ABSTRACT AND REFERENCES

INFORMATION AND CONTROLLING SYSTEM

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DEVELOPMENT OF AN INTELLIGENT DECISION SUPPORT SYSTEM TO CONTROL THE PROCESS OF WELL DRILLING UNDER COMPLICATED CONDITIONS (p. 6-14)

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The paper addresses the task on constructing a method for the identification of complications, arising during oil and gas well drilling, which functions under conditions of an a priori and current uncertainty under the influence of various disturbances, based on the methods of fuzzy sets and fuzzy logic.

The methodological approach to assessing the level of complications in the course of oil and gas well drilling, based on the principles of linguistics of the parameters of the drilling process, the linguistics and hierarchy of knowledge about complications in the drilling process, was proposed.

We have built mathematical models of the controlled object, which, in contrast to deterministic mathematical models, make it possible to describe in the natural language the cause-effect relations between the parameters of the drilling process and possible complications. These models reflect the logic of an operator's reasoning with the involvement of non-numeric and fuzzy information by an expert specialist, which makes it possible to formalize the decision-making procedures based on Fuzzy Logic using the parameters and indicators for the process of oil and gas well drilling.

The structure of decision support system in controlling the process of well drilling under complicated conditions was proposed.

The results of simulation of the developed methods for modeling complications based on the methods of fuzzy sets and fuzzy logic were presented. Their advantages in accuracy in comparison with the known methods in problems of identification of assessment and control under conditions of uncertainty about the structure and parameters of the object were shown.

The actual complications were detected whose elimination would increase the level of safety when drilling wells. It was shown that the developed methods and models could be used to simulate and identify a wide class of complications on drilling rigs functioning under conditions of an a priori and current uncertainty about their structure, parameters, and geo-environment.

Keywords: fuzzy control system, identification of non-stationary processes, Fuzzy-modeling, dynamic object of control (drilling), logical-linguistic rules.

References

1. Larsen, H. F., Alfsen, T., Kvalsund, R., Iversen, F. P., Welmer, M., Hult, O., Ekrene, S. (2010). The Automated Drilling Pilot on Statfjord C. IADC/SPE Drilling Conference and Exhibition. doi: https://doi.org/10.2118/128234-ms
2. Aldred, W., Bourque, J., Chapman, C., Downton, G., Falconer, I., Florence, F. et. al. (2012). Drilling Automation. Oilfield Review, 24 (2), 18–27.
3. Florence, F., Porche, M., Thomas, R., Fox, R. (2009). Multi-Parameter Autodrilling Capabilities Provide Drilling, Economic Benefits. SPE/IADC Drilling Conference and Exhibition. doi: https://doi.org/10.2118/119965-ms
4. Chapman, C. D., Sanchez, J. L., De Leon Perez, R., Yu, H. (2012). Automated Closed-Loop Drilling with ROP Optimization Algorithm Significantly Reduces Drilling Time and Improves Downhole Tool Reliability. IADC/SPE Drilling Conference and Exhibition. doi: https://doi.org/10.2118/151736-ms
5. Okpo, E. E., Dosunmu, A., Odagme, B. S. (2016). Artificial Neural Network Model for Predicting Wellbore Instability. SPE Nigeria Annual International Conference and Exhibition. doi: https://doi.org/10.2118/184371-ms
6. Cayeux, E., Daireaux, B. (2009). Early Detection of Drilling Conditions Deterioration Using Real-Time Calibration of Computer Models: Field Example from North Sea Drilling Operations. SPE/IADC Drilling Conference and Exhibition. doi: https://doi.org/10.2118/119435-ms
7. Cayeux, E., Daireaux, B., Dvergsnes, E., S levik, G. (2012). Early Symptom Detection on the Basis of Real-Time Evaluation of Downhole Conditions: Principles and Results From Several North Sea Drilling Operations. SPE Drilling & Completion, 27 (04), 546–558. doi: https://doi.org/10.2118/150422-pa
8. Jacobs, T. (2015). Automated Drilling Technologies Showing Promise. Journal of Petroleum Technology, 67 (06), 50–55. doi: https://doi.org/10.2118/0615-0050-jpt
9. De Wardt, J. P., Innabinett, C. E., Laing, M. L., Macpherson, J. D. (2016). System Architecture and Operations States for Drilling and Completion: The Foudation to Real Performance Measurement and Drilling System Automation. IADC/SPE Drilling Conference and Exhibition.
10. Bang, J., Jegbefume, O., Ledroz, A., Thompson, J. (2015). Wellbore Tortuosity Analysed by a Novel Method May Help to Improve Drilling, Completion, and Production Operations. SPE/IADC Drilling Conference and Exhibition. doi: https://doi.org/10.2118/173103-ms
11. Oganov, G. S., Shirin-Zade, S. A., Paramonov, A. A. (2009). Dinamicheskiy analiz protsessa uglubleniya skvazhin. Vestnik assotsiatsii burovyh podryadchikov, 1, 40–44.
12. Shavranskyi, M. V., Kuchmystenko, A. V. (2018). Intelligent system for object recognition on optical images using cascade neural networks. Oil and Gas Power Engineering, 1, 50–55. doi: https://doi.org/10.31471/1993-9868-2018-1(29)-50-55
13. Kluska, J. (2005). Exact Fuzzy Modeling of convertional control system. Proceedings of 12-th East-West Fuzzy Colloquium. Zittau, 113–125.
14. Kondratenko, Y., Sydorenko, S., Kravchenko, D. (2005). Fuzzy control systems of non-stationary plants with variable parameters. Proceedings of 12-th East-West Fuzzy Colloquim. Zittau, 140–152.
15. Sokolov, A., Wagenknecht, M. (2005). Chootic Mamdani Recurrent Models. Proceedings of 12-th East-West Fuzzy Colloquim. Zittau, 272–278.
16. Demchyna, M. M. (2012). Vykorystannia nechitkykh pravyl dlia podannia znan v intelektualnykh systemakh naftohazovoi predmetnoi oblasti. Naukovyi visnyk Ivano-Frankivskoho natsionalnoho tekhnichnoho universytetu nafty i hazu, 1 (31), 132–141.
17. Bakumenko, N. S., Kas'yan, O. V., Sokolov, A. YU. (2002). Noviy podhod k postroeniyu nechetkih modeley dinamicheskih obektov. Otkrytye informatsionnye tehnologii, 13, 98–105.
18. Bodyanskiy, Ye., Teslenko, N. (2008). General regression neuro-fuzzy network for identification of nonstationary plants. International Journal "Information Technologies and Knowledge", 2 (2), 136–142. Available at: http://www.foibg.com/ijitk/ijitk-vol02/ijitk02-2-p05.pdf

19. Kuzemin, O., Toroev, A., Klymov, I. (2008). Development of fuzzy-logic model for prediction of the avalanche-dangerous situations risk. International Disaster Risk Conference. Davos, 135.
20. Sokolov, A., Bakumenko, N. (2002). Linguistic approximation of dynamic object. Proceedings of 10-th East-West Fuzzy Colloquium. Zittau, 225–262.
21. Chyhur, L. Ya., Sementsov, H. N., Chyhur, I. I., Kohutiak, M. I., Kohuch, Ya. R., Shavranskyi, M. V. (2009). Intelektualnyi prystriy na nechitkiy lohitsi dlia rozpiznavannia obraziv u burinni. Naftohazova enerhetyka, 1, 75–77.
22. Shtovba, S. D. (2007). Proektirovanie nechetkih sistem sredstvami MATLAB. Moscow: Goryachaya liniya - Telekom, 288.
23. Stepanov, N. V. (1989). Modelirovanie i prognoz oslozhneniy pri burenii skvazhin. Moscow: Nedra, 252.

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APPLICATION OF SYSTEMS APPROACH AT EARLY STAGES OF DESIGNINNG UNMANNED TOWED UNDERWATER SYSTEMS FOR SHALLOW WATER AREAS (p. 15-24)

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Typical configuration of an unmanned towed underwater system (UTUS) was described and advantages of using this type of marine equipment for shallow depth works were outlined.

A list of basic operating modes of the UTUS which are key modes for design calculations of the system was determined. Basic requirements to the design and construction of a competitive UTUS for shallow water areas have been formed. The main requirements include the need for high-performance underwater technologies and the use of state-of-the-art computer research and design software. The need to maximize use of materials, parts and units that are commercially available as components for the UTUS was also indicated.

Expediency and possibility of applying the systems approach methodology at early stages of the UTUS design were shown. Equations of existence were formulated in a matrix form for the UTUS components which make it possible to check engineering solutions for compliance with the requirements of the Requirements Specification already at the stages of technical proposal and sketch design. Structural, power, information and operational characteristics of the UTUS components were used as the compliance criteria.

Sequence of the design works was completed in a form of a generalized design algorithm that implements the systems approach using modern computer technologies and equations of the UTUS existence. The developed algorithm allows the designer to check requirements of the Requirements Specification already at the early stages of the UTUS design and forms a scientifically substantiated methodological basis for creation of competitive underwater equipment.

Keywords: unmanned towed underwater system, design problems, systems approach, equation of existence.

References

1. Ikonnikov, I. B., Gavrilov, V. M., Puzyrev, G. V. (1993). Podvodnye buksiruemye sistemy i bui neytral'noy plavuchesti. Sankt-Peterburg: Sudostroenie, 224.
2. Manning, G. C. (2013). The Theory And Technique Of Ship Design: A Study of the Basic Principles and the Processes Employed in the Design of Ships of all Classes. Literary Licensing, LLC, 288.
3. Gaykovich, A. I. (2014). Teoriya proektirovaniya vodoizmeshchayushchih korabley i sudov. Vol. 1. Opisanie sistemy «Korabl'». Vol. 2. Analiz i sintez sistemy «Korabl'». Sankt-Peterburg: Izdatel'stvo «Morinteh», 822, 874.
4. Matousek, R. (1963). Engineering design: A systematic approach. Springer, 264. doi: https://doi.org/10.1007/978-94-010-9306-4
5. Pahl, G., Beitz, W., Feldhusen, J., Grote, K.-H. (2007). Engineering Design: A Systematic Approach. Springer. doi: https://doi.org/10.1007/978-1-84628-319-2
6. Korte, H. (2000). Track Control of a Towed Underwater Sensor Carrier. IFAC Proceedings Volumes, 33 (9), 89–94. doi: https://doi.org/10.1016/s1474-6670(17)38129-6
7. Linklater, A. (2005). Design and Simulation of a Towed Underwater Vehicle. Blacksburg, Virginia. Available at: https://vtechworks.lib.vt.edu/bitstream/handle/10919/33622/AmyThesis.pdf?sequence=1&isAllowed=y
8. Buckham, B., Nahon, M., Seto, M., Zhao, X., Lambert, C. (2003). Dynamics and control of a towed underwater vehicle system, part I: model development. Ocean Engineering, 30 (4), 453–470. doi: https://doi.org/10.1016/s0029-8018(02)00029-x
9. Srivastava, V. K., Sanyasiraju, Y., Tamsir, M. (2011). Dynamic Behavior of Underwater Towed-cable in Linear Profile. International Journal of Scientific & Engineering Research, 2 (7). Available at: https://pdfs.semanticscholar.org/fe04/8af7057476a54f47dbd7c344e6b59d854fcf.pdf
10. Curado Teixeira, F., Pedro Aguiar, A., Pascoal, A. (2010). Nonlinear adaptive control of an underwater towed vehicle. Ocean Engineering, 37 (13), 1193–1220. doi: https://doi.org/10.1016/j.oceaneng.2010.05.010
11. Minowa, A. (2015). System Analyses and Motion Control of a Towed Underwater Vehicle. Tokyo. Available at: https://oacis.repo.nii.ac.jp/?action=repository_action_common_download&item_id=1305&item_no=1&attribute_id=20&file_no=1
12. Blintsov, O., Sokolov, V., Kucenko, P. (2019). Formulation of design tasks of towed underwater vehicles creation for shallow water and automation of their motion control. EUREKA: Physics and Engineering, 2, 30–42. doi: https://doi.org/10.21303/2461-4262.2019.00854
13. Park, J., Kim, N. (2015). Dynamics modeling of a semi-submersible autonomous underwater vehicle with a towfish towed by a cable. International Journal of Naval Architecture and Ocean Engineering, 7 (2), 409–425. doi: https://doi.org/10.1515/ijnaoe-2015-0029
14. Pang, S., Liu, J., Chen, H., Wang, J., Yi, H. (2017). Analysis of motion state of the tow-part underwater towed vehicle system during cable deployment. OCEANS 2017 - Aberdeen. doi: https://doi.org/10.1109/oceanse.2017.8084915
15. Thomas, N., T. Issac, M. (2017). Analysis of Tow Cables. Universal Journal of Mechanical Engineering, 5 (5), 144–149. doi: https://doi.org/10.13189/ujme.2017.050502
16. Williams, K., McGinnis, T., Miller, V., Brand, B., Light, R. (2016). Final Report. Limited Scope Design Study for Multi-Sensor Tow Body. SERDP Project MR-2501. University of Washington. Available at: https://www.serdp-estcp.org/content/download/39999/383953/file/MR-2501%20Final%20Report.pdf
17. Blintsov, V., Klochkov, O. (2019). Generalized method of designing unmanned remotely operated complexes based on the system approach. EUREKA: Physics and Engineering, 2, 43–51. doi: https://doi.org/10.21303/2461-4262.2019.00878
18. Blintsov, O. V., Sokolov, V. V. (2018). Synthesis of a spatial motion dynamics simulating model of an unmanned underwater towed system as an object of control. Shipbuilding & marine infrastructure, 2, 131–143. Available at: http://smi.nuos.mk.ua/archive/2018/2/15.pdf

19. Strasdat, H., Davison, A. J., Montiel, J. M. M., Konolige, K. (2011). Double window optimisation for constant time visual SLAM. 2011 International Conference on Computer Vision. doi: https://doi.org/10.1109/iccv.2011.6126517
20. Van der Auweraer, H., Anthonis, J., De Bruyne, S., Leuridan, J. (2012). Virtual engineering at work: the challenges for designing mechatronic products. Engineering with Computers, 29 (3), 389–408. doi: https://doi.org/10.1007/s00366-012-0286-6
21. Driss, Z., Necib, B., Zhang, H.-C. (Eds.) (2018). CFD Techniques and Energy Applications. Springer. doi: https://doi.org/10.1007/978-3-319-70950-5
22. Blintsov, V., Klochkov, O. (2016). Equations of existence selfpropelled underwater system as assessment of the possibility of its creation. Pidvodni tekhnolohiyi, 3, 25–30.
23. Blintsov, V. S., Klochkov, O. P. (2018). Proektni zadachi stvorennia bezekipazhnoho samokhidnoho pryviaznoho pidvodnoho kompleksu na osnovi systemnoho pidkhodu. Naukovyi visnyk Khersonskoi derzhavnoi morskoi akademiyi, 2 (19), 4–13.
24. Kensek, K. M. (2014). Building Information Modeling. Routledge, 312. doi: https://doi.org/10.4324/9781315797076

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CONSTRUCTION OF METHODS FOR DETERMINING THE CONTOURS OF OBJECTS ON TONAL AEROSPACE IMAGES BASED ON THE ANT ALGORITHMS (p. 25-34)

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A method has been proposed for determining contours of objects on tonal aerospace images based on ant algorithms. The method, in contrast to those already known, takes into consideration patterns in the image formation; the ant algorithm is used for determining the contours. Determining an object's contours in the image has been reduced to calculating the fitness function, the totality of agents' motion areas, and the pheromone concentration along agents' motion routes.

We have processed a tonal image for determining the contours of objects using a method based on the ant algorithm. In order to reduce the number of "junk" objects, the main principles and stages of the method for multi-scale processing of aerospace images based on the ant algorithm have been outlined. Determining the contours on images with a different value of the scale factor is carried out applying a method based on the ant algorithm. In addition, we rescale images with a different scale factor value to the original size and calculate the image filter. The resulting image is a pixelwise product of the original image and the image filter.

The multiscale processing of tonal aerospace images with different scale values has been performed using methods based on the ant algorithms. It was established that application of a multi-scale processing reduces the number of "junk" objects. At the same time, due to multi-scale processing, not the objects' contours are determined but the objects in full.

We estimated errors of first and second kind in determining the contours of objects on tonal aerospace images based on the ant algorithms. It was established that using the constructed methods has made it possible to reduce the first and second kind errors in determining the contours on tonal aerospace images by the magnitude of 18–22 % on average.

Keywords: aerospace image, objects' contours, ant algorithm, multiscale processing, image-filter.

References

1. Weng, Q. (2009). Remote Sensing and GIS Integration. New York: McGraw-Hill Professional, 416.
2. Chemin, Y. (Ed.) (2012). Remote Sensing of Planet Earth. Rijeka, 250. doi: https://doi.org/10.5772/2291
3. Richards, J. (2013). Remote Sensing Digital Image Analysis. An Introduction. Springer. doi: https://doi.org/10.1007/978-3-642-30062-2
4. Vysotska, V., Lytvyn, V., Burov, Y., Gozhyj, A., Makara, S. (2018). The consolidated information web-resource about pharmacy networks in city. CEUR Workshop Proceedings (Computational linguistics and intelligent systems), 2255, 239–255.
5. Stryzhak, O., Prychodniuk, V., Podlipaiev, V. (2019). Model of Transdisciplinary Representation of GEOspatial Information. Advances in Information and Communication Technologies, 34–75. doi: https://doi.org/10.1007/978-3-030-16770-7_3
6. Lytvyn, V., Vysotska, V. (2015). Designing architecture of electronic content commerce system. 2015 Xth International Scientific and Technical Conference "Computer Sciences and Information Technologies" (CSIT). doi: https://doi.org/10.1109/stc-csit.2015.7325446
7. Karamti, H., Tmar, M., Gargouri, F. (2017). A new vector space model for image retrieval. Procedia Computer Science, 112, 771–779. doi: https://doi.org/10.1016/j.procs.2017.08.202
8. Gonzalez R. C., Woods R. E. (2017). Digital Image Processing. Prentice Hall, 1192.
9. Gupta, V., Singh, D., Sharma, P. (2016). Image Segmentation Using Various Edge Detection Operators: A Comparative Study. Interna-

tional Journal of Innovative Research in Computer and Communication Engineering, 4 (8), 14819–14824.
10. Kabade, A., Sangam, V. (2016). Canny edge detection algorithm. International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), 5 (5), 1292–1295.
11. Yang, M., Chao, H., Zhang, C., Guo, J., Yuan, L., Sun, J. (2016). Effective Clipart Image Vectorization through Direct Optimization of Bezigons. IEEE Transactions on Visualization and Computer Graphics, 22 (2), 1063–1075. doi: https://doi.org/10.1109/tvcg.2015.2440273
12. Sum, K., S. Cheung, P. (2006). A Fast Parametric Snake Model with Enhanced Concave Object Extraction Capability. 2006 IEEE International Symposium on Signal Processing and Information Technology. doi: https://doi.org/10.1109/isspit.2006.270844
13. Karamti, H., Tmar, M., Gargouri, F. (2014). Vectorization of Content-based Image Retrieval Process Using Neural Network. Proceedings of the 16th International Conference on Enterprise Information Systems, 435–439. doi: https://doi.org/10.5220/0004972004350439
14. Nyandwi, E., Koeva, M., Kohli, D., Bennett, R. (2019). Comparing Human Versus Machine-Driven Cadastral Boundary Feature Extraction. Remote Sens, 11, 1662. doi: https://doi.org/10.20944/preprints201905.0342.v1
15. Ramlau, R., Scherzer, O. (Eds.) (2019). The Radon Transform. Berlin/Boston: Walter de Gruyter GmbH. doi: https://doi.org/10.1515/9783110560855
16. Li, Z., Liu, Y., Walker, R., Hayward, R., Zhang, J. (2009). Towards automatic power line detection for a UAV surveillance system using pulse coupled neural filter and an improved Hough transform. Machine Vision and Applications, 21 (5), 677–686. doi: https://doi.org/10.1007/s00138-009-0206-y
17. Manzanera, A., Nguyen, T. P., Xu, X. (2016). Line and circle detection using dense one-to-one Hough transforms on greyscale images. EURASIP Journal on Image and Video Processing, 2016 (1). doi: https://doi.org/10.1186/s13640-016-0149-y
18. El-Baz, A., Jiang, X., Jasjit, S. (Eds.) (2016). Biomedical image segmentation: advances and trends. CRC Press, 546. doi: https://doi.org/10.4324/9781315372273
19. Ruban, I., Khudov, V., Makoveichuk, O., Khudov, H., Khizhnyak, I. (2018). A Swarm Method for Segmentation of Images Obtained from On-Board Optoelectronic Surveillance Systems. 2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T). doi: https://doi.org/10.1109/infocommst.2018.8632045
20. Ruban, I., Khudov, H., Makoveichuk, O., Khizhnyak, I., Khudov, V., Podlipaiev, V. et. al. (2019). Segmentation of optical-electronic images from on-board systems of remote sensing of the earth by the artificial bee colony method. Eastern-European Journal of Enterprise Technologies, 2 (9 (98)), 37–45. doi: https://doi.org/10.15587/1729-4061.2019.161860
21. Ruban, I., Khudov, H., Khudov, V., Khizhnyak, I., Makoveichuk, O. (2017). Segmentation of the images obtained from onboard optoelectronic surveillance systems by the evolutionary method. Eastern-European Journal of Enterprise Technologies, 5 (9 (89)), 49–57. doi: https://doi.org/10.15587/1729-4061.2017.109904
22. Dorigo, M., Stützle, T. (2018). Ant Colony Optimization: Overview and Recent Advances. International Series in Operations Research & Management Science, 311–351. doi: https://doi.org/10.1007/978-3-319-91086-4_10
23. WorldView-1 Satellite Sensor. Satellite Imaging Corporation. Available at: http://www.satimagingcorp.com/satellite-sensors/worldview-1
24. Ruban, I., Khudov, V., Khudov, H., Khizhnyak, I. (2017). An improved method for segmentation of a multiscale sequence of optoelectronic images. 2017 4th International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T). doi: https://doi.org/10.1109/infocommst.2017.8246367

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DEVELOPMENT OF AN ALGORITHM FOR COMPLEX PROCESSING OF GEOSPATIAL DATA IN THE SPECIAL-PURPOSE GEOINFORMATION SYSTEM IN CONDITIONS OF DIVERSITY AND UNCERTAINTY OF DATA (p. 35-45)

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The algorithm of complex processing of geospatial data in special-purpose geoinformation systems in the conditions of diversity and uncertainty of data is developed. The novelty of the algorithm is to ensure the functioning of the geoinformation system in conditions of scarcity of computing resources, taking into account the uncertainty about the status of the monitoring object (exploration object). This algorithm takes into account the coefficient of relative significance of occurring events in the processing of geospatial data circulating in the special-purpose geoinformation system. The proposed algorithm uses the developed complex indicator of occurring events, which characterizes the probability of performing the tasks by the geoinformation

system, the completeness of their solution for the management cycle and taking into account the significance of emerging events. Complementary approaches to resource management of special-purpose geoinformation systems are proposed. The development of the proposed algorithm is due to the need to increase the speed of processing various types of information in geoinformation systems with acceptable computational complexity. The proposed algorithm allows to increase the efficiency of geoinformation systems due to complex processing of geospatial data circulating in it. This algorithm should be used in the development of software for special-purpose geoinformation systems to improve their efficiency by increasing the speed of information processing in special-purpose geoinformation systems. The proposed algorithm improves the processing speed of information in special-purpose geoinformation systems from 16 to 20 % depending on the amount of information about the monitoring object.

Keywords: geoinformation system, monitoring object, geospatial data, computational complexity, information processing, type of information.

References

1. Makridenko, L. A., Volkov, S. N., Khodnenko, V. P., Zolotoy, S. A. (2010). Conceptual problems on creation and application of small spacecraft. Voprosy elektromehaniki, 114 (1), 15–26.
2. Shyshatskyi, A. V., Bashkyrov, O. M., Kostyna, O. M. (2015). Rozvytok intehrovanykh system zviazku ta peredachi danykh dlia potreb Zbroinykh Syl. Ozbroiennia ta viyskova tekhnika, 1 (5), 35–39.
3. Trotsenko, R. V., Bolotov, M. V. (2014). Data extraction process for heterogeneous sources. Privolzhskiy nauchnyy vestnik, 12-1 (40), 52–54.
4. Bodyanskiy, E., Strukov, V., Uzlov, D. (2017). Generalized metrics in the problem of analysis of multidimensional data with different scales. Zbirnyk naukovykh prats Kharkivskoho natsionalnoho universytetu Povitrianykh Syl, 3 (52), 98–101.
5. Noh, B., Son, J., Park, H., Chang, S. (2017). In-Depth Analysis of Energy Efficiency Related Factors in Commercial Buildings Using Data Cube and Association Rule Mining. Sustainability, 9 (11), 2119. doi: https://doi.org/10.3390/su9112119
6. Petras, V., Petrasova, A., Jeziorska, J., Mitasova, H. (2016). Processing UAV and lidar point clouds in Grass GIS. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLI-B7, 945–952. doi: https://doi.org/10.5194/isprs-archives-xli-b7-945-2016
7. Polovina, S., Radic, B., Ristic, R., Milcanovic, V. (2016). Spatial and temporal analysis of natural resources degradation in the Likodra River watershed. Glasnik Sumarskog Fakulteta, 114, 169–188. doi: https://doi.org/10.2298/gsf1614169p
8. Poryadin, I., Smirnova, E. (2017). Binary Classification Method of Social Network Users. Science and Education of the Bauman MSTU, 17 (02), 121–137. doi: https://doi.org/10.7463/0217.0000915
9. Tymchuk, S. (2017). Methods of Complex Data Processing from Technical Means of Monitoring. Traektoriâ Nauki. Path of Science, 3 (3), 4.1–4.9. doi: https://doi.org/10.22178/pos.20-4
10. Semenov, V. V., Lebedev, I. S. (2019). Processing of signal information in problems of monitoring information security of unmanned autonomous objects. Scientific and Technical Journal of Information Technologies, Mechanics and Optics, 19 (3), 492–498. doi: https://doi.org/10.17586/2226-1494-2019-19-3-492-498
11. Zhou, S., Yin, Z., Wu, Z., Chen, Y., Zhao, N., Yang, Z. (2019). A robust modulation classification method using convolutional neural networks. EURASIP Journal on Advances in Signal Processing, 2019 (1). doi: https://doi.org/10.1186/s13634-019-0616-6
12. Zhang, D., Ding, W., Zhang, B., Xie, C., Li, H., Liu, C., Han, J. (2018). Automatic Modulation Classification Based on Deep Learning for Unmanned Aerial Vehicles. Sensors, 18 (3), 924. doi: https://doi.org/10.3390/s18030924
13. Kukulska-Kozieł, A., Salata, T., Cegielska, K., Szylar, M. (2018). Methodology of evaluation and correction of geometric data topology in QGIS software. Acta Scientiarum Polonorum. Formatio Circumiectus, 17 (1), 137–150.
14. Rulev, A., Yuferev, V. (2015). Theory of geoinformatic mapping of erosion geomorphological systems. Vestnik Volgogradskogo Gosudarstvennogo Universiteta. Serija 11. Estestvennye Nauki, 4, 62–67. doi: https://doi.org/10.15688/jvolsu11.2015.4.7
15. Yousefi, M., Kreuzer, O. P., Nykänen, V., Hronsky, J. M. A. (2019). Exploration information systems – A proposal for the future use of GIS in mineral exploration targeting. Ore Geology Reviews, 111, 103005. doi: https://doi.org/10.1016/j.oregeorev.2019.103005
16. Ashkezari, A. D., Hosseinzadeh, N., Chebli, A., Albadi, M. (2018). Development of an enterprise Geographic Information System (GIS) integrated with smart grid. Sustainable Energy, Grids and Networks, 14, 25–34. doi: https://doi.org/10.1016/j.segan.2018.02.001
17. Wang, S., Zhong, Y., Wang, E. (2019). An integrated GIS platform architecture for spatiotemporal big data. Future Generation Computer Systems, 94, 160–172. doi: https://doi.org/10.1016/j.future.2018.10.034
18. Wan-Mohamad, W. N. S., Abdul-Ghani, A. N. (2011). The Use of Geographic Information System (GIS) for Geotechnical Data Processing and Presentation. Procedia Engineering, 20, 397–406. doi: https://doi.org/10.1016/j.proeng.2011.11.182
19. Pedro, J., Silva, C., Pinheiro, M. D. (2019). Integrating GIS spatial dimension into BREEAM communities sustainability assessment to support urban planning policies, Lisbon case study. Land Use Policy, 83, 424–434. doi: https://doi.org/10.1016/j.landusepol.2019.02.003
20. Mokhtara, C., Negrou, B., Settou, N., Gouareh, A., Settou, B. (2019). Pathways to plus-energy buildings in Algeria: design optimization method based on GIS and multi-criteria decision-making. Energy Procedia, 162, 171–180. doi: https://doi.org/10.1016/j.egypro.2019.04.019
21. Karin, S. A. (2012). Integration in the single information space of heterogeneous geospatial data. Informatsionno-upravlyayushchie sistemy, 2, 89–94.
22. Karin, S. A. (2014). Developing a domain-specific ontology in spatial data processing systems. Informatsionno-upravlyayushchie sistemy, 4, 78–84.
23. Belousov, S. M. (2006). Matematicheskaya model' mnogopotochnoy sistemy massovogo obsluzhivaniya, upravlyaemoy planirovshchikom resursov. Vestnik Novosibirskogo gosudarstvennogo universiteta. Seriya: Informatsionnye tehnologii, 4 (1), 14–26.
24. Karin, S., Dudin, E. (2014). Methods for creating distribute systems of geospatial data collection, storage, and search. Information & Cosmos, 3, 48–53.
25. Gatsenko, S. S., Kal'nits'kiy, Yu. M., Gel'veychuk, O. M. (2014). The problem of distribution of information flows in automated control systems of tpoops (forces) of Armed Forces of Ukraine. Zbirnyk naukovykh prats Tsentru voienno-stratehichnykh doslidzhen Natsionalnoho universytetu oborony Ukrainy imeni Ivana Cherniakhovskoho, 2 (51), 107–111.
26. Koshlan, O. (2018). Method of parameters forecasting for the object of intelligence in geoinformation systems of the special purpose. XI naukovo-praktychna konferentsiya "Priorytetni napriamky rozvytku telekomunikatsiynykh system ta merezh spetsialnoho pryznachennia. Zastosuvannia pidrozdiliv, kompleksiv, zasobiv zviazku ta avtomatyzatsiyi v operatsiyi Obiednanykh syl". Kyiv, 125–126.
27. Koshlan, A. (2018). Conceptual model of a specialized geoinformation system. Advanced Information Systems, 2 (3), 36–40. doi: https://doi.org/10.20998/2522-9052.2018.3.06

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DEVELOPMENT OF THE INTERACTING AGENTS BEHAVIOR SCENARIO IN THE CYBER SECURITY SYSTEM (p. 46-57)

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The results of modeling and analysis of scenarios of the behavior of interacting agents in conditions of cyber conflict are presented. General approaches to the development of a scenario of the behavior of antagonistic agents are presented. The definition of the scenario is given and the factors determining the scenario of behavior are highlighted. The given scenarios are determined by such factors as the ratio of the capabilities of the attacking and the defending sides, the presence or absence of information exchange between security agents, and the time of switching to a new attack vector. The value of the time of switching to a new attack vector is found, at which the interaction is more stable. This indicates that the reaction of the defense side should not be purely reactive, and the "wait and see" strategy is not always the best. Modeling and analysis of the results were carried out in the conditions of information exchange between agents of the protection system and in the absence of such an exchange. The advantages and disadvantages of this behavior are noted. It is shown that when changing the time of switching to a new attack vector, not only the financial indicators of the activity of the participants in cyber conflict change, but also the nature of the interaction. The value of the time of switching to a new attack vector was found, in which the interaction is more stable, which suggests that the reaction of the defense side should not be purely reactive, and the "wait and see" strategy is not always the best. It is shown how the proposed approach can be used to justify the choice of a strategy for agent behavior in security systems, as well as for economic assessments of countermeasures and their deterrent effect on attackers. The proposed scenarios can be considered as a useful tool for assessing investments in the security of the business process circuit by decision makers.

Keywords: scenario analysis, scenario modeling, security systems, agent behavior, cybersecurity system.

References

1. Kovalev, P. P. (2009). Stsenarniy analiz, metodologicheskie aspekty. Finansy i kredit, 44 (380), 9–13.
2. Van der Heijden, K., Bradfield, R., Burt, G., Cairns, G., Wright, G. (2002), The Sixth Sense: Accelerating Organizational Learning with Scenarios. Wiley & Sons, 320.
3. Van Notten, Ph. (2005). Writing on the Wall: Scenario Development in Times of Discontinuity. Dissertation.Com., 228.
4. Ducot, G., Lubben, G. J. (1980). A typology for scenarios. Futures, 12 (1), 51–57. doi: https://doi.org/10.1016/s0016-3287(80)80007-3
5. Duncan, N. E., Wack, P. (1994). Scenarios designed to improve decision making. Planning Review, 22 (4), 18–46. doi: https://doi.org/10.1108/eb054470
6. Godet, M. (1997). Scenarios and Strategies: A Toolbox for Scenario Planning. Conservatoire National des Arts etMetiers (CNAM).
7. Godet, M., Roubelat, F. (1996). Creating the future: The use and misuse of scenarios. Long Range Planning, 29 (2), 164–171. doi: https://doi.org/10.1016/0024-6301(96)00004-0
8. Heugens, P. P. M. A. R., van Oosterhout J. (2001). "To boldly go where no man has gone before: integrating cognitive and physical features in scenario studies. Futures, 33 (10), 861–872. doi: https://doi.org/10.1016/s0016-3287(01)00023-4
9. Rolland, C., Ben Achour, C., Cauvet, C., Ralyté, J., Sutcliffe, A., Maiden, N. et. al. (1998). A proposal for a scenario classification framework. Requirements Engineering, 3 (1), 23–47. doi: https://doi.org/10.1007/bf02802919
10. Li, X., He, K. (2008). A Unified Threat Model for Assessing Threat in Web Applications. International Journal of Security and its Applications, 2 (3), 25–30.
11. Li, X., He, K., Feng, Z., Xu, G. (2014). Unified threat model for analyzing and evaluating software threats. Security and Communication Networks, 7 (10), 1454–1466. doi: https://doi.org/10.1002/sec.599
12. Reznikov, D. O., Makhutov, N. A., Akhmetkhanov, R. S. (2018). Analysis of Terrorist Attack Scenarios and Measures for Countering Terrorist Threats. Probabilistic Modeling in System Engineering. doi: https://doi.org/10.5772/intechopen.75099
13. Makhutov, N., Baecher, G. (Eds.) (2012). Comparative Analysis of Technological and Intelligent Terrorism Impacts on Complex Technical Systems. Amsterdam: IOS Press BV.
14. Countering Terrorism: Biological Agents, Transportation Networks, and Energy Systems: Summary of a U.S.-Russian Workshop (2009). Washington: The National Academies Press, 244. doi: https://doi.org/10.17226/12490
15. Frolov, K. V., Baecher, G. B. (Eds.) (2006). Protection of Civilian Infrastructure from Acts of Terrorism. NATO Security through Science Series. Springer. doi: https://doi.org/10.1007/1-4020-4924-2
16. Berman, A. F., Nikolaychuk, O. A., Yurin, A. Y. (2012). Intellectual data system for analyzing failures. Journal of Machinery Manufacture and Reliability, 41 (4), 337–343. doi: https://doi.org/10.3103/s1052618812040036

17. Makhutov, N. A., Reznikov, D. O. (2012). Analysis and ensuring protection of critical infrastructures taking into account risks and limit states. Problemy bezopasnosti i chrezvychaynyh situatsiy, 5, 14–36.
18. Makhutov, N. A., Reznikov, D. O., Zatsarinny, V. V. (2014). Two types of failure scenarios in complex technical systems. Problemy bezopasnosti i chrezvychaynyh situatsiy, 2, 28–41.
19. Bezopasnost' Rossii. Pravovye, sotsial'no-ekonomicheskie i nauchnotehnicheskie aspekty. Kosmicheskie sistemy i tehnologii povysheniya bezopasnosti i snizheniya riskov (2017). Moscow: MGOF «Znanie», 608.
20. Trotsky, D. V., Gorodetsky, V. I. (2009). Scenario–based knowledge model and language for situation assessment and prediction. SPIIRAS Proceedings, 8, 94–127. doi: https://doi.org/10.15622/sp.8.6
21. Tarakanov, A. (1988). Matrichnyy metod avtomaticheskogo sinteza programm. Izvestiya VUZov. Priborostroenie, 31 (10), 21–25.
22. Gorodetski, V. I., Tarakanov, A. O. (1996). Matrix Form of Attributive Grammars for Distributed Processing Planning and Control. Intelligent Control, Neurocomputing and Fuzzy Logic, 2.
23. Milov, O., Yevseiev, S., Ivanchenko, Y., Milevskyi, S., Nesterov, O., Puchkov, O. et. al. (2019). Development of the model of the antagonistic agents behavior under a cyber conflict. Eastern-European Journal of Enterprise Technologies, 4 (9 (100)), 6–19. doi: https://doi.org/10.15587/1729-4061.2019.175978
24. Milov, O., Voitko, A., Husarova, I., Domaskin, O., Ivanchenko, Y., Ivanchenko, I. et. al. (2019). Development of methodology for modeling the interaction of antagonistic agents in cybersecurity systems. Eastern-European Journal of Enterprise Technologies, 2 (9 (98)), 56–66. doi: https://doi.org/10.15587/1729-4061.2019.164730
25. Gordon, L. A., Loeb, M. P., Lucyshyn, W., Zhou, L. (2015). The impact of information sharing on cybersecurity underinvestment: A real options perspective. Journal of Accounting and Public Policy, 34 (5), 509–519. doi: https://doi.org/10.1016/j.jaccpubpol.2015.05.001
26. Gal-Or, E., Ghose, A. (2005). The Economic Incentives for Sharing Security Information. Information Systems Research, 16 (2), 186–208. doi: https://doi.org/10.1287/isre.1050.0053
27. Gordon, L. A., Loeb, M. P., Lucyshyn, W. (2003). Sharing information on computer systems security: An economic analysis. Journal of Accounting and Public Policy, 22 (6), 461–485. doi: https://doi.org/10.1016/j.jaccpubpol.2003.09.001
28. Varian, H. (2004). System Reliability and Free Riding. Advances in Information Security, 1–15. doi: https://doi.org/10.1007/1-4020-8090-5_1
29. Anderson, R., Moore, T. (2006). The Economics of Information Security. Science, 314 (5799), 610–613. doi: https://doi.org/10.1126/science.1130992
30. Bohme, R., Moore, T. (2009). The Iterated Weakest Link A Model of Adaptive Security Investment. In Workshop on Economics in Information Security.

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DETERMINING THE SOURCE DATA TO FORM A CONTROL ALGORITHM FOR HYDROGEN GENERATORS (p. 58-64)

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Constructing an algorithm to control the technical condition of hydrogen generators employs using their amplitude-frequency and phase-frequency characteristics as the source data. Applying the classic method for defining such characteristics predetermines several drawbacks. One of the significant disadvantages is the long time required to form an array of source data. To shorten this time, determining the frequency characteristics of a hydrogen generator is carried out based on the results of measuring its transition function over discrete moments of time. During these time moments, the transition function is approximated by the Heaviside functions. Such an approach reduces the time for determining the frequency characteristics of a hydrogen generator by 1–2 orders. Applying the Kotelnikov–Nyquist–Shannon theorem for determining these discrete time moments is due to uncertainty about the maximum frequency of the test-signal spectrum.

To avoid this uncertainty, discrete time moments for measuring the transitional function of a hydrogen generator are chosen under condition for the permissible error of its approximation.

The error of approximation is determined based on the result from solving a test-problem that uses model characteristics as a standard for the frequency characteristics. It has been shown that at a sampling interval of (0.25÷2.5) ms the magnitude of such an error does not exceed 1.7 %.

Inertial properties of the device that forms a test-impact have been taken into consideration. It has been shown that it is appropriate to apply such a procedure if the equivalent time constant of such a device exceeds the magnitudes of time constants for a hydrogen generator. The inertial properties are taken into consideration by introducing an additional multiplier, which contains the equivalent time constant of the device, to the analytical expressions for the frequency characteristics of a hydrogen generator.

Keywords: hydrogen generator, source data, frequency characteristics, test-problem, approximation error.

References

1. Dli, M. I., Baliabina, A. A., Drozdova, N. V. (2016). Hydrogen energy and development prospects. Alternative Energy and Ecology (ISJAEE), 22, 37–41. doi: https://doi.org/10.15518/isjaee.2015.22.004
2. Rodchenko, V. V., Galeev, A. G., Popov, B. B., Galeev, A. V. (2015). Study of security systems of oxygen-hydrogen propulsion plant test on the stand. Alternative Energy and Ecology (ISJAEE), 20, 42–52. doi: https://doi.org/10.15518/isjaee.2015.20.005
3. Galeev, A. G. (2017). Review of engineering solutions applicable in tests of liquid rocket engines and propulsion systems employing hydrogen as a fuel and relevant safety assurance aspects. International Journal of Hydrogen Energy, 42 (39), 25037–25047. doi: https://doi.org/10.1016/j.ijhydene.2017.06.242
4. Rusman, N. A. A., Dahari, M. (2016). A review on the current progress of metal hydrides material for solid-state hydrogen storage applications. International Journal of Hydrogen Energy, 41 (28), 12108–12126. doi: https://doi.org/10.1016/j.ijhydene.2016.05.244
5. Ley, M., Meggouh, M., Moury, R., Peinecke, K., Felderhoff, M. (2015). Development of Hydrogen Storage Tank Systems Based on Complex Metal Hydrides. Materials, 8 (9), 5891–5921. doi: https://doi.org/10.3390/ma8095280
6. Lototskyy, M. V., Davids, M. W., Tolj, I., Klochko, Y. V., Sekhar, B. S., Chidziva, S. et. al. (2015). Metal hydride systems for hydrogen

storage and supply for stationary and automotive low temperature PEM fuel cell power modules. International Journal of Hydrogen Energy, 40 (35), 11491–11497. doi: https://doi.org/10.1016/j.ijhydene.2015.01.095

7. Dmitriev, A. L., Ikonnikov, V. K. (2017). Hydrogen fueling station using hydrogen generation by aluminum powder hydrothermal oxidation. Alternative Energy and Ecology (ISJAEE), 10-12, 75–85. doi: https://doi.org/10.15518/isjaee.2017.10-12.075-085
8. Abramov, Y. A., Krivtsova, V. I. (2017). To determine the technical state of the gas generator of the hydrogen storage and supply system. Problems of Emergencies, 26, 3–10.
9. Lototskyy, M. V., Tolj, I., Parsons, A., Smith, F., Sita, C., Linkov, V. (2016). Performance of electric forklift with low-temperature polymer exchange membrane fuel cell power module and metal hydride hydrogen storage extension tank. Journal of Power Sources, 316, 239–250. doi: https://doi.org/10.1016/j.jpowsour.2016.03.058
10. Sabadosh, L., Larkov, S., Kravchenko, O., Sereda, V. (2018). Increasingly Safe, High-Energy Propulsion System for Nano-Satellites. Transactions on Aerospace Research, 2018 (4), 38–44. doi: https://doi.org/10.2478/tar-2018-0028
11. Kotowicz, J., Bartela, Ł., Węcel, D., Dubiel, K. (2017). Hydrogen generator characteristics for storage of renewably-generated energy. Energy, 118, 156–171. doi: https://doi.org/10.1016/j.energy.2016.11.148
12. Zhao, L., Brouwer, J. (2015). Dynamic operation and feasibility study of a self-sustainable hydrogen fueling station using renewable energy sources. International Journal of Hydrogen Energy, 40 (10), 3822–3837. doi: https://doi.org/10.1016/j.ijhydene.2015.01.044
13. Kudryavtsev, P. G., Figovsky, O. L. (2016). System of storage and hydrogen generation for power propulsion systems and cars. Alternative Energy and Ecology (ISJAEE), 13-14, 46–55. doi: https://doi.org/10.15518/isjaee.2016.13-14.046-055
14. Abramov, Y., Borisenko, V., Krivtsova, V. (2017). Design of control algorithm over technical condition of hydrogen generators based on hydro-reactive compositions. Eastern-European Journal of Enterprise Technologies, 5 (8 (89)), 16–21. doi: https://doi.org/10.15587/1729-4061.2017.112200
15. Abramov, Y. A., Basmanov, O. E., Salamov, J., Mikhayluk, A. A. (2018). Model of thermal effect of fire within a dike on the oil tank. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 2, 95–101. doi: https://doi.org/10.29202/nvngu/2018-2/12