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DEVELOPMENT OF A FUZZY PRODUCTION MODEL FOR ASSESSING THE DEGREE OF INFORMATION SECURITY IN INTERNATIONAL COOPERATION

pages 6–10

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The object of research is the methods of assessing the information security indicator in the process of international cooperation.

The problem of unification and simplification of the processes of assessing the degree of information security is considered in order to reduce the involvement of human and material resources in them, using the apparatus of fuzzy set theory to take into account the conclusions of competent experts.

A fuzzy production model of assessing the degree of information security is developed, which is based on the use of expert knowledge and fuzzy logic methods. A step-by-step approach is proposed for identifying potential risks, classifying them by categories and calculating influence coefficients. An iterative assessment method is created, which allows obtaining a numerical indicator of the degree of information security. Heuristic rules for determining the effective assessment of the degree of information security are developed, taking into account the criticality factor and influence coefficients of different risk categories.

A classification of potential information security risks in international IT projects is proposed. An example of constructing production rules for a fuzzy knowledge base is demonstrated.

The results are explained by the use of systems analysis to take into account the relationships between different risk categories and the use of fuzzy logic to work with uncertain and incomplete data. The model is based on production rules that integrate expert judgment and allow for adaptive analysis in changing conditions of international cooperation.

The developed model can be used to assess information security in small and medium-sized international projects, where it is necessary to provide a quick and effective assessment of the level of security without involving significant resources. The model is especially useful in conditions where the data is fuzzy or incomplete, and the risks vary depending on the specifics of cooperation between different countries and organizations.

Keywords: fuzzy production model, information security, international cooperation, potential risks, influence coefficients, risk categories.

References

1. Mulesa, O., Yakob, E., Valko, P., Sviezhentseva, O., Marhitych, D. (2024). Development of decision-making technology for the provision of services in project implementation. *Technology Audit and Production Reserves, 2 (2 (76))*, 13–17. https://doi.org/10.15587/2706-5448.2024.301317
2. Mulesa, O., Horvat, P., Radivilova, T., Sabadosh, V., Baranovskyi, O., Duran, S. (2023). Design of mechanisms for ensuring the execution of tasks in project planning. *Eastern-European Journal of Enterprise Technologies, 2 (4 (122))*, 16–22. https://doi.org/10.15587/1729-4061.2023.277585
3. Vedadi, A., Warkentin, M., Dennis, A. (2021). Herd behavior in information security decision-making. *Information & Management, 58 (8)*, 103526. https://doi.org/10.1016/j.im.2021.103526
4. Georg-Schaffner, L., Prinz, E. (2021). Corporate management boards' information security orientation: an analysis of cybersecurity incidents in DAX 30 companies. *Journal of Management and Governance, 26 (4)*, 1375–1408. https://doi.org/10.1007/s10997-021-09588-4
5. Banitalebi Dehkordi, A., Soltanaghaei, M., Boroujeni, F. Z. (2020). The DDoS attacks detection through machine learning and statistical methods in SDN. *The Journal of Supercomputing, 77 (3)*, 2383–2415. https://doi.org/10.1007/s11227-020-03323-w
6. Ashok, K., Gopikrishnan, S. (2023). Statistical Analysis of Remote Health Monitoring Based IoT Security Models & Deployments From a Pragmatic Perspective. *IEEE Access, 11*, 2621–2651. https://doi.org/10.1109/access.2023.3234632
7. Radivilova, T., Kirichenko, L., Alghawli, A. S., Ageyev, D., Mulesa, O., Baranovskyi, O. et al.; Oliynykov, R., Kuznetsov, O., Lemeshko, O., Radivilova, T. (Eds.) (2022). Statistical and Signature Analysis Methods of Intrusion Detection. *Information Security Technologies in the Decentralized Distributed Networks. Vol. 115*. Cham: Springer International Publishing, 115–131. https://doi.org/10.1007/978-3-030-95161-0_5
8. Viktoriia, H., Hnatienko, H., Babenko, T. (2021). An intelligent model to assess information systems security level. *2021 Fifth World Conference on Smart Trends in Systems Security and Sustainability (WorldS4)*. London, 128–133. https://doi.org/10.1109/worlds451998.2021.9514019
9. Ganguli, C., Shandilya, S. K., Izonin, I. (2023). Design and implementation of adaptive network stabilization based on artificial bees colony optimization for nature inspired cyber security. *Journal of King Saud University – Science, 35 (5)*, 102713. https://doi.org/10.1016/j.jksus.2023.102713
10. Jin, X., Lü, S., Qin, J., Zheng, W. X., Liu, Q. (2023). Adaptive ELM-Based Security Control for a Class of Nonlinear-Interconnected Systems With DoS Attacks. *IEEE Transactions on Cybernetics, 53 (8)*, 5000–5012. https://doi.org/10.1109/tcyb.2023.3257133
11. Chen, H., Galteland, Y. J., Liang, K.; Guo, J., Steinfeld, R. (Eds.) (2023). CCA-1 Secure Updatable Encryption with Adaptive Security. *Advances in Cryptology – ASIACRYPT 2023. Vol. 14442*. Singapore: Springer Nature Singapore, 374–406. https://doi.org/10.1007/978-981-99-8733-7_12
12. Lizunov, P., Biloshchytskyi, A., Kuchansky, A., Andrashko, Y., Biloshchytska, S. (2019). Improvement of the method for scientific publications clustering based on n-gram analysis and fuzzy method for selecting research partners. *Eastern-European Journal of Enterprise Technologies, 4 (4 (100))*, 6–14. https://doi.org/10.15587/1729-4061.2019.175139
13. Saatchi, R. (2024). Fuzzy Logic Concepts, Developments and Implementation. *Information, 15 (10)*, 656. https://doi.org/10.3390/info15100656
14. Kerimkhulle, S., Dildebayeva, Z., Tokhmetov, A., Amirova, A., Tussupov, J., Makhazhanova, U., Adalbek, A., Taberkhan, R., Zakirova, A., Salykbayeva, A. (2023). Fuzzy Logic and Its Application in the Assessment of Information Security Risk of Industrial Internet of Things. *Symmetry, 15 (10)*, 1958. https://doi.org/10.3390/sym15101958
15. Vaidya, O. S., Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research, 169 (1)*, 1–29. https://doi.org/10.1016/j.ejor.2004.04.028

16. Paz, F., Moquillaza, A., Lecaros, A., Falconi, F., Aguirre, J., Ramos, C. (2023). Applying Heuristic Evaluation with Different Evaluator Profiles: A Comparative Study Between Novice and Expert Specialists. *Proceedings of the XI Latin American Conference on Human Computer Interaction*. Puebla: ACM, 1–7. https://doi.org/10.1145/3630970.3631063
17. Zhu, Y., Tian, D., Yan, F. (2020). Effectiveness of Entropy Weight Method in Decision-Making. *Mathematical Problems in Engineering, 2020,* 1–5. https://doi.org/10.1155/2020/3564835
18. Božanić, D., Pamučar, D., Milić, A., Marinković, D., Komazec, N. (2022). Modification of the Logarithm Methodology of Additive Weights (LMAW) by a Triangular Fuzzy Number and Its Application in Multi-Criteria Decision Making. *Axioms, 11 (3),* 89. https://doi.org/10.3390/axioms11030089
19. Balboa, A., Cuesta, A., González-Villa, J., Ortiz, G., Alvear, D. (2024). Logistic regression vs machine learning to predict evacuation decisions in fire alarm situations. *Safety Science, 174,* 106485. https://doi.org/10.1016/j.ssci.2024.106485
20. Herrera-Viedma, E., Palomares, I., Li, C.-C., Cabrerizo, F. J., Dong, Y., Chiclana, F., Herrera, F. (2021). Revisiting Fuzzy and Linguistic Decision Making: Scenarios and Challenges for Making Wiser Decisions in a Better Way. *IEEE Transactions on Systems, Man, and Cybernetics: Systems, 51 (1),* 191–208. https://doi.org/10.1109/tsmc.2020.3043016

SYSTEMS AND CONTROL PROCESSES

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ANALYSIS OF MACHINE LEARNING MODELS FOR FORECASTING RETAIL RESOURCES

pages 11–15

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The object of research is the process of forecasting loosely structured data of retail artifacts by means of machine learning.

The paper analyzes data and models for forecasting retail resources. The analysis is carried out for a specific business situation and task, when a large corporation needs a fuller loading of its own warehouses with goods and resources that will be used in future periods for sale or in projects. The task is to reduce overall corporate costs by purchasing the necessary goods/resources in advance. The data required for forecasting, their sources and properties are defined. It is shown that the data will come from different sources, will have a different time interval, categorical component and logistic reference. RNN, LSTM, Random Forest, Gradient Boosting, XGBoost models and forecasting methods were chosen for such data. They were analyzed according to the criteria of data source, time interval, categorization of data, availability of a logistic component, flexibility of tools in working with heterogeneous data, requirements of tools for computing resources, interpretability of modeling results.

Data sources explain where the data for analysis comes from. Usually it is: stores, warehouses, logistics companies, projects and strategic plans of the corporation. The time interval characterizes the frequency and regularity of receiving data for analysis. The criterion "data categorization" characterizes how this type of data affects the quality of the analysis. The logistic parameters of the data also characterize the impact on the analysis. "Flexibility in working with heterogeneous data" shows the ability of the model to effectively work with data of different formats and sources. Requirements for computing resources determine their necessary power for training and operation of the model. Interpretability of a model characterizes its ability to explain how and why it makes specific decisions or predictions based on input data. The more complex the model, the more difficult it is to interpret. In the retail business, interpretability is important for explaining demand forecasts.

Based on the results of the analysis, the XGBoost model was recommended as the best for forecasting retail resources.

Keywords: machine learning models, retail, forecasting, retail resources, categorical data, model interpretability.

References

1. Vanessa Munoz Macas, C., Andres Espinoza Aguirre, J., Arcentales-Carrion, R., Pena, M. (2021). Inventory management for retail companies: A literature review and current trends. *2021 Second International Conference on Information Systems and Software Technologies (ICI2ST),* 71–78. https://doi.org/10.1109/ici2st51859.2021.00018
2. Tereshchenko, S. I., Hrymailo, O. V. (2023). Innovatsiini formy orhanizatsii rozdribnoi torhivli. *MNPK Tsyfrova transformatsiia ta dydzhytal tekhnolohii dlia staloho rozvytku vsikh haluzei suchasnoi osvity, nauky i praktyky,* 281–285. Available at: https://repo.btu.kharkov.ua/bitstream/123456789/29872/1/Zbi%C3%B3r_prac_3_2023-281-285.pdf
3. Zimmermann, R., Mora, D., Cirqueira, D., Helfert, M., Bezbradica, M., Werth, D. et al. (2022). Enhancing brick-and-mortar store shopping experience with an augmented reality shopping assistant application using personalized recommendations and explainable artificial intelligence. *Journal of Research in Interactive Marketing, 17 (2),* 273–298. https://doi.org/10.1108/jrim-09-2021-0237
4. Barskyi, S. Yu., Teslenko, P. O. (2024) Upravlinnia resursamy infrastrukturnykh proiektiv. *Informatsiini systemy v upravlinni proiektamy ta prohramamy.* KhNURE, 53–56.
5. Mitchell, T. M. (1997). Does machine learning really work? *AI magazine, 18 (3),* 11.
6. Bishop, C. M. (2016). *Pattern Recognition and Machine Learning.* New York: Springer, 778.
7. Goodfellow, I., Bengio, Y., Courville, A. (2016). *Deep Learning.* MIT Press. Available at: http://www.deeplearningbook.org
8. Hastie, T., Tibshirani, R., Friedman, J. (2009). *The Elements of Statistical Learning.* Data Mining, Inference, and Prediction. https://doi.org/10.1007/978-0-387-84858-7
9. Chai, T.-Y., Haw, S. C., Jahangir, M., Hoe, K. B., Heng, L. E., Vellaisamy, M. (2023). Advancing Retail Operations: A Customizable IoT-Based Smart Inventory System. *International Journal of Membrane Science and Technology, 10 (3),* 1885–1897. https://doi.org/10.15379/ijmst.v10i3.1848
10. Barskyi, S., Kopaniev, A. (2023). Sutnist ta osoblyvosti upravlinnia infrastrukturnymy proiektamy. *Project, program, portfolio management. R3M-2023.* IShIR, 228–230.
11. Grewal, D., Benoit, S., Noble, S. M., Guha, A., Ahlbom, C.-P., Nordfält, J. (2023). Leveraging In-Store Technology and AI: Increasing Customer and Employee Efficiency and Enhancing their Experiences. *Journal of Retailing, 99 (4),* 487–504. https://doi.org/10.1016/j.jretai.2023.10.002

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THEORETICAL AND PRACTICAL SUBSTANTIATION FOR PREDICTION OF EQUIVALENT DOSE RATE OF GAMMA RADIATION AT THE SUKHACHIVSKE TAILINGS STORAGE FACILITY I SECTION

pages 16–27

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The object of the study is the Sukhachivske industrial site, tailings storage facility section I (Ukraine). The main reason for conducting the study is to establish actual and forecast numerical values of absorbed and exposure dose rates. The state of radiation contamination of the tailing's storage facilities of the Sukhachivske industrial site was analyzed. The actual and prolonged levels of equivalent dose rate, absorbed dose rate, and total personnel exposure dose were determined. Dependencies were established that allow determining approximate numerical values for specific conditions and certain areas using the finite element method with subsequent transfer of values to 2024–2027. Based on the conducted studies, the dynamics of contamination at the Sukhachivske tailings storage facility section I was predicted. The estimated, forecast, and actual values of personnel exposure doses were determined for the period from 2010 to 2023. New methods and algorithms for instrumental measurement of radiation parameters at the tailing's facilities of the former uranium production facility of the Prydniprovsky Chemical Plant have been developed. The state of radiation contamination of the tailing's facilities of the Sukhachivke industrial site has been analyzed. The actual and prolonged levels of equivalent dose rate, absorbed dose rate, total personnel exposure dose, and contamination levels of the territories adjacent to the tailings facilities have been determined. Monitoring studies over ten years have allowed to determine the actual values of the exposure dose rate, which range from 0.08 to 0.21 μSv/h with certain local values up to 0.26 μSv/h. In general, the total personnel exposure dose does not exceed 1.1–1.4 mSv/year. The obtained data on prognostic values, in turn, make it possible to predict the further radiation situation at the Sukhachivske industrial site in the coming years. As well as to improve the system for calculating the total effective radiation dose, both to the personnel of the radiation-hazardous facility and to the population living near the industrial site.

Keywords: measurement of parameters, tailings facility, radiation facility, radiation monitoring, γ-radiation, absorbed and exposure dose rates.

References

1. Coulibaly, A., Kpeglo, D. O., Darko, E. O. (2023). Assessment of Radiological Hazards in Some Foods Products Consumed by the Malian Population Using Gamma Spectrometry. *Journal of Radiation Protection and Research, 48 (2),* 84–89. https://doi.org/10.14407/jrpr.2022.00178
2. Nkoulou, J. E. N., Engola, L. N., Dallou, G. B., Saïdou, Bongue, D., Hosoda, M. et al. (2023). Public Exposure to Natural Radiation and the Associated Increased Risk of Lung Cancer in the Betare-Oya Gold Mining Areas, Eastern Cameroon. *Journal of Radiation Protection and Research, 48 (2),* 59–67. https://doi.org/10.14407/jrpr.2021.00388
3. Ghazal, A. A., Alakash, R., Aljumaili, Z., El-Sayed, A., Abdel-Rahman, H. (2023). Enhancing Gamma-Neutron Shielding Effectiveness of Polyvinylidene Fluoride for Potent Applications in Nuclear Industries: A Study on the Impact of Tungsten Carbide, Trioxide, and Disulfide Using EpiXS, Phy-X/PSD, and MCNP5 Code. *Journal of Radiation Protection and Research, 48 (4),* 184–196. https://doi.org/10.14407/jrpr.2023.00213
4. Lee, C. (2024). A Review of Organ Dose Calculation Methods and Tools for Patients Undergoing Diagnostic Nuclear Medicine Procedures. *Journal of Radiation Protection and Research, 49 (1),* 1–18. https://doi.org/10.14407/jrpr.2023.00087
5. Lee, Y., Choi, J. W., Braunstein, L., Lee, C., Yeom, Y. S. (2024). Investigation on Individual Variation of Organ Doses for Photon External Exposures: A Monte Carlo Simulation Study. *Journal of Radiation Protection and Research, 49 (1),* 50–64. https://doi.org/10.14407/jrpr.2023.00661
6. Poorbaygi, H., Salimi, S. M., Torkzadeh, F., Hamidi, S., Sheibani, S. (2023). Determination of Exposure during Handling of 125I Seed Using Thermoluminescent Dosimeter and Monte Carlo Method Based on Computational Phantom. *Journal of Radiation Protection and Research, 48 (4),* 197–203. https://doi.org/10.14407/jrpr.2023.00255
7. Nizam, Q. M. R., Ahmed, A., Ahmed, I. (2023). Monte Carlo Calculation for Production Cross-Sections of Projectile's Isotopes from Therapeutic Carbon and Helium Ion Beams in Different Materials. *Journal of Radiation Protection and Research, 48 (4),* 204–212. https://doi.org/10.14407/jrpr.2023.00262
8. Pylypenko, O., Shalomov, V., Strezhekurov, Y., Rudenko, V., Tymchenko, P. (2024). The effect of external radiation exposure per person depending on his position and anthropometric indicators. *E3S Web of Conferences, 534,* 01016. https://doi.org/10.1051/e3sconf/202453401016
9. Bernhardsson, C. (2014). Experimental determination of dose conversion coefficients for external radiation exposure with gamma emitting radionuclides. *Radiatsionnaya Gygiena, 7 (4),* 125–133. Available at: https://lup.lub.lu.se/record/5048649
10. Sasaki, M., Furukawa, K., Satoh, D., Shimada, K., Kudo, S., Takagi, S. et al. (2023). SUMRAY: R and Python Codes for Calculating Cancer Risk Due to Radiation Exposure of a Population. *Journal of Radiation Protection and Research, 48 (2),* 90–99. https://doi.org/10.14407/jrpr.2022.00213

11. *Deiaki pytannia identyfikatsii obiektiv pidvyshchenoi nebezpeky* (2022). Postanova KMU No. 1030. 13.09.2022. Available at: https://www.kmu.gov.ua/npas/deiaki-pytannia-identyfikatsii-obiektiv-1030
12. *Deiaki pytannia obiektiv krytychnoi infrastruktury* (2024). Postanova KMU No. 1109. 09.10.2020. Available at: https://zakon.rada.gov.ua/laws/show/1109-2020-%D0%BF#Text
13. *ICRP, 1991. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Ann. ICRP 21 (1–3)* (1991). ICRP. Available at: https://www.icrp.org/publication.asp?id=icrp%20publication%2060
14. *ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2–4)* (2007). ICRP. Available at: https://www.icrp.org/publication.asp?id=ICRP%20Publication%20103
15. *ICRP, 2022. Occupational Intakes of Radionuclides: Part 5. ICRP Publication 151. Ann. ICRP 51 (1–2)* (2022). ICRP. Available at: https://www.icrp.org/publication.asp?id=ICRP%20Publication%20151
16. Trubey, D. K., Harima, Y. (1986). *New Buildup Factor Data for Point Kernel Calculations.* Technical Report. Oak Ridge National Lab. Available at: https://www.osti.gov/servlets/purl/6401756
17. Little, A., Piggott, M. D., Buchan, A. G. (2022). Development of a gamma ray dose rate calculation and mapping tool for Lagrangian marine nuclear emergency response models. *Marine Pollution Bulletin, 181,* 113895. https://doi.org/10.1016/j.marpolbul.2022.113895
18. *ICRP, 2022. Radiation detriment calculation methodology. ICRP Publication 152. Ann. ICRP 51(3)* (2022). ICRP. Available at: https://www.icrp.org/publication.asp?id=ICRP%20Publication%20152

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DEVELOPMENT OF A TRAFFIC DECONGESTION MODEL AT CONSTANTINE CITY TO IMPROVE URBAN MOBILITY: CASE OF THE ZOUAGHI SLIMANE CROSSROAD (ALGERIA)

pages 28–34

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The object of the study is modeling traffic congestion. For modeling traffic congestion in the aim to get better fluidity of road traffic mainly in urban areas, it is necessary to use powerful computers, ahead the complexity of the task. Because, road traffic is a complex phenomenon especially at crossroads, firstly due to the high number of users who use it, secondly the nature of the crossroads which have a complex mesh network. In this paper, a mathematical approach based on the Greenshield model who interested in the study of traffic performance at crossroads is developed. This model permit to control and regulate traffic urban which must meet various objectives like: minimizing wait times for vehicles at crossroads, optimization of traffic flows on the road network. The application treated in this papier is the Zouaghi Slimane crossroads of Constantine city (Algeria). According obtained results, the time spent at crossroads Zouaghi Slimane can reach more than 45 minutes and more for day. This situation brings to asking the following question: how to reduce the travel time lost at this crossroads? To give the answer at this last question, the first step is to considering the different variables that characterize the progressive movement of vehicles on a road. In the objective to give a mathematical formulation, which links, the number of vehicles present at time t over a length L of the road. Speed is one of the basic parameters of traffic flow, the relationship between the fundamental parameters of traffic considers the different variables that characterize the progressive movement of vehicles on a road permit to give a mathematical formulation which links the number of vehicles present at time "t" over a length "L" of the road. The main objective is to bring out indicators such as speeds, density and critical flows allowing to set up a dynamic management of the traffic, for a decongestion the crossroads Zouaghi Slimane.

Keywords: traffic road, modelling traffic congestion, critical flows, traffic dynamic management, regulate traffic urban.

References

1. Forstall, R. L., Greene, R. P., Pick, J. B. (2009). Which are the largest? Why lists of major urban areas vary so greatly. *Tijdschrift Voor Economische En Sociale Geografie, 100 (3),* 277–297. https://doi.org/10.1111/j.1467-9663.2009.00537.x
2. Greene, R. P., Pick, J. B. (2012). *Exploring the Urban Community: A GIS Approach*. Pearson Prentice Hall, 432.
3. Abdo, J. (2011). *Construire de nouvelles infrastructures routières. La solution to la congestion du trafic ?* Centre d'inforamtion sur le ciment et ses application. Available at: https://www.infociments.fr/route/t32-construire-de-nouvelles-infrastructures-routieres
4. Ujjwal, J., Bandyopadhyaya, V., Bandyopadhyaya, R. (2021). Identifying key determinants for parking management to reduce road traffic congestion for congested cities-A Structural Equation Modelling approach. *Advances in Transportation Studies, 54*, 143–158.
5. Pick, J. B., Azari, R. (2008). Global digital divide: Influence of socioeconomic, governmental, and accessibility factors on information technology. *Information Technology for Development, 14 (2),* 91–115. https://doi.org/10.1002/itdj.20095
6. Weisbrod, G., Vary, D., Treyz, G. (2003). Measuring Economic Costs of Urban Traffic Congestion to Business. *Transportation Research Record: Journal of the Transportation Research Board, 1839 (1),* 98–106. https://doi.org/10.3141/1839-10
7. Apte, J. S., Bombrun, E., Marshall, J. D., Nazaroff, W. W. (2012). Global Intraurban Intake Fractions for Primary Air Pollutants from Vehicles and Other Distributed Sources. *Environmental Science & Technology, 46 (6),* 3415–3423. https://doi.org/10.1021/es204021h
8. Lighthill, M. J., Whitham, G. B. (1955). On kinematic waves I. Flood movement in long rivers. *Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences, 229 (1178),* 281–316. https://doi.org/10.1098/rspa.1955.0088
9. Richards, P. I. (1956). Shock Waves on the Highway. *Operations Research, 4 (1),* 42–51. https://doi.org/10.1287/opre.4.1.42
10. Greenshields, B. D., Bibbins, J. R., Channing, W. S., Miller, H. H. (1935). A study of traffic capacity. *Highway Research Board proceedings*. Available at: https://www.safetylit.org/citations/index.php?fuseaction=citations.viewdetails&citationIds[]=citjournalarticle_248667_38
11. Payne, H. J. (1971). Model of Freeway Traffic and Control. *Mathematical Model of Public System, 1 (1),* 51–61.
12. Fares, B., Kechida, S., Bencheriet, C. ennehar. (2013). Modélisation d'un Reseau du Trafic Urbain par Automate Hybride. *Proceedings of Conference International Conference on Systems and Information Processing*. Guelma. https://doi.org/10.13140/RG.2.2.31132.90241
13. Geroliminis, N., Sun, J. (2011). Properties of a well-defined macroscopic fundamental diagram for urban traffic. *Transportation Research*

ISSN-L 2664-9969; E-ISSN 2706-5448

Part B: Methodological, 45 (3), 605–617. https://doi.org/10.1016/j.trb.2010.11.004

14. Treiber, M., Kesting, A., Helbing, D. (2010). Three-phase traffic theory and two-phase models with a fundamental diagram in the light of empirical stylized facts. *Transportation Research Part B: Methodological, 44 (8-9)*, 983–1000. https://doi.org/10.1016/j.trb.2010.03.004
15. Khelf, M., Boukebbab, S., Boulahlib, M. S.; Zamojski, W., Mazurkiewicz, J., Sugier, J., Walkowiak, T., Kacprzyk, J. (Eds.) (2016). A Mathematical Model to Regulate Roads Traffic in Order to Decongest the Urban Areas of Constantine City. *Dependability Engineering and Complex Systems*. Cham: Springer International Publishing, 279–289. https://doi.org/10.1007/978-3-319-39639-2_24
16. Guo, Y. R., Wang, X. M., Wang, M., Zhang, H. (2020). Research on prediction of urban congestion based on radial basis function network. *Advances in Transportation Studies, Special Issue 1,* 145–156.
17. Wang, H. X., Zheng, H. J. (2021). Prediction method of traffic congestion volume in traffic jam road section based on genetic algorithm. *Advances in Transportation Studies, Special Issue 2,* 79–90.
18. Lidbe, A., Tedla, E., Hainen, A., Sullivan, A., Jones Jr, S. (2017). Comparative assessment of arterial operations under conventional time-of-day and adaptive traffic signal control. *Advances in Transportation Studies, 42,* 5–22.
19. Mathew, T. V. (2017). Fundamental Relations of Traffic Flow. *Lecture Notes in Transportation Systems Engineering.* IIT Bombay.
20. Mathew, T. V., Krishna Rao, K. V. (2007). Introduction to Transportation Engineering. *Lecture Notes in Transportation Systems Engineering.*
21. Greenshields, B. D., Shapiro, D., Erickson, E. L. (1947). *Traffic performance at urban street intersections. Tech. Rep. No. 1, Yale Bureau of Highway Traffic*. New Haven: Yale University.

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DEVELOPMENT OF A HARDWARE-SOFTWARE SOLUTION FOR DETECTION OF COMPLEX-SHAPED OBJECTS IN VIDEO STREAM

pages 35–40

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The object of the study is the process of diagnosing complex-shaped objects in a video stream. The paper investigates the applied problem of creating a hardware-software solution for detecting complex-shaped objects in a video stream. Single-board computers Raspberry Pi models 4 and 5 with additional UPS HAT (D) modules and 21700 batteries were used as hardware, ensuring operation in the absence of power supply. Serial Camera Interface cameras and Full HD 1080p webcams were connected to the single-board computers to study effective methods of video processing using several studied video processing architectures. Eight video processing architectures based on the Oriented Features from Accelerated Segment Test and Rotated Binary Robust Independent Elementary Features and Scale-Invariant Feature Transform methods were considered. Each video processing architecture was tested using a one-minute video, where its average performance was determined. The limitations of video processing were a region of interest of 400×300 pixels and the presence of a limited number of reference images. To automate the launch of programs on single-board computers, the systemd initialization system was used.

Known video processing algorithms were considered and a modification of the algorithm was proposed by using a double check for the presence of an object in the video stream. A hardware-software solution was implemented, consisting of a single-board computer with external cameras connected to it, and software for detecting complex-shaped objects in the video stream was created. The solution is useful as an auxiliary tool for detecting complex-shaped objects in the video stream on robotic platforms, in industry, everyday life, the educational process, and when repairing electronic modules. The practical significance of the study lies in the fact that the architecture for processing complex-shaped objects has been further developed. They provide for a double check for the presence of an object in the video stream, which increases the processing time of one frame, and on the other hand, increases the efficiency of object detection based on only one reference photo.

Keywords: computer vision, single-board computer, initialization system, double-check, video processing algorithms.

References

1. Guo, J., Shao, M., Chen, X., Yang, Y., Sun, E. (2024). Research on night-time vehicle target detection based on improved KSC-YOLO V5. *Signal, Image and Video Processing, 19 (1)*. https://doi.org/10.1007/s11760-024-03576-5
2. Krasnobayev, V., Yanko, A., Fil, I. (2024). Fault-Tolerant Operation of an Integer Data Processing System. *Mathematical Modeling and Simulation of Systems*. Springer, 172–185. https://doi.org/10.1007/978-3-031-67348-1_13
3. Krasnobayev, V., Yanko, A., Kovalchuk, D., Fil, I. (2024). Synthesis of a Mathematical Model of a Fault-Tolerant Real-Time Computer System Operating in Non-positional Arithmetic in Residual Classes. *Mathematical Modeling and Simulation of Systems*. Springer, 186–199. https://doi.org/10.1007/978-3-031-67348-1_14
4. Krasnobayev, V., Yanko, A., Hlushko, A., Kruk, O., Kruk, O., Gakh, V. (2023). Cyberspace protection system based on the data comparison method. *Economic and cyber security.* Kharkiv: PC TECHNOLOGY CENTER, 3–29. https://doi.org/10.15587/978-617-7319-98-5.ch1
5. Pushkarenko, Y., Zaslavskyi, V. (2024). Research on the state of areas in Ukraine affected by military actions based on remote sensing data and deep learning architectures. *Radioelectronic and Computer Systems, 2024 (2),* 5–18. https://doi.org/10.32620/reks.2024.2.01
6. *Ultralytics YOLO Docs*. Available at: https://docs.ultralytics.com
7. Liu, W., Anguelov, D., Erhan, D., Szegedy, C., Reed, S., Fu, C.-Y., Berg, A.; C. Leibe, B., Matas, J., Sebe, N., Welling, M. (Eds.) (2016). SSD: Single Shot MultiBox Detector. *Computer Vision – ECCV 2016*. Cham: Springer, 21–37. https://doi.org/10.1007/978-3-319-46448-0_2
8. Svistun, L., Glushko, A., Shtepenko, K. (2018). Organizational Aspects of Development Projects Implementation at the Real Estate Market in Ukraine. *International Journal of Engineering & Technology, 7 (3.2)*, 447. https://doi.org/10.14419/ijet.v7i3.2.14569
9. Ran, Y., Xu, X. (2020). Point cloud registration method based on SIFT and geometry feature. *Optik, 203,* 163902. https://doi.org/10.1016/j.ijleo.2019.163902
10. Singh, P. K., Jana, B., Datta, K. (2022). Robust data hiding scheme through distinct keypoint selection exploiting modified Bilateral-

Laplacian SIFT with encoding pipeline. *Displays, 74,* 102268. https://doi.org/10.1016/j.displa.2022.102268
11. Sun, Y. (2024). Exploration on Data Collection and Analysis System Based on Integrated SIFT Algorithm. *Procedia Computer Science, 243,* 388–395. https://doi.org/10.1016/j.procs.2024.09.048
12. Yu, Q., Ni, D., Jiang, Y., Yan, Y., An, J., Sun, T. (2021). Universal SAR and optical image registration via a novel SIFT framework based on nonlinear diffusion and a polar spatial-frequency descriptor. *ISPRS Journal of Photogrammetry and Remote Sensing, 171,* 1–17. https://doi.org/10.1016/j.isprsjprs.2020.10.019
13. Li, Y., Li, Q., Liu, Y., Xie, W. (2019). A spatial-spectral SIFT for hyperspectral image matching and classification. *Pattern Recognition Letters, 127,* 18–26. https://doi.org/10.1016/j.patrec.2018.08.032
14. Pavithra, S., Shreyashwini, N. K., Bhavana, H. S., Nikhitha, G., Kavitha, T. (2023). Hand-Drawn Electronic Component Recognition Using ORB. *Procedia Computer Science, 218,* 504–513. https://doi.org/10.1016/j.procs.2023.01.032
15. Belmessaoud, N. M., Bentoutou, Y., Chikr El-Mezouar, M. (2022). FPGA implementation of feature detection and matching using ORB. *Microprocessors and Microsystems, 94,* 104666. https://doi.org/10.1016/j.micpro.2022.104666
16. Sharif, H., Hölzel, M. (2017). A comparison of prefilters in ORB-based object detection. *Pattern Recognition Letters, 93,* 154–161. https://doi.org/10.1016/j.patrec.2016.11.007
17. A, V., Cholin, A. S., Bhat, A. D., Murthy, K. N. B., Natarajan, S. (2018). An Efficient ORB based Face Recognition framework for Human-Robot Interaction. *Procedia Computer Science, 133,* 913–923. https://doi.org/10.1016/j.procs.2018.07.095
18. Taranco, R., Arnau, J.-M., González, A. (2023). LOCATOR: Low-power ORB accelerator for autonomous cars. *Journal of Parallel and Distributed Computing, 174,* 32–45. https://doi.org/10.1016/j.jpdc.2022.12.005
19. Wu, T., Hung, I.-K., Xu, H., Yang, L., Wang, Y., Fang, L., Lou, X. (2022). An Optimized SIFT-OCT Algorithm for Stitching Aerial Images of a Loblolly Pine Plantation. *Forests, 13 (9),* 1475. https://doi.org/10.3390/f13091475
20. Khudov, H., Hridasov, I., Khizhnyak, I., Yuzova, I., Solomonenko, Y. (2024). Segmentation of image from a first-person-view unmanned aerial vehicle based on a simple ant algorithm. *Information and Controlling System, 4 (9 (130)),* 44–55. https://doi.org/10.15587/1729-4061.2024.310372
21. Rebrov, V., Lukin, V. (2023). Post-processing of compressed noisy images by BM3D filter. *Radioelectronic and Computer Systems, 4,* 100–111. https://doi.org/10.32620/reks.2023.4.09
22. Bilozerskyi, V., Dergachov, K., Krasnov, L., Zymovin, A., Popov, A. (2023). New method for video stream brightness stabilization: algorithms and performance evaluation. *Radioelectronic and Computer Systems, 3,* 125–135. https://doi.org/10.32620/reks.2023.3.10
23. Shefer, O., Laktionov, O., Pents, V., Hlushko, A., Kuchuk, N. (2024). Practical principles of integrating artificial intelligence into the technology of regional security predicting. *Advanced Information Systems, 8 (1),* 86–93. https://doi.org/10.20998/2522-9052.2024.1.11
24. Polshchykov, K., Zdorenko, Y., Masesov, M. (2015). Neuro-fuzzy system for prediction of telecommunication channel load. *2015 Second International Scientific-Practical Conference Problems of Infocommunications Science and Technology (PIC S&T)*. Kharkiv, 33–34. https://doi.org/10.1109/infocommst.2015.7357261
25. Onyshchenko, S., Haitan, O., Yanko, A., Zdorenko, Yu., Rudenko, O. (2024). Method for detection of the modified DDoS cyber attacks on a web resource of an Information and Telecommunication Network based on the use of intelligent systems. *Proceedings of the Modern Data Science Technologies Workshop (MoDaST 2024)*. Lviv, 219–235. Available at: https://ceur-ws.org/Vol-3723/paper12.pdf
26. Rublee, E., Rabaud, V., Konolige, K., Bradski, G. (2011). ORB: An efficient alternative to SIFT or SURF. *2011 International Conference on Computer Vision,* 2564–2571. https://doi.org/10.1109/iccv.2011.6126544
27. Lowe, D. G. (1999). Object recognition from local scale-invariant features. *Proceedings of the Seventh IEEE International Conference on Computer Vision,* 1150–1157. https://doi.org/10.1109/iccv.1999.790410
28. Muja, M., Lowe, D. G. (2009). Fast approximate nearest neighbors with automatic algorithm configuration. *International Conference on Computer Vision Theory and Application (VISSAPP),* 331–340. https://doi.org/10.5220/0001787803310340
29. Lowe, D. G. (2004). Distinctive Image Features from Scale-Invariant Keypoints. *International Journal of Computer Vision, 60 (2),* 91–110. https://doi.org/10.1023/b:visi.0000029664.99615.94
30. *Visual Studio Code*. Available at: https://code.visualstudio.com/
31. Männel, W. (2023). *The ultimate guide on using systemd to autostart scripts on the Raspberry Pi*. TheDigitalPictureFrame.com. Available at: https://www.thedigitalpictureframe.com/ultimate-guide-systemd-autostart-scripts-raspberry-pi/
32. Laktionov, O., Yanko, A., Pedchenko, N. (2024). Identification of air targets using a hybrid clustering algorithm. *Eastern-European Journal of Enterprise Technologies, 5 (4 (131)),* 89–95. https://doi.org/10.15587/1729-4061.2024.314289
33. Fedorenko, G., Fesenko, H., Kharchenko, V. (2022). Analysis of methods and development of the concept of guaranteed detection and recognition of explosive objects. *Innovative Technologies and Scientific Solutions for Industries, 4 (22),* 20–31. https://doi.org/10.30837/itssi.2022.22.020
34. Sun, Y., Fesenko, H., Kharchenko, V., Zhong, L., Kliushnikov, I., Illiashenko, O., Morozova, O., Sachenko, A. (2022). UAV and IoT-Based Systems for the Monitoring of Industrial Facilities Using Digital Twins: Methodology, Reliability Models, and Application. *Sensors, 22 (17),* 6444. https://doi.org/10.3390/s22176444
35. *MultiWii. MultiWii flight controller source code and documentation*. Available at: https://github.com/multiwii

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CONTROL OF BOILER EQUIPMENTS DURING STARTING AND STOPPING PERIODS AND METHODS OF OPTIMIZING THESE PROCESSES THROUGH THE USE OF A DECISION SUPPORT SYSTEM WITH A MACHINE VISION SUBSYSTEM

pages 41–49

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The object of research is the automation of starting and stopping steam power boilers. The problem of automating the starting and stopping of steam power boilers is important for thermal power plants (TPP) and industrial enterprises. These processes require significant efforts from service personnel due to their complexity, partial automation and the need to take into account the human factor. It is emphasized that full automation of starting and stopping steam boilers is economically impractical, since most of the time the boilers

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operate in continuous automatic operations and only a short time is allocated for periodic procedures, which are mostly performed manually. However, the significant impact of the human factor at critical stages of boiler operation requires the introduction of new technologies that can increase the efficiency and safety of such operations. The study outlines the main challenges associated with steam boiler control and proposes new approaches to solving these problems. It is noted that operators often perform actions during boiler starting and stopping based on instructions or their own experience. This knowledge can be formalized and integrated into the database of an expert decision support system (DSS), which automates some of the manual actions and helps operators avoid errors. For this purpose, it is proposed to use machine vision subsystems that can validate the operator's actions, analyze the interaction of personnel with the equipment and signal about possible incorrect actions. This approach can not only reduce the risk of errors due to fatigue or stress of personnel, but also make the starting and stopping processes safer and more efficient.

It is proposed to integrate machine vision subsystems to obtain information that is difficult to measure by traditional means, in particular, regarding the operator's interaction with manual mechanisms or its presence at the workplace. The structure of the proposed DSS also takes into account the possibility of transferring knowledge bases between different objects, which ensures the scalability and adaptability of the system. The implementation of such a system is based on modern international automation standards, in particular ISA-88, ISA-106 and VDI/VDE/VDMA 2632.

Keywords: decision support system, machine vision, steam boiler, production equipment, control procedures, manual equipment.

References

1. Kochanek, S., Xing, J., Yilmaz, A., Edward Gibson, G., Tang, P. (2022). Using Computer Vision to Reduce Human Errors of Operating on the Wrong Control Valves in Nuclear Power Plants. *Human Factors in Energy: Oil, Gas, Nuclear and Electric Power*. https://doi.org/10.54941/ahfe1002217
2. Mo, K., Lee, S. J., Seong, P. H. (2007). A neural network based operation guidance system for procedure presentation and operation validation in nuclear power plants. *Annals of Nuclear Energy, 34 (10)*, 813–823. https://doi.org/10.1016/j.anucene.2007.04.008
3. Sethu, M., Titu, N., Hu, D., Madadi, M., Coble, J., Boring, R. et al. (2021). Using Artificial Intelligence to Mitigate Human Factor Errors in Nuclear Power Plants: A Review. *12th Nuclear Plant Instrumentation, Control and Human-Machine Interface Technologies (NPIC&HMIT 2021)*, 129–141. https://doi.org/10.13182/t124-34339
4. Sun, Z., Xing, J., Tang, P., Cooke, N. J., Boring, R. L. (2020). Human reliability for safe and efficient civil infrastructure operation and maintenance – A review. *Developments in the Built Environment, 4*, 100028. https://doi.org/10.1016/j.dibe.2020.100028
5. Shi, Y., Li, M., Wang, J., Wen, J., Cui, F., Qiao, G. (2022). Prediction of Ash Deposition on Heating Surfaces of Coal-fired Power Plant Boiler based on Dynamic Neural Network. *2022 34th Chinese Control and Decision Conference (CCDC)*, 779–783. https://doi.org/10.1109/ccdc55256.2022.10034385
6. Levchenko, O. I., Sidletskyi, V. M. (2014). *Osnovy avtomatyzatsiyi teploenerhetychnykh protsesiv ta ustanovok*. Kyiv: NUKhT, 227.
7. Pupena, O., Klymenko, O., Shyshak, A., Mirkevych, R. (2019). *Standarty intehruvannia system keruvannia pidpryiemstvom ta vyrobnytstvom: suchasnyi stan ta perspektyvy v Ukraini*. Standart MEK 62264. Kyiv. Available at: https://tk185.appau.org.ua/whitepapers/62264.pdf
8. Wilkins, M., Tennant, M. (2015). *ISA-106 and concepts of procedural automation*. InTech. Available at: https://web-material3.yokogawa.com/InTech_ISA106_ePrints.pdf
9. Bondarenko, Ye. A. (2024). Avtomatyzatsiya kontroliu stanu ruchnykh mekhanichnykh ventyliv za dopomohoiu Python ta biblioteky kompiuternoho zoru OpenCV. *Materialy XI Mizhnarodnoi naukovo-tekhnichnoi Internet-konferentsiyi "Suchasni metody, informatsiyne, prohramne ta tekhnichne zabezpechennia system keruvannia orhanizatsiyno-tekhnichnymy ta tekhnolohichnymy kompleksamy"*. Kyiv: NUKhT, 191–192. Available at: http://kist.ntu.edu.ua/konferencii/53_konf_2024.pdf
10. Ladaniuk, A. P., Smitiukh, Ya. V., Vlasenko, L. O. et al. (2013). *Systemnyi analiz skladnykh system upravlinnia*. Kyiv: NUKhT, 276.

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ANALYSIS OF THE DISTRIBUTION OF GAS TURBINE UNIT OPERATION MODES AS A TOOL FOR IMPROVING THE STABILITY OF THE POWER SYSTEM

pages 50–57

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The object of research is the optimal distribution of operating modes of gas turbine units (GTU) as a tool for increasing the stability of the Ukrainian power system in crisis situations. Given the challenges caused by the destruction of the energy infrastructure due to massive shelling, ensuring the stability of electricity supply requires the development of new approaches to frequency regulation. The frequency of electricity is a critical parameter that determines the balance between generation and consumption. Its violation can cause serious consequences, such as equipment shutdown and destabilization of the power system.

The work was aimed at creating mathematical models of GTU and the power system, allowing to analyze the change in frequency and power depending on the operating modes. As well as at developing a methodology for optimal load distribution between units under conditions of variable external influences. The work describes in detail the structure of the GTU model in the Simulink environment, which takes into account dynamic processes in gas volumes, the combustion chamber and the rotor of the unit. The proposed methodology is based on the study of two approaches to power distribution: uniform and proportional to the control range of each GTU. A numerical experiment has shown that uniform distribution is better suited for positive disturbances, reducing the integral indicator (integral square error ISE) by 15 % compared to traditional methods, while for negative disturbances, proportional distribution demonstrates a decrease in ISE by 20 %. In the case of positive disturbances, uniform distribution for different combinations of capacities on average shows 0.6 % better control quality than the proportional approach, and for negative disturbances, proportional distribution on average shows 0.25 % better control quality, compared to uniform.

The research results have significant practical potential and can be used to improve the control systems of the power systems of Ukraine in conditions of a shortage of generating capacities and crisis situations.

Keywords: power system, gas turbine units, angular velocity, integral indicator, electricity frequency control.

References

1. Basok, B., Bazeev, E. (2023). Energy, science and engineering today: the state and challenges of development. *Thermophysics and Thermal Power Engineering, 45 (1),* 35–45. Available at: https://ihe.nas.gov.ua/index.php/journal/article/view/522
2. Goldrin, V., Chervonenko, I., Zbinskiy, V., Brodich, R., Slonevskiy, O. (2020). Participation of Ukrainian NPPs in Regulating Frequency and Power in the United Energy System: Problem Analysis and Solutions. *Nuclear and Radiation Safety, 1 (85),* 50–56. https://doi.org/10.32918/nrs.2020.1(85).05
3. Bardyk, Y., Bondarenko, O., Bolotnyi, M. (2024). Operational reliability analysis for sustainable energy system planning development. *Vidnovluvana Energetika, 4 (79),* 46–58. https://doi.org/10.36296/1819-8058.2024.4(79).46-58
4. Sahu, R., Panigrahi, P. K., Lal, D. K., Dey, B. (2024). Hybrid Intelligent Algorithm Applied to Economic Dispatch of Grid-Connected Microgrid System Considering Static and Dynamic Load Demand. *Control Applications in Modern Power Systems,* 109–119. https://doi.org/10.1007/978-981-99-9054-2_7
5. Patra, N., Chatterjee, A., Sahoo, R. K. (2024). Design of Hybrid Energy Storage System Model with Multi-input Converter. *Control Applications in Modern Power Systems,* 121–131. https://doi.org/10.1007/978-981-99-9054-2_8
6. Deng, Y., Fang, X., Gao, N., Tan, J. (2024). Multi-Timescale Modeling Framework of Hybrid Power Plants Providing Secondary Frequency Regulation. *IEEE Open Access Journal of Power and Energy, 11,* 595–609. https://doi.org/10.1109/oajpe.2024.3504835
7. Zhang, Y., Shotorbani, A. M., Wang, L., Mohammadi-Ivatloo, B. (2021). Distributed Secondary Control of a Microgrid with A Generalized PI Finite-Time Controller. *IEEE Open Access Journal of Power and Energy, 8,* 57–67. https://doi.org/10.1109/oajpe.2021.3056507
8. Nagendra, M., Kalyan, Ch. N. S., Rao, R. S. (2024). Comparison of SMES and RFB Performance in Combined Voltage and Frequency Regulation of Multi Source Power System. *Control Applications in Modern Power Systems,* 91–107. https://doi.org/10.1007/978-981-99-9054-2_6
9. Yavorskyi, O., Tarakhtii, O., Maksymov, M., Kryvda, V. (2023). Model of Gas Turbine Plant with Concentrated Parameters for Analysis of Dynamic Properties Patterns. *Energy Engineering and Control Systems, 9 (2),* 105–118. https://doi.org/10.23939/jeecs2023.02.105
10. Bundiuk, A. M., Tarakhtii, O. S. (2015). O povyshenii kachestva upravleniya moshchnostyu GTU kogeneratsionnoy energeticheskoy ustanovki. Avtomatyzatsiya, kontrol ta upravlinnya: poshuk idey ta rishen. *Zbirnyk naukovykh prats I Vseukrayinskoyi naukovo-tekhnichnoyi konferentsiyi v m. Krasnoarmiysku 25–29 travnya 2015 r.* Krasnoarmiisk: DVNZ "DonNTU", 444–447.
11. *GOST 13109-97. Elektricheskaya energiya. Sovmestimost tekhnicheskikh sredstv. Normy kachestva elektricheskoy energii v sistemakh obshchego naznacheniya.* (1998). Vved. 1999-01-01. Izdatelstvo standartov, 17.