interface will guarantee the repeated returning of the user to such a resource. Internet allows people to communicate easily and to publish their materials. So, the theme of the information systems (IS) development, which contains all necessary information on a particular city, is very relevant [1-17]. The work purpose is to create various contents integration and management method of multiple sources in a single IS. It contains all the necessary information on a particular city according to the end-user needs. The research object is content from various sources concerning different cities, the creation of information directories about cities. The research subject is information resources network that contains and displays required user content. The practical value of the work is the single information base creation that allows to locate and to provide required content on Ukrainian cities. The system allows users to monitor the weather for a while, to search public transport schedule, to browse the movies poster in cinemas and news, to view available phone directories, restaurants directory and all about tourism, cities photo, monuments, institutions address, etc. In this case, the IS serves as an integrated content directory, designed as a reference book of each information resource.

In the paper information systems are described that are defined as portal site. The portals sites examples are described that are networked sites on a particular topic. The administrative information system concept is determined, but rather as a decision support system for such projects. And the main competitors as developed information system prototypes of sites city network are described. As well it is written as and what necessary to improve data in information systems.

In the paper the method of integrated processing of heterogeneous information resources of Web-systems for their integration and the subsequent management has been described. This method is based on the model of data description as a coherent combination of data values, rules of data representation, interpretation rules and data structure. The method involves decomposition of general process into subprocesses of data values integration, data syntax integration, semantics and structure integration. The advantage of this approach is that the integration process can be performed at the data meta-scheme level. It allows to reduce the number of access operation to very large data sets of web-systems. In the given article the content lifecycle model in Web-systems is proposed. The model describes the processes of information resources processing in the Web-systems and simplifies the content automation integration and management technology. In the paper the main problems of content function integration and management services are analyzed. The method of content integration and management as the content life cycle stage in Web-systems is proposed. The method of content integration and management describes the formation of information resources in Web-systems and automation technology that simplifies the content processing. The proposed method gives an opportunity to create an instrument of information resources processing in Web-systems and to implement the subsystem of content integration and management. The article focuses on the development of unified methods and software tools for processing information resources in the Web-systems. A new approach to application and implementation of business processes is formulated for the construction of these Web-systems. The methods and software tools of content and information resource processing are developed.

This article describes information about the structure of constructed information system, constructed UML diagram and subject area about information resources network of Ukrainian cities. Essential requirements are delivered and structure towards their objectives is constructed. The paper describes the methods and means of the problem solving for building an information system of city sites network, and such advantages of the tools are presented.

Key words: content, information resources, content analysis, content monitoring, content search, Web-systems, Web-resource, data value, data integration, distributed data systems, heterogeneous data, business-process, content management system, content lifecycle, Internet tourism.

1. Клименко Р. *Web-мастеринг на 100%* / Р. Клименко. – СПб: Питер, 2013.— 512 с. 2. Ленгсторф Дж. *Искусство общения в Интернет. Краткое руководство* / Д. Ленгсторф. — М.: Вильямс, 2011.— 334 с.
3. *Основні правила побудови семантично відкритих інформаційних систем* / Жежнич П., Кравець Р., Пасічник В., Пелецишин А. // Вісник НУ “Львівська політехніка”. – Львів, 1999. – № 383. – С. 84–95.
4. Пелецишин А. *Позиціонування сайтів у глобальному інформаційному середовищі* / А. Пелецишин.— Львів: НУ «Львівська політехніка», 2007. – 260 с. 5. *Methods based on ontologies for information resources processing* / [V. Lutyun, V. Vysotska, L. Chyrun, D. Dosyn] // LAP Lambert Academic Publishing. Saarbrücken, Germany. – 2016. – 324 p. 6. Берко А. *Системи електронної контент-комерції: монографія* / А. Берко, В. Висоцька, В. Пасічник. – Львів: НУ «Львівська політехніка», 2009. – 612 с. 7. *Математична лінгвістика.* / [В. Пасічник, Ю. Щербина, В. Висоцька, Т. Шестакевич] // Серія «Комп'ютинг». – Львів : «Новий світ -2000», 2012. – 359 с. 8. Висоцька В. *Методи і засоби опрацювання інформаційних ресурсів в системах електронної контент-комерції: автореф. дис. ... к. т. н.: 05.13.06 – інформаційні технології* / В. Висоцька; НУ «Львівська політехніка». – Львів, 2014. – 27 с. 9. Vysotska V. *Web Content Processing Method for Electronic Business Systems* / V. Vysotska, L. Chyrun // *International Journal of Computers & Technology.* – Vol 12, No 2. – December 2013. – P. 3211–3220. 10. Висоцька В. *Моделювання етапів життєвого циклу комерційного web-контенту* / В. Висоцька, Л. Чирун, Л. Чирун // Вісник НУ “Львівська політехніка”. – Львів, 2011. – № 715. – С. 69-87. 11. Висоцька, В. *Особливості проектування та впровадження систем електронної комерції.* / В. Висоцька // Вісник НУ “Львівська політехніка”. – Львів, 2008. – № 631. – С. 55–84. 12. Vysotska V. *Analysis and evaluation of risks in electronic commerce* / V. Vysotska, I. Rishnyak, L. Chyrun // *CAD Systems in Microelectronics, CADSM '07.* – 2007. – P. 332–333. 13. Vysotska V. *Comprehensive method of commercial content support in the electronic business systems* / V. Vysotska, L. Chyrun, L. Chyrun // Вісник НУ “Львівська політехніка”. – Львів, 2013. – № 777. – С. 21–30. 14. Berko A. *Content formation method in the electronic content commerce systems* / A. Berko, V. Vysotska, L. Chyrun // *Computer Science & Engineering (CSE-2013).* – 2013. – P. 174–179. 15. Vysotska V. *Uniform method of operative content management in the electronic content commerce systems* / V. Vysotska, L. Chyrun, L. Chyrun // *Computer Science & Engineering (CSE-2013).* – 2013. – P. 180–185. 16. Берко А. *Метод формування контенту в системах електронної контент-комерції* / А. Берко, В. Висоцька, Л. Чирун // Вісник НУ “Львівська політехніка”. – № 751. – Львів, 2013. – С. 108–118. 17. Берко А. *Моделювання процесів опрацювання інформаційних ресурсів в системах електронної контент-комерції* / А. Берко, В. Висоцька, Л. Чирун // Вісник НУ “Львівська політехніка”. – Львів, 2013. – № 771. – С. 126–135. 18. Висоцька В. *Уніфікований метод формування інформаційного продукту в системах електронної контент-комерції* / В. Висоцька, Л. Чирун // *Наукові праці Чорноморського держ. Унів. ім. П. Могили.* – 2013. – №. 217(229). – С. 91–101. 19. Висоцька В. *Уніфіковані методи опрацювання інформаційних ресурсів в системах електронної контент-комерції* / В. Висоцька, Л. Чирун, Л. Чирун // *Наукові праці Чорноморського держ. університету ім. П. Могили.* – 2013. – № 201(213). – С. 13–24. 20. Висоцька В. *Уніфікований метод оперативного управління контентом в системах електронної контент-комерції* / В. Висоцька, Л. Чирун, Л. Чирун // Вісник НУ “Львівська політехніка”. – Львів, 2013. – № 751.– С. 118–128. 21. Висоцька В. *Особливості проектування та аналіз узагальненої архітектури систем електронної контент-комерції* / В. Висоцька, Л. Чирун, Л. Чирун // Вісник НУ “Львівська політехніка”.– Львів, 2013. – № 770.– С. 83–101. 22. Берко А. *Структура засобів опрацювання інформаційних ресурсів в системах електронної контент-комерції* / А. Берко, В. Висоцька, Л. Чирун // Вісник НУ “Львівська політехніка”. – Львів, 2013. – № 770. – С. 12–21. 23. Щербина Ю. *Утворення українських дісприкетників за допомогою породжувальних граматик* / Ю. Щербина, Ю. Нікольський, В. Висоцька, Т. Шестакевич // Вісник НУ “Львівська політехніка”. – Львів, 2011. – № 715. – С. 354–369. 24. Висоцька В. *Метод вибору оптимального алгоритму криптографічного захисту інформації* / В. Висоцька, О. Гарасим // Вісник НУ “Львівська політехніка”. – Львів, 2010. – № 673. – С. 220–233. 25. Щербина Ю. *Науковий напрям та навчальна дисципліна “Математична лінгвістика”* / Ю. Щербина, Т. Шестакевич, В. Висоцька // Вісник НУ “Львівська політехніка”. – Львів, 2010. – № 673. – С. 384–393. 26. Чирун Л. *Застосування контент-аналізу текстової інформації в системах електронної комерції* / В. Висоцька, Л. Чирун // Вісник НУ “Львівська політехніка”. – Львів, 2010. – № 689. – С. 332–347. 27. Висоцька В. *Схеми моделювання систем керування контентом* / В. Висоцька // Вісник НУ “Львівська політехніка”. – Львів, 2010. – № 689. – С. 90–108. 28. Висоцька, В. *Умовна ентропія та ентропія поєднання контенту в системах електронної комерції* / В. Висоцька // Вісник НУ “Львівська політехніка”. – Львів, 2008. – № 626. – С. 116–125. 29. Берко, А. *Аналіз і класифікація моделей систем електронної комерції* / А. Берко, В. Висоцька // Вісник НУ “Львівська

політехніка”. – Львів, 2007. – № 591. – С. 103–112. 30. Берко А. Методи та засоби оцінювання ризиків безпеки в інформаційних системах електронної комерції / А. Берко, В. Висоцька, І. Рішняк // Вісник НУ “Львівська політехніка”. – 2007. – № 591. – С. 81–87. 31. Висоцька, В. Система опрацювання структури електронного підручника / В. Висоцька // Вісник НУ “Львівська політехніка”. – Львів, 2003. – № 489. – С. 49–63. 32. Vysotska V. Analytical methods for commercial web content processing of information resource in electronic business systems / V. Vysotska, L. Chyrun // MEST Journal. – Vol. 2, No. 2. – P. 285–300. 33. Vysotska V. Features of the content-analysis method for text categorization of commercial content in processing online newspaper articles / V. Vysotska, L. Chyrun // Applied Computer Science. ACS journal. – Vol. 11, Is. 1. – Poland, 2015. – P. 5–19.

4. Берко А. Ю. Моделі великих даних для систем електронної комерції

BIG DATA MODELS FOR E-COMMERCE SYSTEMS

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Nowadays there are many areas requiring to solve problems with analytical methods and tools supplemented with the necessity to use big data sources. It concerns many tasks in business, finance, medicine, politics, ecology and ecological surveillance, and many other all requiring data analytics solution. One of the most important of these areas is e-commerce. E-commerce tasks need to take into consideration such features of big data like volume, velocity, and variety. Meanwhile, significance and reliability of the data should be kept. So, value and veracity of data source must be supported as well.

The presented paper considers some aspects of problems of Big Data using in e-commerce applications. Generalized structural model of Big Data information resource for e-commerce systems is developed in this paper. The analysis and substantiation of possibility and expediency of use of the Big Data in the processes of e-commerce are performed. The concept of metascheme for control of access to Big Data source is developed. The application of such metascheme allows to form a subset of data resource relevant to a certain type of e-commerce tasks.

The generalized model of Big Data source for e-commerce systems has been developed based on analysis of set of typical e-commerce tasks. These tasks are classified on three types:

1st type contains the tasks of operational management of the activity of the electronic commerce system (optimization of assortment, price policy management, business process management, online advertising, customer service optimizing, resource management, transaction management etc.);

2nd type of tasks includes strategic tasks aimed at making perspective decisions and planning activities (determining market consumer needs, goods and services of market segmentation, system productivity increase, introduction of innovative models, business development improvement planning, Infrastructure development);

3rd type unites analytical tasks (personalization of system activity, logistics planning, system security planning, predictive and prescriptive analytics, system activity targeting).

Big Data source which provides the solving of presented tasks need such types of data:

- company's own data source such as customer database, goods and services database, activity data, supplier data, personnel data etc.,
- company partners data sources – contractor data, supplier data, logistic data, finance data, advertising data etc.,
- public data sources such as stock exchange activity data, marketing data, statistical data, government documents, social networks, electronic media and so on,
- competitor data – public data, insider data, activity data and other.

The structure of such Big Data source needs special description and management tools. Such a tool is a metaschema of Big Data source. Metaschema includes description of data source units in accordance with e-commerce typical tasks. Using of metaschema provides simple and fast access of e-commerce program tools to relevant data.

Keywords: E-commerce, Big Data, data structures, data resource model.

1. Akter S. Big data analytics in E-commerce: a systematic review and agenda for future research / Shahriar Akter, Samuel Fosso Wamba // *Electronic Markets*. – Volume 26, Issue 2. – Springer International Publishing AG. – 2016. – P. 173–194. 2. Allen R. Top E-commerce Trends to inform your 2017 marketing strategy [Електронний ресурс] / Robert Allen. – June, 2017. – Режим доступу : <http://www.smartinsights.com/e-commerce/e-commerce-strategy/top-e-commerce-trends-inform-2017-marketing-strategy/>. 3. Radde B. *Big Data: Future Of E-Commerce*

[Електронний ресурс] / Björn Radde. – November, 2014. – Режим доступу : <https://www.linkedin.com/pulse/20141112200850-1172947-big-data-future-of-e-commerce>. 4. Большие данные (Big Data) [Електронний ресурс]. – TAdviser: Деловой портал. – 2016. – Режим доступу : [http://www.tadviser.ru/index.php/Статья: Большие данные \(Big Data\)](http://www.tadviser.ru/index.php/Статья:Большие_данные_(Big_Data)) 5. Большие данные в электронной коммерции [Електронний ресурс]. – TAdviser: Деловой портал. – 2014. – Режим доступу : [http://www.tadviser.ru/index.php/Статья:Большие данные_в_электронной_коммерции](http://www.tadviser.ru/index.php/Статья:Большие_данные_в_электронной_коммерции)

5. Литвин В. В., Висоцька В. А., Кучковський В. В., Оливко Р. М. Архітектура інформаційної системи інтеграції та формування контенту про криптовалюту на основі аналізу діяльності бірж

ARCHITECTURE FOR THE INFORMATION SYSTEM OF THE CRYPTOCURRENCY CONTENT INTEGRATION AND FORMATION ON THE BASIS OF THE EXCHANGE ACTIVITY ANALYSIS

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Cryptocurrency is a type of currency that allows to transfer coins from one client to another without intermediaries using an open key as a purse address and a private key to access an open address. Cryptocurrency is divided into bitcoin and altcoins, derivative fork of bitcoin with its own peculiarities. There are many doubts that bitcoin will hold its leadership position among investment tools. Fortunately, for all depositors, miners and speculators a great future is predicted for bitcoin associated with its growth, as well as integration with fiat payment systems. If one relies only on the experience of using, bitcoin has a great future. This type of financial system has a number of positive sides, namely: the status of world currency; bitcoin became a competitor of the traditional currency; high transaction speed; lack of ability to forge coins; lack of inflation. Therefore, nowadays it is relevant to develop various information approaches to the cryptocurrency and the updating of the mechanisms of integration and the formation of content taking into account the cryptocurrency needs of the user. Web resources for providing cryptocurrency services contain information about bitcoins and altcoins, such as: exchange rates, trading exchange information, ISO announcements, services of researcher unit. There is not so much in the Internet as about other subjects. But mostly, such sites often encounter outdated information. To get a complete picture of the creation of the service it is required to take into account many nuances during the development and, in order not to fail, it is necessary to analyze a large number of websites on the subject, as well as to learn the principles of the structure and features of bitcoin and his forks.

From the above listed peculiarities of the known web resources for the provision of cryptocurrency services, the corresponding system of integration and content formation taking into account the crypto-consumer needs of the user should support the following processes:

- automatic collection of courses via API;
- analysis of current information on trading exchanges;
- analysis of the results of the subscription to the exchange rates;
- prediction of the course on human behavior;
- optimization for search engines;
- aggregation of data from social media;
- the creation of a warrant book for sale and purchase;
- analysis of the characteristics and features of cryptocurrency;
- support for an open API for integration of the system with other systems.

The main tasks of such a system are:

- aggregation of information from the API cryptocurrency trading exchanges;
- aggregation of information from social media;
- aggregation of data from exchange systems;
- cryptocurrency data, features and characteristics;
- sorting of courses, warrants, purchase and sale transactions;
- time markers at the time of the beginning and the end of the bidding and the volume of the bidding;
- functionality for adding exchangers and new coins;

- search by coins, trading exchanges and exchangers;
- graphs for course fluctuations over a certain period of time;
- selection of news imported from social media;
- e-mail newsletter about fluctuations of rates and selected information for the user according to interests on the subject of cryptocurrency;
- preservation of the course historical changes, historical minima and maxima;
- forecasting based on people posts;
- forecasting based on the trend;
- forecasting of the course correction;
- open API for developers;
- export of data to social networks via hashtags;
- multilingual service;
- having feedbacks for problem solving

The given general architecture of the intellectual system of integration and formation of the content with consideration of cryptocurrency needs of the user is proposed. The basic functional services of such a system are determined. Examples of services that perform similar functions of working with crypto currency are presented and analyzed. The described prototype of the developed intellectual system is described. The general structure of the intellectual information system is constructed. The basic requirements for the development of similar systems are developed. The main functions of the system are described, graphical examples of system design are given, the main principles of forecasting are described and the system is put into operation.

Key words: cryptocurrency, stock exchange, intellectual data analysis, forecasting, bitcoin, token.

1. *Bitcoin: A Peer-to-Peer Electronic Cash System [Электронный ресурс] / Mode of access: <https://bitcoin.org/bitcoin.pdf>.* 2. *Valey Dzh. PHP 5 dlya chaynikov / Dzhanel Valey D.* – M.: Vil'yams, 2006. – 320 p. 3. *Gerasevich V.A. Blogi i RSS: Internet-tehnologii novogo pokoleniya.— SPb.: BKHV-Peterburg, 2006. – 256 p.* 4. *Zakaz N. JavaScript dlya professional'nykh Veb-razrabotchikov / Nikolas Zakas.* – SPb: Piter, 2015. – 330 p. 5. *Zandstra M. PHP: objekty, shablony i metodiki programmirovaniya / Mett Zandstra.* – M.: Vil'yams, 2015. – 576 p. 6. *Lengstorf Dzh. PHP i jQuery dlya professionalov / Dzheyson Lengstorf.* – M.: Vil'yams, 2011. – 334 p. 7. *Lengstorf Dzh. Iskusstvo obshcheniya v Internet. Kratkoye rukovodstvo / Dzheyson Lengstorf.* – M.: Vil'yams, 2011. – 334 p. 8. *Nikson R. Sozdayem diyeticheskiye Web-sayty s pomoshch'yu PHP, MySQL, JavaScript, CSS i HTML5 / Robin Nikson.* – SPb.: Piter, 2013. – 560 p. 9. *Osnovni pravyla pobudovy semantychno vidkrytykh informatsiynykh system / Zhezhnych P. I., Kravets R. B., Pasichnyk V. V., Peleshchyshyn A. M. // Visnyk Nats. un-tu "Lvivska politekhnika". – Lviv, 1999. – №383: Informatsiyni systemy ta merezhi. – P. 84–95.* 10. *Peleshchyshyn A. M. Pozytsionuvannya saytiv u hlobal'nomu informatsiynomu seredovyshchi / A.M.Peleshchyshyn.* – Lviv: Vyd-vo «Lvivska politekhnika», 2007. – 260 p. 11. *Prokhorenok N. HTML, JavaScript, PHP i MySQL. Dzhentl'menskiy nabor Web-mastera / Nikolay Prokhorenok, Vladimir Dronov.* – SPb.: BKHV-Peterburg, 2015. – 701 p. 12. *Reysig Dzhon. Sekrety JavaScript / Dzhon Rezig, Beer Bibo.* – M.: Izdatel'stvo «Manning Publications», 2013. – 416 p. 13. *Robbins Dzh. HTML5, CSS3 i JavaScript. Ischerpyvayushcheye rukovodstvo / Dzhennifer Niderst Robbins.* – M.: Izdatel'stvo «Eksmo», 2014. – 528 p. 14. *Frimen E. Izuchayem programmirovaniye na JavaScript / Erik Frimen, Elizabet Robson.* – SPb: Piter, 2015. – 640 p. 15. *Makkou A. Veb-prilozheniya na JavaScript / Aleks Makkou.* – SPb.: BKHV-Peterburg, 2012. – 875 p. 16. *Stoyan S. JavaScript. Shablony: / Stoyan Stefanov.* – M.: Simvol-Plyus, 2011. – 272 p. 17. *Flenagan D. JavaScript. Podrobnoye rukovodstvo / Devid Flenagan.* – M.: Simvol-Plyus, 2012. – 391 p. 18. *Methods based on ontologies for information resources processing : Monograph / [Vasyl Lytvyn, Victoria Vysotska, Lyubomyr Chyrun, Dmytro Dosyn] // LAP Lambert Academic Publishing, Saarbrücken, Germany. – ISBN-13: 978-3-659-89905-8, ISBN-10: 3659899054, EAN: 9783659899058. – 2016. – 324 p. – Access mode: <https://www.lap-publishing.com/catalog/details/store/gb/book/978-3-659-89905-8/methods-based-on-ontologies-for-information-resources-processing?locale=gb>.* 19. *Berko A.YU. Systemy elektronnoyi kontent-komertsiyi: monohrafiya / A.YU. Berko, V.A. Vysotska, V.V. Pasichnyk.* – Lviv: Vydavnytstvo Natsionalnoho universytetu «Lvivska politekhnika», 2009. – 612 p. 20. *Matematychna lingvistyka. [Knyha 1. Kvantyatyvna lingvistyka] : navch. posibnyk / [V. V. Pasichnyk, YU. M. Shcherbyna, V. A. Vysotska, T. V. Shestakevych] // Seriya «Kompyutyng». – Lviv : «Novyy svit -2000», 2012. – 359 p.* 21. *Vysotska V. A. Metody i zasoby opratsyuvannya informatsiynykh resursiv v systemakh elektronnoyi kontent-komertsiyi : avtoreferat dysertatsiyi na zdobuttya naukovooho stupenya kandydata tekhnichnykh nauk : 05.13.06 – informatsiyni tekhnolohiyi / Viktoriya Anatoliyivna Vysotska; Natsionalnyy universytet «Lvivska politekhnika». – Lviv, 2014. – 27 p.* 22. *Vysotska Victoria. Web Content Processing Method for Electronic Business Systems / Victoria Vysotska, Lyubomyr Chyrun // International Journal of Computers & Technology. – Vol 12, No 2. – December 2013. – P. 3211–3220. – ISSN 2277-3061. –*

[Online] <http://cirworld.org/journals/index.php/ijct/article/view/3299>. 23. Vysotska V.A. *Modelyuvannya etapiv zhyttyevoho tsykladu komertsynoho web-kontentu* / V. A. Vysotska, L. B. Chyrun, L. V. Chyrun // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv 2011. – No. 715. – P. 69–87.

24. Vysotska, V. A. *Osoblyvosti proektuvannya ta vprovadzhennya system elektronnoyi komertsyi*. / V. A. Vysotska // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv 2008. – No. 631. – P. 55–84.

25. Vysotska Victoria. *Analysis and evaluation of risks in electronic commerce* / Victoria Vysotska, Ihor Rishnyak, Lyubomyr Chyrun // *CAD Systems in Microelectronics, CADSM '07, 9th International Conference. – The Experience of Designing and Applications of CAD Systems in Microelectronics*. – Lviv, 24 February 2007. – P. 332–333.

26. Vysotska V. *Comprehensive method of commercial content support in the electronic business systems* / Victoria Vysotska, Lyubomyr Chyrun, Liliya Chyrun // *Kompyuterni systemy proektuvannya. Teoriya i praktyka, Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2013. – No. 777. – P. 21–30.

27. Berko A. *Content Formation Method in the Electronic Content Commerce Systems* / Andriy Berko, Victoria Vysotska, Lyubomyr Chyrun // *6th International Conference of Young Scientists "Computer Science & Engineering" (CSE-2013)*. – Lviv, Ukraine, November 21–23, 2013. – P. 174–179.

28. Vysotska V. *Uniform Method of Operative Content Management in the Electronic Content Commerce Systems* / Victoria Vysotska, Lyubomyr Chyrun, Liliya Chyrun // *6th International Conference of Young Scientists "Computer Science & Engineering" (CSE-2013)*. – Lviv, Ukraine, November 21–23, 2013. – P. 180–185.

29. Berko A.YU. *Metod formuvannya kontentu v systemakh elektronnoyi kontent-komertsyi* / A.YU. Berko, V. A. Vysotska, L. V. Chyrun // *Kompyuterni nauky ta informatsiyni tekhnolohiyi, Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – No. 751. – Lviv 2013. – P. 108–118.

30. Berko A.YU. *Modelyuvannya protsesiv opratsyuvannya informatsiynykh resursiv v systemakh elektronnoyi kontent-komertsyi* / A.YU. Berko, V. A. Vysotska, L. V. Chyrun // *Kompyuterni nauky ta informatsiyni tekhnolohiyi, Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2013. No. 771. – P. 126–135.

31. Vysotska V.A. *Unifikovanyy metod formuvannya informatsynoho produktu v systemakh elektronnoyi kontent-komertsyi* / V. A. Vysotska, L. B. Chyrun // *Naukovi pratsi Chornomorskoho derzh. Universytetu im. P. Mohyly : Komp'yuterni tekhnolohiyi*. – 2013. – Vyp. 217, Tom 229. – P. 91–101.

32. Vysotska V. A. *Unifikovani metody opratsyuvannya informatsiynykh resursiv v systemakh elektronnoyi kontent-komertsyi* / V. A. Vysotska, L. V. Chyrun, L. B. Chyrun // *Naukovi pratsi Chornomorskoho derzh. Universytetu im. P. Mohyly : Komp'yuterni tekhnolohiyi*. – 2013. – Vyp. 201, Tom 213. – P. 13–24.

33. Vysotska V. A. *Unifikovanyy metod operatyvnoho upravlinnya kontentom v systemakh elektronnoyi kontent-komertsyi* / V. A. Vysotska, L. V. Chyrun, L.B. Chyrun // *Kompyuterni nauky ta informatsiyni tekhnolohiyi, Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2013. – No. 751. – P. 118–128.

34. Vysotska V. A. *Osoblyvosti proektuvannya ta analiz uzahalnenoyi arkhitektury system elektronnoyi kontent-komertsyi* / V. A. Vysotska, L. V. Chyrun, L. B. Chyrun // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2013. – No. 770. – P. 83–101.

35. Berko A.YU. *Struktura zasobiv opratsyuvannya informat-siynykh resursiv v systemakh elektronnoyi kontent-komertsyi* / A.YU. Berko, V.A. Vysotska, L.V. Chyrun // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – No. 770. – Lviv 2013. – P. 12–21.

36. Shcherbyna YU. M. *Utvorennya ukraiyinskykh diyeprykmetnykiv za dopomohoyu porodzhivalnykh hramatyk* / YU. M. Shcherbyna, YU. V. Nikolskyy, V. A. Vysotska, T. V. Shestakevych // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2011. – No. 715. – P. 354–369.

37. Vysotska V. A. *Metod vyboru optymalnogo alhorytmu kryptohrafichnogo zakhystu informatsyi* / V. A. Vysotska, O. R. Harasym // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv 2010. – No. 673. – P. 220–233.

38. Shcherbyna YU. M. *Naukovyy napryam ta navchalna dystsyplina "Matematychna lingvistyka"* / YU. M. Shcherbyna, T. V. Shestakevych, V. A. Vysotska // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2010. – No. 673. – P. 384–393.

39. Chyrun L. V. *Zastosuvannya kontent-analizu tekstovoyi informatsyi v systemakh elektronnoyi komertsyi* / V.A. Vysotska, L. V. Chyrun // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv 2010. – No. 689. – P. 332–347.

40. Vysotska V. A. *Skhemy modelyuvannya system keruvannya kontentom* / V. A. Vysotska // *Informatsiyni systemy ta merezhi. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2010. – No. 689. – P. 90–108.

41. Vysotska, V. A. *Umovna entropiya ta entropiya poyednannya kontentu v systemakh elektronnoyi komertsyi*. / V.A. Vysotska // *Kompyuterni systemy proektuvannya. Teoriya i praktyka, Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2008. – No. 626. – P. 116–125.

42. Berko, A.YU. *Analiz i klasyfikatsiya modeley system elektronnoyi komertsyi* / A.YU. Berko, V. A. Vysotska // *Kompyuterni systemy proektuvannya. Teoriya i praktyka. Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – Lviv, 2007. – No. 591. – P. 103–112.

43. Berko A. YU. *Metody ta zasoby otsinyuvannya ryzykiv bezpeky v informat-siynykh systemakh elektronnoyi komertsyi* / A. YU. Berko, V. A. Vysotska, I. V. Rishnyak // *Visnyk Natsionalnogo universytetu "Lvivska politekhnika"*. – 2007. – No. 591 : *Komp'yuterni systemy proektuvannya. Teoriya i praktyka*. – P. 81–87.

44. Vysotska, V.A. *Systema opratsyuvannya struktury elektronnoho pidruchnyka* / V.A. Vysotska // *Informatsiyni*

systemy ta mezzi. Visnyk Natsionalnoho universytetu "Lvivska politekhnika". – Lviv 2003. – No. 489. – P. 49–63.

45. Vysotska V. *Analytical methods for commercial web content processing of information resource in electronic business systems / Victoria Vysotska, Lyubomyr Chyrun // MEST Journal (Management Education Science & Society Technologie). – Vol. 2, No. 2. – P. 285–300 [Online]. – ISSN 2334-7171, ISSN 2334-7058 (Online), DOI 10.12709/issn.2334-7058. This issue: DOI 10.12709/mest.02.02.02.0. – Access mode: <http://mest.meste.org/R4.html>, http://mest.meste.org/MEST_2_2014/4_29.pdf, http://www.meste.org/mest/Archive/MEST_II_2_2.pdf.*

46. Vysotska V. *Features of the content-analysis method for text categorization of commercial content in processing online newspaper articles / Victoria Vysotska, Lyubomyr Chyrun // Applied Computer Science. ACS journal. – Volume 11, Number 1. – Poland, 2015. – ISSN 2353-6977 (Online), ISSN 1895-3735 (Print) – P. 5–19 [Online]. – www.acs.pollub.pl, <http://www.acs.pollub.pl/index.php/-current-issue/applied-computer-science-volume-11-number-1-2015.html>, <http://www.acs.pollub.pl/pdf/v11n1/2.pdf>.*

6. Кравець П. О. Ігрова модель системи з авторитарним прийняттям рішень

GAME MODEL OF THE SYSTEM WITH AUTHORITARIAN DECISION MAKING

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Modern distributed decision-making systems often have a hierarchical structure. A hierarchy is the placement of elements of the system in order from the higher to the lower level or rank. In hierarchical systems, decision-making functions are distributed between elements of a different level. An element of the average level of the hierarchy controls the lower-level elements that are in its direct subordination, and it is itself guided by a higher-level element.

Depending on the predominance of an individual or group method of decision-making, there are authoritarian, liberal and democratic decision-making systems.

Among the possible options for organizing hierarchical decision-making systems, separate authoritarian systems that can be effective when there is a need for rapid response in extreme conditions, for example in the military sphere, to resolve conflict and crisis situations.

Authoritarian systems are based on the unconditional submission of the authority of the head or authority. Decision making is carried out by the head of the highest level. The ability to make decisions at lower levels is limited. The decisions made at the upper levels of the hierarchy come at lower levels as directives that are not negotiable and enforceable. The stream of information is directed from the top to down. The control and evaluation of the quality of the work of the grassroots system of the system is carried out by the senior management.

Often decision-making by agents is carried out under conditions of incomplete information. Thus, the problem of decision-making at the upper level is less structured and formalized, containing many uncertainties. A higher-level subsystem may not fully understand the goals and limitations of the subsystems of the lower levels. In authoritarian systems, managers and sub-units of the lower levels are only acquainted with their functional tasks and do not always have an idea of the general purpose of the system.

The smooth operation of hierarchical systems is ensured by the coordination of the actions of all decision-makers. The purpose of the hierarchical system is to develop a coherent collective solution. Adoption of coordinated solutions in hierarchical systems is an actual scientific and practical problem, the solution of which is aimed at preventing the occurrence of chaotic operating modes, ensuring the resilience to external factors, improving the reliability of work, increasing the accuracy and efficiency of solutions, reducing the cost of organizing the management of the hierarchical system.

In the process of collective decision-making in the hierarchical system, there are conditions for the emergence of an agreed or competitive state, which is the subject of the study of the theory of games, and under conditions of uncertainty, the theory of stochastic games. Theoretical game simulation is the main method of research of hierarchical systems. It allows predicting the behavior of game agents and choosing management methods that translate the system into optimal states in accordance with the specified performance criteria. The global goal of the hierarchical system is to develop a coherent collective solution. To simulate hierarchical decision-making systems, they use games in normal form or hierarchical games.

Games in the normal form are characterized by the simultaneous selection of actions by all players and the independence of the choice of one player's action from the choice of others. Instead, in the hierarchical games, a central player who makes the first move, and players who choose their actions based on the well-known action of the center.

Solutions of the game in the normal form satisfy the conditions of collective optimality or equilibrium, for example, on Pareto or Nash. Solutions of hierarchical games with the right of the first turn of the root player are described by equilibrium on Stackelberg.

In the conditions of incomplete information on the choice of solution options and their consequences, it is necessary to use adaptive game techniques that, in the process of self-study, compensate for the uncertainty of the parameters by their stochastic identification. The object of this study is the processes of game decision making in authoritarian systems that function in conditions of uncertainty.

The subject of research is the game model of decision making in hierarchically organized authoritarian systems.

The purpose of the work is to solve the stochastic game of agents to make a coherent solution in a hierarchical authoritarian system and to determine the factors of the convergence of the game method under uncertainty.

To solve the problem of hierarchical decision-making under uncertainty, a self-learning game method based on stochastic approximation of the complementary slackness condition was developed. To ensure convergence, the parameters of the method must satisfy the fundamental conditions of stochastic approximation.

The model and method of solving a stochastic game developed in this work provide a coherent decision-making process in authoritarian hierarchical systems. Coordination of player strategies is achieved during the process of solving a stochastic game based on the collection of current information and its adaptive elaboration.

The efficiency of decision-making in the authoritarian hierarchical system is controlled by the characteristic functions of average losses, the coefficient of the agreed solutions, and the Euclidean norm of deviation of the dynamic mixed strategies of players belonging to different levels of the system hierarchy. The decline of the average loser function, the growth of the coefficient of agreed decisions, and the reduction of the norm of rejection of mixed strategies indicates a convergence of player strategies.

The dimensionality of the task and the parameters of the game method affect the convergence rate of the stochastic game. Optimization of the parameters of the game method taking into account the restrictive conditions of stochastic approximation provides close to 1 order of convergence rate. The probability of the results is ensured by averaging the convergence of the game in a series of experiments with different sequences of random variables.

The findings of the research can be used to construct hierarchical decision-making systems with an authoritarian style of management, effective in emergency and crisis situations.

Key words: hierarchical system, authoritarian decision-making, stochastic game, uncertainty conditions.

1. Дубовой В. М. *Моделі прийняття рішень в управлінні розподіленими динамічними системами: монографія* / В. М. Дубовой, О. О. Ковалюк. – Вінниця: УНІВЕРСУМ, 2008. – 185 с.
2. Verma D. *Decision Making Style: Social and Creative Dimensions* / D. Verma. – Global India Publications Pvt Ltd, 2009. – 309 pp.
3. Воронин А. А. *Оптимальные иерархические структуры* / А. А. Воронин, С. П. Мишин. – М.: ИПУ РАН, 2003. – 210 с.
4. Саати Т. *Принятие решений. Метод анализа иерархий* / Т. Саати. – М.: Радио и связь, 1993. – 320 с.
5. Пушкар Р. М. *Менеджмент: теорія і практика: підручник* / Р. М. Пушкар, Н. П. Тарнавська. – Тернопіль: Карт-блани, 2003. – 490 с.
6. *Теорія і практика прийняття управлінських рішень* / А.С. Крупник, К.О. Линьов, Є. М. Нужний, О. М. Рудик. – К.: Видавничий дім „Простір”, 2007. – 119 с.
7. Демидова Л. *Принятие решений в условиях неопределенности* / Л. Демидова, В. Кираковский, А. Пылькин. – М.: Горячая линия – Телеком, 2015. – 284 с.
8. Катренко А. В. *Механізми координації у складних ієрархічних системах* / А. В. Катренко, І.В.Савка / *Інформаційні системи та мережі: Вісник НУ “Львівська політехніка”*. – 2008. – № 631. – С. 156–166.
9. Peters H. *Game Theory: A Multi-Leveled Approach* / H. Peters. – Springer-Verlag Berlin Heidelberg, 2015. – 493 pp.
10. Мулен Э. *Теория игр с примерами из математической экономики* / Э. Мулен. – М.: Мир, 1985. – 200 с.
11. Гермейер Ю. Б. *Игры с противоположными интересами* / Ю. Б. Гермейер. – М.: Наука, 1976. – 328 с.
12. Губко М. В. *Теория игр в управлении организационными системами* / М. В. Губко, Д. А. Новиков. – М.: Синтез, 2002. – 148 с.
13. *Stochastic Games and Application* / Neuman A., Sorin S. (editors), NATO Science Series, Springer Science & Business Media New York, 2003. – 473 pp.
14. Доманский В.К. *Стохастические игры* / Доманский В. К. // *Математические вопросы кибернетики*. – 1988. – № 1. – С. 26–49.
15. Fudenberg D. *The Theory of Learning in Games* / D. Fudenberg, D.K. Levine. – Cambridge, MA: MIT Press, 1998. – 292 pp.
16. Назин А. В. *Адаптивный выбор вариантов* / А. В. Назин, А. С. Позняк. – М.: Наука, 1986. – 288 с.
17. Кравець П. О. *Ігрова модель прийняття рішень в ієрархічних системах* / П. О. Кравець // *Інформаційні системи та мережі: Вісник НУ “Львівська політехніка”*. – 2017. – № 872. – С. 111–120.
18. Граничин О.Н. *Введение в методы стохастической аппроксимации и оценивания: Учеб. пособие* / О.Н. Граничин. – СПб.: Изд-во С.-Пб. ун-та, 2003. – 131 с.

7. Лобур М. В., Шварц М. С., Стех Ю. В. Моделі і методи прогнозування рекомендацій для колаборативних рекомендаційних систем

MODELS AND METHODS FOR FORECASTING RECOMMENDATIONS FOR COLLABORATIVE RECOMMENDER SYSTEMS

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In recent decades there has been a significant increase in information in the world's information space. The widespread introduction of Internet technologies in all areas of public life, the availability of information, requires the development of new methods of information seeking. The search engines Google, Yahoo, Altavista do not take into account the personalization of information. Recommendation systems are systems that work with a certain type of information, a filter system that recommends information items that may be of interest to the user. A typical advisory system accepts user recommendations as input, aggregates and sends them to the appropriate recipients in the form of recommendations. This technology allows users to spend minimum time to find the right information on the Internet.

The most widespread use has now been acquired by collaborative reference systems. The main idea of collaborative filtration algorithms is to offer new elements for a particular user based on previous user preferences or thoughts of other user-like users.

The important tasks of the development of advisory systems currently include: increasing the accuracy of forecasting recommendations; solution to the problem of the influence of the dissipation and the dimension of the matrix user-subject on the accuracy of prediction recommendations; solving the problem of a new user and a new subject.

Recently, considerable attention of researchers has been devoted to the development and research of methods of group collaborative recommendation. In many cases, giving advice to user groups is more appropriate than providing recommendations for individual users.

The article analyzes the group method of collaborative recommendation. To increase the accuracy of prediction recommendations, it is proposed to extend the vector of the numerical rating profile of the user by introducing the demographic categorical attributes of the user. The method of mixed categorical-numerical clusterization is developed, which allows determining the number and position of cluster centers automatically. The definition of cluster areas is carried out by determining the density of the categorical-numeric vector of user profiles. Determining the position of cluster centers is performed by calculating distances between clusters. The final definition of clusters is done using the density scan method or by clustering objects by calculating the distance from each object to the cluster center. The hybrid method of searching for user groups has been developed, which includes the method of numerical non – hierarchical clusterization, the method of mixed categorical – numerical clusterization, the two-stage method of clusterization. The two-stage method carries out categorical clustering in the first stage, at the second stage numerical clustering. The choice of the method of clusterization is carried out by means of calculating the degree of dissipation of the matrix of the user-object. Rare threshold values appear for each method. At low rarity the method of numerical non-hierarchical clusterization is used, with the mean value of the rarity the method of mixed categorical-numerical clusterization is used, with a high degree of rarity, a two-stage method of clusterization is used. Categorical clustering is carried out with the help of the modified method ROCK.

1. J. A. Konstan *Recommender systems: from algorithms to user experience* / J. A. Konstan J. A. // *User Modeling and User-Adapted Interaction*. – 2012 –Vol. 22. – No. 1–2. – P. 101–123. 2. Schafer J.B. *E-Commerce Recommendation Applications* / J. B. Schafer J. B., J. A. Konstan, J. Riedl // *Data Mining and Knowledge Discovery*. – 2001. – Vol. 5. – No. 1–2. – P. 115–123. 3. Sarwar B. *Analysis of recommendation algorithms for e-commerce* / B. Sarwar, G. Karypis, J. Konstan, J. Riedl // *In Proceedings of the 2nd ACM conference on Electronic.*— Minnesota, USA – October 17–20, 2000. – P. 158–167. 4. Pu P, Chen L, Hu R. *A user-centric evaluation framework for recommender systems* / P. Pu, L. Chen, R. Hu // *In: Proceedings of the fifth ACM conference on Recommender Systems (RecSys'11)*, ACM.— New York, NY, USA. – 2011. – P. 57–164. 5. як 2. 6. Candillier L. *Comparing State-of-the-Art Collaborative Filtering Systems.* / L. Candillier, F. Meyer, M. Boullé. // *In Proceedings of the 5th International Conference on Machine Learning and Data Mining in Pattern Recognition, LNCS*. – Vol. 4571. – 2007. – P. 548–562. 7. Su X., Khoshgoftaar T. M. *A survey of collaborative filtering techniques* / X. Su, T. M. Khoshgoftaar // *Adv. Artif. Intell.* — Vol. 4571. – 2007 – P. 1–19. 8. Isinkaye F. O. *Recommendation systems: Principles, methods and evaluation* / F. O. Isinkaye F. O., Y. O. Folajimi, B. A. Ojokoh // *Egyptian Informatics Journal*. – Vol. 16. – 2015. – P. 261–273. 9. Das D. *A Survey on Recommendation System* / D. Das, L. Sahoo, S. Datta // *International Journal of Computer Applications*. – Vol. 160. – No. 7. – 2017. – P. 6–10.

10. Bobadilla J. *Recommender systems survey* / J. Bobadilla, F. Ortega, A. Hernando, A. Gutiérrez // *Knowledge-Based Systems*. – Vol. 46. – 2013. – P. 109–132. 11. Resnick P., Varian H. R. *Recommender systems* / P. Resnick, H. R. Varian // *Communications of the ACM*. – Vol. 40. – 1997. – P. 56–58. 12. G. Adomavicius, A. Tuzhilin *Toward the next generation of recommender systems: a survey of the state-of-the-art and possible extensions* / Adomavicius G., Tuzhilin A. // *IEEE Transactions on Knowledge and Data Engineering*. – Vol. 17. – 2005. – P. 734–749. 13. Jameson A., Smyth B. *Recommendation to groups* / Jameson A., Smyth B. // *In The adaptive web: methods and strategies of web personalization*. – 2007. – P. 596–627. 14. Konstan J. *GroupLens: applying collaborative filtering to usenet news*. / J. Konstan, B. Miller, D. Maltz, J. Herlocker, L. Gordon, J. Riedl // *Commun. ACM* – Vol. 40. – No. 3. – 1997. – P. 77–87. 15. J. Masthoff *Group modeling: selecting a sequence of television items to suit a group of viewers* / J. Masthoff // *User Model. User-Adap. Inter.* – Vol. 14. – No. 1. – 2004 – P.37–85. 16. L. Boratto, S. Carta, “*State-of-the-art in group recommendation and new approaches for automatic identification of groups*,” / L. Boratto, S. Carta // *In Information Retrieval and Mining in Distributed Environments*. – vol. 324. – Springer Berlin Heidelberg – 2011. – P. 1–20. 17. Guha S. *Rock: A robust clustering algorithm for categorical attributes* / S. Guha, R. Rastogi, K. Shim // *Information Systems*. – vol. 25, No. 5. – 2000. – P. 345–366.

8. Андруник В. А., Шестакевич Т. В., Пасічник В. В., Кунанець Н. Е. Інформаційні технології навчання учнів з аутизмом

INFORMATION TECHNOLOGY FOR STUDENTS WITH AUTISM

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Early detection of the peculiarities of psychophysical development enables to improve the development of a child, which is of exceptional importance for children with disorders of the nervous system, such as autism. In the DSM-5 classification system used in the United States, all diagnoses related to autism are proposed to be replaced by the term Autism Spectrum Disorder. The autism spectrum disorder is a common term used to group some disorders of the brain, including autistic disorders, Asperger's syndrome, disintegration children disorder, and other widespread developmental disorders, including intellectual. The autistic disorders are characterized by the violation of social communication and interaction, as well as limited and repetitive behavior. Education for children with special needs is considered one of the best ways of their socialization.

The designing and application of information and communication technologies for the educational needs of people with autism should take into account the special features of such students. Children with autism feel comfortable while *communicating* with modern gadgets and other technological devices, and the use of modern information technologies for teaching such children makes it possible to use topical developments in the IT industry to improve the socialization of a person with special needs. For information technology designers, who produce ITs to educate children with autism, it is necessary to use the principles of accessibility and usability of web content, for example, as in the ISO/IEC40500: 2012 standard, and proposed in Universal Design for Learning methodology, etc.

Technologies for autistic child training are classified according to the skills that these technologies are designed to develop or adapt: those that support communication skills, social skills and traditional (academic) learning. About a quarter of autistic people have limited communicative skills or have lack of them, so there are many information technologies, that allow people with autism to communicate while using gestures, graphic symbols, and speech. The ITs to support alternative communication were developed, *Picture Exchange Communication System (PECS)* and *Voice Output Communication Aids (VOCAs)*, as well as specialized applications based on The iPad and other mobile technologies. An even greater level of visualization can be achieved by using PECS with the augmented reality, which enables the creation of virtual learning environments for students with autism to improve the work of gestures and understanding the tasks requirements.

The authors examined the information and communication technology paradigm used in the world to support the teaching of autistic children. In such children teaching, it is advisable to use innovative techniques that use assistive learning technologies such as personal computers, mobile and communication devices (smartphones, tablets, etc.) with appropriate software applications, robots, glasses of augmented, virtual or mixed reality, other technologies that help students with autism to learn and become more confident.

The most promising technologies for supporting the teaching of children with autism include technology of augmented and virtual reality. Such technologies make it possible to create environments where students with autism

can study and re-perform various tasks in a comfortable communication environment. To recreate various social situations, the avatars were developed in such technologies, and such technologies give an opportunity to study with a virtual teacher.

The proposed classification of information and communication technologies to support the training of students with autism considers the peculiarities of psychophysical development of such students. Future **research** areas include developing a methodology for designing and evaluating technologies developed for the needs of students with autism.

Key words: information technologies, autism, social skills, traditional education, augmented alternative communication, augmented/virtual reality

1. *Diagnostic and Statistical Manual of Mental Disorders*.- Available online: <https://www.psychiatry.org/psychiatrists/practice/dsm>.
2. Проблема аутизму в сім'ї і Україні.- Режим доступу: <http://autism.in.ua/uk/proautism/uamir>.
3. Takeo, T. *Development application softwares on PDA for autistic disorder children* / Takeo, T.; Toshitaka, N.; Daisuke, K. // *IPJS SIG Tech. Rep.* – 2007. – No. 12. – P. 31–38;
4. *The Technology That's Giving Students With Autism a Greater Voice.* – Available online: https://www.huffingtonpost.com/2015/04/20/teaching-technologyautism_n_6865030.html.
5. *Rita Jordan Educational Interventions for Children with Autism : A Literature Review of Recent And Current Research* / Rita Jordan, Glenys Jones, Dinah Murray. – Available online: <http://dera.ioe.ac.uk/15770/1/RR77.pdf>.
6. Powell S. *The use of computers in teaching people with autism*/ Powell S. // *In Autism on the Agenda: Papers from a National Autistic Society Conference (NAS '96).* – London, 1996.
7. Nuria Aresti-Bartolome, Begonya Garcia-Zapirain *Technologies as Support Tools for Persons with Autistic Spectrum Disorder*/ Nuria Aresti-Bartolome, Begonya Garcia-Zapirain // *A Systematic Review. Internat. Journal of Environmental Research and Public Health.* – Available online: www.mdpi.com/journal/ijerph.
8. Dolic J. *Evaluation of ainstream tablet devices for symbol based AAC communication* / Dolic J., Pibernik J., Bota J. // *Agent and multi-agent systems. Technologies and applications* / G. Jezic, M. Kusek, N.- T. Nguyen, R. J. Howlett, & L. C. Jain (Eds.).- Berlin; Heidelberg: Springer, 2017. – P. 251–260.
9. *App Wheel.* – Available online: <https://dart.ed.ac.uk/app-wheel-update/>;
10. *Design and development of VR learning environments for children with ASD* / Yiyu Cai, Ruby Chiew, Zin Tun Nay, Chandrasekaran Indhumathi & Lihui Huang // *Journal Interactive Learning Environments.* – 2017. – Volume 25, Issue 8. – P. 25–29.
11. *ROBOTS4AUTISM RESEARCH.*- Available online: <https://robots4autism.com/what/research/>.
12. *Augmented reality social story for autism spectrum disorder* / M. F. Syahputra, D. Arisandi, A. F. Lumbanbatu, L. F. Kemit, E. B. Nababan, O. Sheta // *2nd International Conference on Computing and Applied Informatics. 2017 IOP Publishing IOP Conf. Series: Journal of Physics: Conf. Series 978.* – 2018. – P. 120.
13. *The State of Virtual and Augmented Reality Therapy for Autism Spectrum Disorder (ASD)* / Sinan Turnacioglu, Joseph P. McCleery, Julia Parish-Morris, Vibha Sazawal and Rita Solorzano // *Virtual and Augmented Reality in Mental Health Treatment, IGI Global. Publication forthcoming.*- Available online: <https://www.igi-global.com/.../the-state-of-virtual-and-augmented-reality-therapy-for-aut>.
14. *Sue Fletcher-Watson ATargeted Review of Computer-Assisted Learning for People with Autism Spectrum Disorder* / Sue Fletcher-Watson // *Towards a Consistent Methodology. Rev J Autism Dev Disord.* – Available online: <https://link.springer.com/article/10.1007/s40489-013-0003-4>.
15. *Mobile Technology for Students & Adults with Autistic Spectrum Disorders (ASD)* / Jenny A. Vlachou, Athanasios S. Drigas . – Available online: https://www.researchgate.net/.../313233395_Mobile_Technology_for_Students_Adults.
16. *ЭКСИПТЫ ПЛО MICROSOFT HOLOLENS.* – Available online: <https://www.holo.group/>.
17. *To Disrupt The Paradigm of Education.* – Available online: <http://www.holo.study/>;
18. *Parsons S. Virtual environments for social skills training: Comments from two adolescents with autistic spectrum disorder* / S. Parsons, Leonard A., Mitchell P. // *Comput. Educ.* – 2006. – No. 47. – P. 186–206;
19. *Effectiveness of the PECS Phase III app and choice between the app and traditional PECS among preschoolers with ASD* / Jennifer B. Ganz, Ee ReaHong, Fara D. Goodwyn // *Research in Autism Spectrum Disorders.* – 2013. – Vol. 7, Issue 8, August. – P. 973–983.
20. *Effectiveness of Virtual Reality for Children and Adolescents with Autism Spectrum Disorder: An Evidence-Based Systematic Review* / Patricia Mesa-Gresa, Hermenegildo Gil-Gómez, José-Antonio Lozano-Quilis and José-Antonio Gil-Gómez // *Sensors (Basel).* – 2018. – No. 18(8). – P. 2486.
21. *F. Ke. Virtual-Reality-Based Social Interaction Training for Children with High-Functioning Autism* / Fengfeng Ke, Tami Im // *The Journal of Educational Research J. Educ. Res.* – 2013. – No. 106. – P. 441–461.
22. *Using Augmented Reality to Elicit Pretend Play for Children with Autism* / Zhen Bai, Alan F. Blackwell, G. Coulouris, G. Coulouris // *Transactions on Visualization and Comp. Graphics.* – 2015. – No. 21(5). – P. 598–610;
23. *Using the social robot probo as a social story telling agent for children with ASD* / B. Vanderborgh, R. Simut, J. Saldien, C. Pop, A. S. Rusu, S. Pintea, D. Lefeber and D. O. David // *Trans Neural Syst Rehabil Eng.* – 2013. – No. 21(2). – P. 10.

9. Мельник М., Керницький А., Рубаха Я., Камісінські Т. Розроблення конвертера 3D-моделей приміщень з системи SketchUP в систему Catt-Acoustic

DEVELOPMENT OF THE 3D PREMISES MODELS CONVERTER FROM THE SKETCHUP INTO THE CATT-ACOUSTIC SYSTEM

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There are many systems for modeling acoustic parameters of indoor premises on the software applications market. The Catt -Acoustic system is one of such systems. The model of the room in the Catt-Acoustic system is constructed parametrically, building the coordinates on the first stage, and then the coordinates are combined into the plane. This way of constructing models is rather complicated, because it requires a good spatial imagination and programming skills. That is why the task was set to find a way to simplify the construction of models for the Catt-Acoustic system using visual design systems. In an attempt to find a suitable tool for designing 3D-models of premises for the purpose of their subsequent export to the Catt-Acoustic system, a number of systems for 3D-modeling have been analyzed and it has been found that the SketchUP system is a good candidate as it is an easy-to-use tool with a simple and intuitive interface. The feature of this system is that the way 3D objects are processed inside the SketchUp application is similar to that of the Catt-Acoustic system. That is why, in the next step, the task was to develop a method of converting premises models, which should enable the export of complex models of premises from the SketchUP system to the input file of the Catt-Acoustic system.

For more automation of the process of constructing indoor models, it was proposed to transfer information about the materials used when exporting models from the SketchUP system to the CattAcoustic system. By developing a library of materials with their sound absorbing and sound-scattering properties, we would be able to automatically set their acoustic properties when generating an input file for the Catt-Acoustic system. The proposed method searches the titles of the used materials in the SketchUP system against the database of the materials integrated into the converter and, based on the found matches, generates a code for the Catt-Acoustic system with the specified sound absorption, sound-scattering and also set a corresponding color. The main idea of the method is creating a library of materials and its constant expansion, where the names of materials in the library must correspond to the names provided by the converter. In order to implement the automatic determination of the sound absorption coefficients of materials, it is necessary to set the base of the absorption coefficients of frequently used materials in the converter.

The converter provides error checking. If at least one of the points of the plane is used as the point of another plane, then the surface is modeled correctly. This means that the surface is not an internal surface. If no point (coordinate) of the plane is used in another plane, then this plane is an inner surface. The converter will turn this model into a Catt-Acoustic system, but will display a warning in the form of a dialog that will contain messages and coordinates of the points of the surfaces that may cause errors in the Catt-Acoustic system. The article presents an algorithm for implementation of the method and a block diagram, on the basis of which the software of the converter in the language of Ruby is implemented.

The article also presents the results of testing the developed converter on a complex model. Such a model can be built in the SketchUP system very quickly, but to write a program for such a model in the Catt-Acoustic system will be several times more. Test results confirm that the developed converter works even on complex geometric models of premises and can be used for converting any models of premises from the system SketchUp to the system Catt-Acoustic.

The result of the presented work is the converter of models of premises from the system SketchUP into the system Catt-Acoustic to study their acoustic characteristics. The converter implements the method of automatic determination of sound absorption and scattering coefficients, which allows to significantly increase the efficiency of the converter and reduce the time spent on the construction of indoor models.

Keywords – Converter, SketchUP, Catt-Acoustic, sound absorption coefficient, interior acoustic properties.

1. Dalenback, B. I. "CATT-Acoustic v9. 0c User's Manual." 2012. 2. Dalenbäck, B.I.L. "CATT-Acoustic v9 powered by TUCT use manuals." *Computer Aided Theatre Technique* 2011. 3. Chopra A. *Introduction to google sketchup*. John Wiley & Sons, 2012. 4. Scarpino M. *Automatic SketchUp: Creating 3-D models in ruby*. Eclipse Engineering LLC, 2010. 5. Mykhaylo MELNYK, Andriy KERNYSKY, Petro PUKACH *Development of subsystems for reverberation time definition in lecture auditorium. In: Experience of Designing and Application of CAD Systems in Microelectronics (CADSM), 2017 14th International Conference The. IEEE, 2017. p. 354–356.*

INTELLECTUAL ANALYSIS OF TRANSFORMATION PROCESS OF THE ALGEBRA ALGORITHM FORMULAS

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The purpose of the study is to determine the main ways of transforming the algebra algorithm formulas. The conducted research will allow to form a methodological basis for creation of editing systems and creation of editors of formulas of algorithms with the ability to work with a large number of formulas.

To achieve the goal, the following main tasks need to be addressed:

- to analyze the main types of transformations of algebra algorithm formulas;
- to develop an algorithm for transforming the algebra algorithm formulas;
- to analyze known systems with the ability to set and edit algorithm formulas.

The object of the research is the process of transforming the algebra algorithm formulas.

The subject of the research is the methods and means of editing algebra algorithm formulas.

The scientific novelty is in the study of the peculiarities of the transformation processes of the algebra algorithm formulas.

The practical value of the work is to develop an algorithm for transforming the algebra algorithm formula which provides the necessary means for a set of large-scale formulas.

The authors have developed a methodological basis for constructing a system for transforming the formulas of algebraic algorithms:

- the analysis of existing systems for the recruitment and editing of algorithm formulas is carried out. Well-known specialized systems have been analyzed.
- the analysis of algebra of algorithms on the peculiarities of constructing signs of specific operations has been carried out.

– the factors that have the greatest influence on the correct implementation of the transformation processes of the algebra algorithm formulas have been revealed.

– the algorithm of transformation of algorithm formulas has been developed. The conducted research has shown that in spite of the sufficient level of quality of the processes of recruiting and editing of algebra algorithm formulas, it is necessary to create an algorithm for the transformation of the algebra algorithm formula transformations. The factors are: the geometric dimensions of the embedded formulas at different levels, the preservation of the location of the transformed formulas of the algebra of algorithms for further memorization of the structure of the formula.

Results of the conducted research:

- a synthesis model of the process of transforming the formulas of abstract algorithms;
- a minimized model describes the process of transforming the formulas of abstract algorithms
- using the synthesized model of the process of transforming the formulas of abstract algorithms provides less time for manual correction of the formula after removing the term and more efficient usage of the development environment.
- an urgent task is the further transition from automatic simplification by removing the terms in the formula of the abstract algorithm to automatic simplification by evaluating the logical content of the formula of the abstract algorithm.
- an abstract algorithm for transforming the formulas of abstract algorithms describes the process of automatic transformation by removing terms in the formulas of abstract algorithms.

1. Ovsyak V. *Syntezy i doslidzennia alhorytmiv kompyuternykh system* / V. Ovsyak., O. Ovsyak, V. Brytkovskyi – Lviv, 2004. – 276 s. 2. Ovsyak V. *ALHORYTMY: metody pobudovy, optymizatsii, doslidzennia virogidnosti* / V. Ovsyak. – Lviv: Svit, 2001. – 160 s. 3. Ovsyak V. *Teoriya sekventsiinykh alhorytmiv i proektuvannia kompyuternykh system* // V. Ovsyak, Yu. Ovsyak, V. Brytkovskyi – Lviv: UAD, 2001. – 142 s. 4. Brytkovskyi V. M. *Modelyuvannia redaktora formul sekventsiinykh alhorytmiv. avtoref. dys. rob. k.t.n.* – Lviv: vydavnycho-poligrafichnyi viddil LvCNTEI. – 18 s. 5. Vasylyuk A.S. *Pryntsyp pobudovy pidsystemy redaguvannia formul abstraktnykh alhorytmiv* // A. Vasyliuk, V. Ovsyak. *Kompyuterni tekhnologii drukarstva.* – Lviv: UAD, – 2004. – No. 12. – S. 137–146. 6. Vasylyuk A. S. *Intelektualnyi analiz struktury danykh ta matematychnogo zabezpechennia redaktora formul alhorytmiv* // A. S. Vasylyuk – Lviv: Naz. un-t “Lvivska politekhnika”, 2015. – No. 832. – S. 34–48 7. Basyuk T. M. *Graph visualization in a heterogeneous environment by means of algebra algorithms* / T. M. Basyuk, A. S. Vasylyuk, *Science and Education a New Dimension. Natural and Technical Sciences.* – Hungary: Budapest – IV(10), Issue: 91, 2016. – 66–71 p.

PROJECT OF INFORMATION SYSTEM FOR THE RECOGNITION OF MATHEMATICAL EXPRESSIONS

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Unlike texts, printed or written mathematical expressions have a two-dimensional nature, and their recognition implies the recognition of the structure of the formula and of the symbols contained in it. There are many mathematical symbols, they can be very similar, and new symbols are being invented by scientists. The layout of expressions, however, is being evolved less.

Available OCR systems are good and high-quality products in their field of application. However, the specifics of the recognition of mathematical expressions require more specialized software. Character recognition is performed by classical OCR methods, for example, using methods of reference vectors, matching patterns. The analysis of the structure is mainly carried out using geometric considerations based on implicit rules or grammatical rules.

For the system of recognition of mathematical expressions, a graphical representation will be involved into the working process. It raises some problems, such as understanding the relationship between characters. They have a structure that is used for mathematical communication between people without computers. A mathematical expression is not just random symbols. They have a well-organized structure that is subject to the rules of the system of mathematical notation. The location of two symbols relative to each other conveys a certain meaning.

During the recognition, the format of the data is being changed. At the input a binary image is obtained, and at the output the interpretation of the expression must be gained. As a system entry, the binary image is selected. The segmentation algorithm reads the image and receives the related components from it. From the obtained components only restrictive rectangles are stored. The list of bounding rectangles is used to create a representation of the expression, which is a list of characters.

To find the relationship between characters and define character classes, the classification is performed. Several technologies of machine learning are used. Bayesian derivation carries a rude classification. Classification using the context is handled by artificial neural networks. Different classifiers work separately, but they are used together. They are related in order to return the optimal result.

A project of the system for the recognition of mathematical expressions using machine learning methods, such as neural networks and fuzzy logic was created. A binary image representing a mathematical expression is segmented, and the recognition is performed using the symbols' bounding boxes. An iterative algorithm using a multi-classifier system recognizes the structure and classifies the symbols.

The results showed that the context of a symbol, when it is known and used, can help classify the symbol. The structure recognition using a non-recursive algorithm with very few backtracking showed good results. The machine learning approach produced a flexible system, able to adapt to unknown symbols and writing styles, and to return confidence values for the recognition, rather than a clear interpretation.

The prototype of the experimental implementation of the intellectual system uses the frameworks (Weka and JLatexMath) and the database, which is implemented using MS Access. A graphical user interface has been created. It allows to quickly and easily use the expression recognition system.

Keywords – classification, classifier, symbol, structure, mathematical expression, machine learning.

1. *Optychne_rozpiznavannya_symboliv* [Electronic resource] – Available : https://uk.wikipedia.org/wiki/Optychne_rozpiznavannya_symboliv
2. *ABBYY FineReader 14* [Electronic resource] – Available: <http://www.abbyy.ua/ua/>.
3. *SimpleOCR* [Electronic resource] – Available: <https://www.simpleocr.com/>.
4. *Free OCR Software* [Electronic resource] – Available : <http://www.paperfile.net/>.
5. *Microsoft Office Document Imaging* [Electronic resource] – Available : https://ru.wikipedia.org/wiki/Microsoft_Office_Document_Imaging.
6. Antonacopoulos A. *Competition on Historical Book Recognition* / A. Antonacopoulos, C. Clausner, C. Papadopoulos, S. Pletschacher // *12th International Conference on Document Analysis and Recognition*. – 2013. – No. 12. – P. 1459–1463.
7. Potapov A. S. *Rospoznavanie obrazov i mashynnoe vospriyatie* / A. S. Potapov. – Sankt-Peterburg: Izdatelstvo "Politekhnika", 2007. – 548 s.
8. Zanibbi R. *Recognizing mathematical expressions using tree transformation* / R. Zanibbi, D. Blostein, J. Cordy // *IEEE Transactions on Pattern Analysis and Machine Intelligence*. – 2002. – No. 24. – P. 1455–1467.
9. Tapia E. *Recognition of on-line handwritten mathematical formulas in the e-chalk system* / E. Tapia, R. Rojas // *Seventh International Conference on Document Analysis and Recognition*. – 2003. – No. 7. – P. 980–984.
10. Zhang L. *Using fuzzy logic to analyze superscript and subscript relations in handwritten mathematical expressions* / L. Zhang, D. Blostein, Zanibbi R. // *Eighth International Conference on Document Analysis and Recognition*. – 2005. – No. 8. – P. 972–976.
11. Suzuki T. *Using fuzzy logic to analyze superscript and subscript relations in handwritten mathematical expressions* / T. Suzuki, S. Aoshima, K. Mori, Y. Suenaga // *Eighth*

International Conference on Pattern Recognition. – 2000. – No. 25. – P. 515–518. 12. Toyozumi K. A system for real-time recognition of handwritten mathematical formulas / K. Toyozumi, T. Suzuki, K. Mori, Y. Suenaga // *Sixth International Conference on Document Analysis and Recognition*. – 2001. – No. 6. – P. 1059–1063. 13. Lee H. Understanding mathematical expressions using procedure-oriented transformation / H. Lee, M. Lee // *Pattern Recognition*. – 1994. – No. 3. – P. 447–457. 14. Chang S. A method for the structural analysis of two-dimensional mathematical expressions / S. Chang // *Information Sciences*. – 1970. – No. 3. – P. 253–272. 15. Chaudhuri B. An approach for recognition and interpretation of mathematical expressions in printed document / B. Chaudhuri, U. Garain // *Pattern Analysis and Applications*. – 2000. – №2. – P. 120–131. 16. Tapia E. Recognition of on-line handwritten mathematical expressions using a minimum spanning tree construction and symbol dominance / E. Tapia, R. Rojas // *Graphics Recognition Algorithms and Applications*. – 2004. – (Lecture Notes in Computer Science). – P. 329–340. 17. Xiangwei Q. The study of structure analysis strategy in handwritten recognition of general mathematical expression / Q. Xiangwei, P. Weimin, Y. Sup, W. Yang // *International Forum on Information Technology and Applications*. – 2009. – No. 2. – P. 101–107. 18. Ha M. Structural analysis of printed mathematical expressions based on combined strategy / M. Ha, X. Tian, N. Li // *International Conference on Machine Learning and Cybernetics*. – 2006. – P. 2254–3358. 19. Y. Eto and M. Suzuki. Mathematical formula recognition using virtual link network / Y. Eto, M. Suzuki // *6th International Conference on Document Analysis and Recognition*. – 2001. – P. 762–767. 20. Rhee T. Efficient search strategy in structural analysis for handwritten mathematical expression recognition / T. Rhee, J. Kim // *Pattern Recognition*. – 2009. – No. 12. – P. 3192–3201. 21. Miller E. Ambiguity and constraint in mathematical expression recognition / E. Miller, P. Viola // *Fifteenth National Conference on Artificial Intelligence. Tenth Conference on Innovative Applications of Artificial Intelligence*. – 1998. – P. 784–791. 22. Chen Y. Fundamental study on structural understanding of mathematical expressions / Y. Chen, T. Shimizu, M. Okada // *Systems, Man, and Cybernetics*. – 1999. – P. 910–914. 23. Tian X.. Structural analysis of printed mathematical expression / X. Tian, S. Wang, X. Liu // *International Conference on Computational Intelligence and Security*. – 2007. – P. 1030–1034. 24. Garcia P. Using a generic document recognition method for mathematical formulae recognition / P. Garcia, B. Couasnon // *Graphics Recognition Algorithms and Applications*. – 2001. – (Lecture Notes in Computer Science). – P. 236–244. 25. Lavirotte S. Optical formula recognition / S. Lavirotte // *4th International Conference on Document Analysis and Recognition*. – 1997. – P. 357–361. 26. Awal A. Towards handwritten mathematical expression recognition / A. Awal, H. Mouchere, P. Viard-Gaudin // *10th International Conference on Document Analysis and Recognition*. – 2009. – P. 1046–1050. 27. Wang Z. Automatic perception of the structure of handwritten mathematical expressions / Z. Wang, C. Faure // *In Computer Processing of Handwriting*. – 1990. – P. 337–361. 28. Winkler H. A soft-decision approach for structural analysis of handwritten mathematical expressions / H. Winkler, H. Fahrner, M. Lang // *International Conference on Acoustics, Speech, and Signal Processing*. – 1995. – P. 2459–2462. 29. Genoe R. An online fuzzy approach to the structural analysis of handwritten mathematical expressions / R. Genoe, J. Fitzgerald, T. Kechadi // *IEEE International Conference on Fuzzy Systems* – 2006. – P. 244–250. 30. Aly W. Identifying subscripts and superscripts in mathematical documents. / W. Aly, S. Uchida, M. Suzuki // *Mathematics in Computer Science*. – 2008. – P. 195–209. 31. Bepec O. M. Selection of methods for searching some or similar images / Oleh Veres, Yaroslav Kis, Vladislav Kugivchak, Igor Ryshniak // *Informatsiyni systemy ta merezhi: [zb. nauk. pr.] / vidp. red. V.V. Pasichnyk*. – Lviv: Vyd-vo Lviv. politekhniki, 2018. – S. 43–50. – (Visnyk / Nats. un-t "Lviv. politekhnika"; No. 887). 32. Veres O., Rusyn B., Sachenko A., Rishnyak I. Choosing the method of finding similar images in the reverse search system // *CEUR Workshop Proceedings*. – 2018. – Vol. 2136: proceedings of the 2nd International conference on computational linguistics and intelligent systems. Lviv, Ukraine, June 25–27, 2018. Vol. 1. – P. 99–107. 33. Gamma E. *Methods of object-oriented design. Design Patterns*. St. Petersburg: Publishing House "Peter", 2007. – 366 p.

12. Досин Д. Г. Пертинентність інформації як цінність знань для інтелектуального агента

THE PERTINENCY OF INFORMATION AS THE VALUE OF KNOWLEDGE FOR AN INTELLECTUAL AGENT

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Science begins where there is a measurement, there is a measure of value and one can fix a certain fact. If we consider such a phenomenon as knowledge, then it is important for science to be able to measure it. Thanks to Claude Shannon's theory, we know how to measure information – 1 bits are taken as the unit of information. Obviously, knowledge is information, but it is also obvious that not all information is knowledge, The measure of knowledge is strictly subjective. There must be a subject who can apply this information to use it, that is, to literally benefit from it.

And this is an element of definition: knowledge is information that can be useful, that is, knowledge is a useful part of information. Useful for an intelligent agent, as an autonomous entity that can learn, which operates in some environment rationally for a certain purpose, using sensors, actuators and knowledge. And that is why some information for him can serve as knowledge, while the other does not promise any benefits. This benefit could be estimated as an expected utility within the framework of the theory of automatic planning – a section of the general theory of artificial intelligence, designed to build a model of rational behavior of the agent in various, including unfavorable conditions: insufficient information, uncertainty of the end goal, limited resources, etc. in their various combinations. Some of the model approximations may be useful for practical application. These may include partly observable Markov Decision Process (POMDP). In this model only possible future conditions, possible solutions in these states and likely results of such decisions are taken into consideration. In this case, information about the states – both running and future, not to mention the possible actions and predictive estimates of their results should be stored, accumulated and improved in some form of knowledge of the agent in a certain form (in a certain format). The choice of form (knowledge base architecture) and the format for representing knowledge about states and actions (decisions) is a particular actual serious problem. Without having a knowledge base that includes a calculated optimal behavior strategy, the agent can not evaluate the usefulness of new knowledge – the pertinence of a new portion of information, which in contrast to relevance, characterizes the usefulness of the information provided to the client by the information search service upon his request. The purpose of this article is to formulate ways of constructing tools for evaluating the pertinence of information in a given subject area.

In this article the methodological principles of estimation of information pertinence using expected value of perfect information are described, the basic concepts of involving of automated planning methods are formulated, the features and advantages of partly observable Markov decision process model is outlined. The example of application of the developed approach to the metal surface corrosion protection domain is discussed.

Key words: information pertinence, expected value of perfect information, automated planning, partly observable Markov decision process..

1. Shannon, Claude E. (July 1948). "A Mathematical Theory of Communication". *Bell System Technical Journal*. 27 (3): 379–423. 2. фон Нейман Дж., Моргеништерн Э. *Теория игр и экономическое поведение*. – М.: Наука, 1970. – 708 с. 3. Bernoulli, Daniel; Originally published in 1738; translated by Dr. Louise Sommer. (January 1954). "Exposition of a New Theory on the Measurement of Risk". *Econometrica. The Econometric Society*. 22 (1): 22–36; 4. Стратонович Р. Л. *Про цінність інформації* Р. Л. Стратонович // *Изв. АН СРСР: Технічна кібернетика*. 1965. № 5. С. 25–38. 5. Стратонович, Р. Л. *Теория информации* / Р. Л. Стратонович. М.: Сов. радио, 1975, 424 с.; 6. Бочуля Т. *Вартість інформації в обліковому вимірі: реалії теорії та практики* // *Бухгалтерський облік і аудит*. – 2013. – № 10. – С. 28–32. 7. Рассел С. *Искусственный интеллект* / С. Рассел, П. Норвиг. – М.: Вильямс, 2006. – 1408 с. 8. Malik G. *Automated Planning Theory & Practice* / G. Malik, N. Dana, P. Traverso – San Francisco : Morgan Kaufman, 2004. – 635 p.

13. Цимбал Ю. В. Нейромережевий метод симетричного шифрування даних

SYMMETRIC ENCRYPTION SCHEME BASED ON NEURAL NETWORK

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Technology of artificial neural networks is one of the current trends in the development of effective and reliable methods for cryptographic information security. Neural networks are distinguished by a variety of architectures and learning algorithms, as well as flexible settings, including for symmetric encryption tasks.

Feed-forward back propagation networks, recurrent networks, counter-propagation network and radial basis networks are among the well known variants of the neural networks used in this area. The common feature of these approaches is the use of iterative algorithms, which limits the possibility of their use in real-time data protection systems.

The purpose of the paper is to develop a method (scheme) for symmetric encryption based on neural networks with non-iterative training. The proposed method is based on the application of the feed-forward neural network architecture with lateral connections between the hidden neurons, which is trained on the basis of the paradigm "geometric transformations model" (GTM). The construction of a hyperplane with a given dimension in the input data space on a hidden layer is the specific feature of the GTM neural networks. This hyperplane approximates the set of input data with minimal variance (analogous to statistical principal component analysis) using of Gram-Schmidt

orthogonalization in the transition to a new basis. If you choose the number of vectors of the training set by 1 greater than the number of inputs, then the construction of a hyperplane with a dimension equal to the number of inputs provides an absence of residual variance (transformation error).

The use of two types of GTM networks of the above structure – encrypting neural network and decrypting neural network is at the core of the offered symmetric encryption method. It is supposed to form a symmetric key consisting of two equal parts. The first part (Key1) is fed to the input of the GTM neural network at the training stage. The network output at the training stage contains a data set for encryption. The second part (Key2) is applied to the input of the trained network at the testing stage. There should be no linear relationship between Key1 and Key2. The values at the output thus form a set of encrypted input data belonging to the hyperplane constructed at the training stage. When decrypting the part Key2 is fed to the input of the neural network at the training stage. The network output contains a set of encrypted data. At the same time, the hyperplane constructed during encryption, has been restored. Part Key1 is provided to the input of the trained network at the testing stage. The values at the output will be a set of decrypted input data.

The paper deals with the basic algorithm of training and testing of the GTM neural network and the features of the application of the offered symmetric encryption method on an example of raster images. Experiments on encryption and decryption of test half-tone images “Boy” and “Cat” with 8x8 pixels size were carried out. The test halftone images “Lena” and “Baboon” with 64x63 pixels size are selected as keys. The results of the experiments confirm the correctness of the offered method and the absence of correlation between original and encrypted data.

Key words: feed-forward neural networks, geometric transformation model.

1. Shihab K. *A backpropagation neural network for computer network security // Journal of Computer Science, Vol. 2, No. 9, 2006, pp. 710–715.* 2. Volna E., Kotyrba M., Kocian V., Janosek M. *Cryptography Based On Neural Network // Proceedings of the 26th European Conference on Modelling and Simulation, 2012, pp. 386–391.* 3. Arvandi M., Wu S., Sadeghian A., Melek W. W., Woungang I. *Symmetric cipher design using recurrent neural networks // Proceedings of the IEEE International Joint Conference on Neural Networks, 2006, pp. 2039–2046.* 4. Chan C. K., Chan C. K., Lee L. P. Cheng L. M. *Encryption system based on neural network // Communications and Multimedia Security Issues of the New Century, Springer, 2001, pp. 117–122.* 5. Sagar V., Kumar K. *A Symmetric Key Cryptographic Algorithm Using Counter Propagation Network (CPN) // Proceedings of the 2014 ACM International Conference on Information and Communication Technology for Competitive Strategies, 2014, p. 51.* 6. Zhou K., Kang Y., Huang Y., Feng E. *Encrypting Algorithm Based on RBF Neural Network // Proceedings of the IEEE Third International Conference on Natural Computation, Vol. 1, 2007, pp. 765–768.* 7. Tkachenko R., Tkachenko P., Izonin I., Tsybal Y. *Learning-based image scaling using neural-like structure of geometric transformation paradigm // Advances in Soft Computing and Machine Learning in Image Processing, Springer, 2018, pp. 537–565.*

Image Processing, Springer, 2018, pp. 537–565.

14. Литвин В. В., Рибчак З. Л., Завущак І. І. *Методи та засоби розвитку територіальної громади в напрямку ремонту доріг*

METHODS AND MEANS OF DEVELOPMENT OF TERRITORIAL COMMUNITIES IN THE DIRECTION OF REPAIRING ROADS

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Today, the issue of integration of settlements into the capable territorial communities is topical. On February 5, 2015, the Parliament of Ukraine approved the Law of Ukraine "On voluntary association of territorial communities", and for the formation of capable territorial communities the Methodology for the formation of capable territorial (Resolution of the Cabinet of Ministers of Ukraine No.214 dated April 8, 2015) was approved. Within the territorial community, there are important administrative buildings, hospitals, schools, etc. Therefore, getting to these establishments within the community is a significant problem, since 95 % of the roads in Ukraine are unsatisfactory. In order to effectively use the existing funds for road repairs, it is necessary to take into account the state of roads and the specifics of subordination of roads. Roads belong to 3 subsets: national subordination, regional subordination,

district subordination. Subordination determines for which budget this road will be repaired. As a rule, there are three budgets: the national budget, the regional budget, the budget of the territorial community. The state of the road determines the required cost for the repair of the corresponding road. As a rule, there are five classes:

- 1) visible minor defects and the need for repair up to 5%;
- 2) shelled, separate coating inequalities, partially present cracks and small potholes, repair need up to 25%;
- 3) soldering, sinks, landslides, subsidence, slightly pronounced track, destruction of the edges of the road surface, faces of concrete cover, borders, the need for repair up to 50%;
- 4) potholes, fissures, large pits, considerable distance, places of movement are much more complicated, the need for repair up to 75 %;
- 5) the basic type of coverage is practically absent, the apparent rigidity, the movement is much more complicated, the need for repair up to 100 %.

The task of efficient allocation of funds for modeling a road repair plan can be solved by modifying Prim's algorithm. Optimization and modification of Prim's algorithm was studied by McConnell J., Yevstigneev A., Svami M., Kopylova V., Titenko S., Bartish M. and others. Prim's algorithm gradually builds the desired minimal skeleton, adding to it one edge at each step. At the beginning of the algorithm, the resulting tree consists of one vertex (it can be chosen arbitrarily). The algorithm consists of $N-1$ iteration, each of which adds exactly one edge to the tree, does not violate the properties of the tree (that is, one end of the attached edge belongs to the tree, and the other does not). A key point is that from all such ribs an edge with a minimum weight is selected. That is, in the Prim's algorithm, another iterative process is added, whose purpose is to reduce the dimension of the initial graph by rejecting the edges which can be assumed will not be reflected in the finite tree. It is important to make sure that the graph does not appear to have isolated peaks in such a rejection, otherwise it will not be possible to reach the settlement that sets this vertex.

To find the minimum skeletal tree, Prim's algorithms are used $w(T) = \sum_{e_i \in T} w(e_i) \rightarrow \min$. To solve the problem, Prim's algorithm was modified. The modification is in the iterative use of the Prim's algorithm, until the condition is fulfilled $w(T_j) = \sum_{e_s^j \in T_j} w(e_s^j) \leq W_j, j = 1, 2, 3$.

An example of using the proposed approach within the Khodorovsky territorial community is given. The developed module allows to filter the cost of repairing roads within the limits of TG according to the following parameters: type of road, type of coverage, condition, which ultimately will allow calculating the cost of roads repairs.

Keywords: territorial community, settlement, graph, Prima algorithm.

1. Закон України (2015). Про добровільне об'єднання територіальних громад [Електронний ресурс]. – Режим доступу: <http://zakon5.rada.gov.ua/laws/show/157-19>. 2. Постанова Кабінету Міністрів України Про затвердження Методики формування спроможних територіальних громад [Електронний ресурс]. – Режим доступу: <http://zakon.rada.gov.ua/laws/show/214-2015-n> 3. Стан українських доріг [Електронний ресурс]. – Режим доступу: http://censor.net.ua/news/430063/95_ukrainskih_dorog_ostayutsya_v_neprigodnom_sostoyanii_otelyan 4. Стан про ремонту доріг в Україні на сьогодні [Електронний ресурс]. – Режим доступу: http://censor.net.ua/news/430172/ukravtodoru_nado_organizatsionno_pravilno_rabotat_95_dorog_nahodyatsya_v_ujasnom_sostoyanii_groyisman 5. В. В. Литвин, Д. І. Угрин, А. М. Фітьо, «Моделювання процесу формування територіальних громад як задачі розбиття графу», Східно-Європейський журнал передових технологій, № 1/4(79), С. 47–52, 2016. 6. В.В. Литвин, Д. І. Угрин, О.Д. Іллюк, С. В. Білоус, З. Л. Рибчак, «Система оптимізації маршрутів туризму на основі модифікації генетичного та мурашиного алгоритмів», Вісник НУ ЛП № 872, С. 210–220, 2017. 7. В. В. Литвин, Д.І.Угрин, А.М.Фітьо «Формалізація задачі формування територіальних громад», 11 Міжнародна науково-практична конференція „Математичне та імітаційне моделювання систем МОДС” (27 червня – 1 липня 2016). – Жукін. – С. 290-292 8. Макконелл Дж., «Основи сучасних алгоритмів: 2-е доповнене видання», М.: Техносфера, 2004, 368с. 9. В. А. Евстигнеев, «Применение теории графов в программировании», М.: Наука, 1985, 352 с. 10. М. Свами, К. Тхуласираман «Графы, сети и алгоритмы», М.: Наука, 2014, 256с.

THE USE OF CONTEXTUAL GRAPHS FOR DECISION SUPPORT IN RECRUITING

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One of the trends in the development of enterprise information systems today is the growing demand for quality management solutions. This problem is solved by intellectualization of information systems, which resulted in the transition to the concept of a cognitive enterprise. One of the main requirements for such an enterprise is taking into consideration the contextual information in decision-making process.

For the depiction of contextual information a variety of symbolic or graphical representations are used based on the chosen mathematical formalism. The most known formal context models are key-value models, markup languages, graphic models, object-oriented models, logical models, rule-based models, ontology-based models. When choosing a type of formalism for contextual model in the field of employment, it is not advisable to restrict the use to only one type, since different formalisms are helpful for solving various types of problems. At the same time, the models based on ontologies occupy a special place among the contextual models. The main advantages of using an ontological approach are:

- ontologies make it possible to formally define the concepts in the subject area and the relationships between them. This knowledge reflects the features of the subject area and can be reused.
- based on concepts, relationships and axioms of ontology, one can build models for representing different types of context (historical, personal, location contexts).
- for the ontological representation of knowledge, tools for logical reasoning and verification of logical integrity have been developed.

The business processes of employment area are modeled by contextual graphs. Such a graph has one vertex input and one vertex output. The input vertex is the identified situation that needs to be acted upon. The contextual graph has two types of vertices: contextual elements and actions. Contextual elements represent contextual knowledge that is relevant to the situation. Depending on actual values of parameters, describing a situation, specific practices (courses of actions) are selected. The model of contextual graphs is used at the final stage of the process of processing the context as a part of the modified JDL model. It reflects the use of context-sensitive knowledge to select an appropriate practice, define its parameters, as well as relevant data and knowledge.

In some cases, especially when there are not enough data for making decision, the refinement of context is required. This leads to the inclusion of new elements into contextual ontology, finding values of their properties and using this additional information in decision making. Such context refinement operation can occur several times in a row.

The task of choosing the right practice, taking into account the values of the parameters of the initialized context model, is multi-criterial and difficult to formalize. For its implementation, it is necessary to use the knowledge of experts who understand the nuances of each particular situation, can predict the consequences of actions, assess the risks and make compromises. Thus, the development of decision support techniques based on the context of the situation, requires the collaboration with experts to formalize their knowledge. Given the informal and multi-criterial nature of the task of choosing a practice, it is advisable to utilize the method of the analytical hierarchy and modify it for use with ontological contextual models.

In the developed modification of analytical hierarchy method, the decision space is split into areas, in such a way that matrices of pair-wise comparison of criteria and alternatives are constant in each of them. The algorithm for building such a split is proposed.

The formalization of contextual expert knowledge for typical business processes and situations within those processes makes it possible to conduct a detailed analysis of context and improve the quality of decisions.

Keywords: ontology, knowledge, context, contextual graph, analytical hierarchy

1. Quinn, J. B. *The intelligent enterprise a new paradigm. The Executive*, 6(4) – 1992. – pp. 48–63. 2. Bob Lewis and Scott Lee. *The Cognitive Enterprise. Meghan-Kiffer Press, Tampa, FL, USA., 2015, 212 p.* 3. *Smart Machines: IBM's Watson and the Era of Cognitive Computing. Columbia Business School Publishing by John E. Kelly III, Steve Hamm* <https://cup.columbia.edu/book/978-0-231-16856-4/smart-machines>. 4. Mary Bazire and Patrick Brézillon. *Understanding Context Before Using It. A. Dey et al. (Eds.): CONTEXT 2005, LNAI 3554, pp. 29–40, 2005. © Springer-Verlag Berlin Heidelberg 2005.* 5. Strang T, Linnhoff-Popien C. *A context modeling survey. In Workshop on advanced context modelling, reasoning and management, UbiComp 2004 Sep 7, Vol. 4, pp. 34–4).* 6. Смирнов а.в., Левашова т.в., Пашкин м.п. *модели контекстно-управляемых систем поддержки принятия решений в динамических структурированных областях, 2009.* 7. Bettini, Claudio/ *A survey of context modelling and reasoning techniques./ Pervasive and Mobile Computing 6.2 (2010): 161–180.* 8. Ye, Juan, Lorcan

Coyle, Simon Dobson, and Paddy Nixon. "Ontology-based models in pervasive computing systems". *The Knowledge Engineering Review* 22, no. 4 (2007): 315–347. 9. Iryna Zavuschak. *The Context of Operations as the Basis for the Construction of Ontologies of Employment Processes* // Iryna Zavuschak, Yevhen Burov. /I.J. Modern Education and Computer Science, 2017, 11, 13–24 Published Online November 2017 in MECS (<http://www.mecspress.org/>) DOI: 10.5815/ijmecs.2017.11.02. 10. Steinberg, A. N. and Bowman, C. L.,. *Revisions to the JDL data fusion model.* // *Handbook of multisensor data fusion.* – CRC Press, 2008. – pp. 65–88. 11. Cabrera O, Franch X, Marco J. A context ontology for service provisioning and consumption. In *Research Challenges in Information Science (RCIS), 2014 IEEE Eighth International Conference on 2014 May 28 (pp. 1–12).* 12. Brézillon, Patrick. *Task-realization models in contextual graphs. Modeling and Using Context(2005) pp. 1–8.* 13. Brézillon, Patrick. *Elaboration of the Contextual Graphs representation: From a conceptual framework to an operational software.* 2017. 14. Буров Є. Опрацювання контексту у когнітивній інформаційній системі керованій моделями *Східно-Європейський журнал передових технологій № 1/7(43).* – Харків: Технологічний центр. ç 2010. – С. 40–47.

16. Слухаська О. К., Захарія Л. М. Розроблення системи пошуку вакансій

INTELLIGENT AGENTS IN THE EMPLOYMENT SYSTEM

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Nowadays, the results of a comprehensive analysis of data available on the Internet are becoming increasingly popular. As a result of the occurrence of such significant changes and approaches to obtaining data in the information space, a common task is to resolve the issues of using the results of such analysis in various industries and areas of life. At the moment, there are already many ready-made tools that provide the ability to collect, analyze data and bring them to the desired form for further processing and / or storage.

This paper will discuss the use of such tools on the example of the organization of the site for recruiting.

An important problem for a user who is looking for a job or looking for a candidate for a certain position is the lack of a unified system that would help to describe your professional skills or the skills of the candidate you are looking for. Also, one of the problems is the lack of a transparent process in the communication between the recruiter and the candidate. Very often, the recruiter needs to quickly remember what the negotiations with the candidate stopped at, the date of the interview, or at what stage is the consideration of the candidate from the employer's point of view.

One of the ways to neutralize the impact of such problems on the process of filling a vacancy is to automate the description of relevant and existing professional skills: the system already contains a large set of skills, so users should select the necessary ones when searching or creating vacancies.

Thanks to artificial intelligence it is possible to effectively solve the problem of reducing the search time for a vacancy or candidate. Based on the criteria by which the user processes the search, the system automatically offers vacancies that may be interesting to the user.

Using this service, a candidate for a position does not spend time writing a resume, but uses already existing personal data that provides the opportunity to create a resume automatically on the site. In the same way, the recruiter has the ability to generate a resume for the selected candidate.

The system contains a limited set of skills, allows them to be divided into certain categories and presented in a hierarchical tree, which in turn allows them to use clustering algorithms for advanced search. Also, a predetermined set of skills allows both recruiters and candidates to manipulate the same terms, clarifies the communication process.

For an accurate comparison of data between vacancies and candidate profiles (resume), the same sets of pre-defined categories and skills that apply to them are used.

On the employer's side, when filling a vacancy, a branch of work, appropriate skills and tools are chosen. From the side of the candidate is filled:

- experience in a particular area, skills and/or tools that he/she used;
- the desired industry of work and skills acquired independently or from previous jobs.

As with one, and with the other hand, it is possible to indicate the necessary/existing level of skills. The system provides an opportunity to choose from three available levels: beginner, experienced expert.

The introduction of this system allows for a more detailed and individual selection of work. Detailing occurs through the implementation of a self-assessment of the level of existing work experience of professional abilities on a specific scale.

The system has the ability to automatically select potentially interesting candidate positions. The process of selection of vacancies is carried out on the basis of the data that the candidate has provided about himself by filling out a profile on the site. If there are no vacancies that exactly match the data provided by the candidate, then the search criteria are expanded using clustering:

- first of all, related categories are included in the search; if the desired result has not been achieved, then categories that are one level higher are included. This continues until the result is achieved, or the categories that can be included in the search run out;

- data such as the age of the candidate, year of experience, location will also receive advanced search criteria to achieve the best result. The boundaries for the age of the candidate and his years of experience will expand as numerical data. The location will use the same algorithm as for the category (based on the hierarchy).

The more data was specified in the profile, the more accurate the search will be performed.

1. L. Bing. *Web Data Mining. Exploring Hyperlinks, Contents, and Usage Data, Second Edition* / L. Bing // «Springer». – 2016. – 851 p. 2. Yaser S. Abu-Mostafa, Malik Magdon-Ismail, Hsuan-Tien Lin. *Learning from data* / Yaser S. Abu-Mostafa, Malik Magdon-Ismail, Hsuan-Tien Lin // «Williams». – 2015. – 542 p. 3 Vihar Kurama. *Linear Algebra for Deep Learning* / Vihar Kurama // *Towards Data Science*. – 2017. – 1–12 p. 4 Divyansh Dwivedi. *Machine Learning for beginners* / Divyansh Dwivedi. // *Towards Data Science*. – 2016. – 1–7 p. 5. Amid Fish. *Lessons Learned Reproducing a Deep Reinforcement Learning Paper* / Amid Fish // *Amid Fish. Blog*. – 2018. – 1–39 p. 6. Drew Conway, John Myles White. *Machine Learning for Hackers* / Drew Conway, John Myles White. // O'Reilly. – 2014. – 746 p.