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## SUPPORT OF METROLOGICAL TRACEABILITY OF CAPACITANCE MEASUREMENTS IN UKRAINE (p. 4-10)

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The comparative analysis of the results of the RMO international key and supplementary comparisons of national standards of units of electrical capacitance is conducted with the aim of evaluation of convergence. For the comparisons, the reference values with the expanded uncertainties are calculated and the degrees of equivalence of standards of participants and expanded uncertainties for the nominal values of measures of 10 pF and 100 pF on frequencies of 1 kHz and 1.592 kHz are determined. Metrological traceability of the national standard of every participant of comparisons to the units of the International system of units SI is determined.

For verification of consistency of the results of comparisons, the values of the  $\chi^2$  criterion for the results of comparisons of standards of participants taking into account the measurement uncertainty are calculated. The obtained values of the criterion of consistency for the participants can be considered consistent, which is the objective confirmation of the measurement uncertainties declared by the participants.

The evaluation of calibration and measurement capabilities of Ukraine for the unit of electrical capacitance is realized. The methodology of evaluation of measurement uncertainty in the wide range of capacitance values (from 10 pF to 10 nF) is proposed. The results the calculations of the values of measurement uncertainties according to the proposed methodology revealed that the results correspond to the data published in the international key comparison database for Ukraine in the range of capacitance values from 10 pF to 10 nF on frequencies of 1 kHz and 1.592 kHz.

**Keywords:** comparison of standards, metrological traceability, electrical capacitance, national metrology institute, calibration and measurement capabilities.

### References

1. Measurement comparisons in the context of the CIPM MRA. CIPM MRA-D-05:2013 (2016). Available at: <http://www.bipm.org/en/cipm-mra/cipm-mra-documents/>
2. The BIPM key comparison database (KCDB). Available at: <http://kcdb.bipm.org/>
3. Text of the CIPM MRA. Available at: <http://www.bipm.org/en/cipm-mra/cipm-mra-text/>
4. International vocabulary of metrology – Basic and general concepts and associated terms (VIM 3-rd edition). JCGM 200:2012. Available at: <http://www.bipm.org/en/publications/guides/vim.html>
5. Velichko, O. N. (2009). Traceability of measurement results at different levels of metrological work. *Measurement Techniques*, 52 (11), 1242–1248. doi: 10.1007/s11018-010-9428-7
6. Uncertainty of measurement. – Part 3: Guide to the expression of uncertainty in measurement (GUM). JCGM 100:2008. Available at: <http://www.bipm.org/en/publications/guides/gum.html>
7. Calibration and Measurement Capabilities in the context of the CIPM MRA. CIPM MRA-D-04:2013 (2013). Available at: <http://www.bipm.org/en/cipm-mra/cipm-mra-documents/>
8. Velichko, O. N. (2010). Calibration and measurement capabilities of metrological institutes: features of preparation, examination, and publication. *Measurement Techniques*, 53 (6), 721–726. doi: 10.1007/s11018-010-9567-x
9. Velychko, O., Gordiyenko, T. (2010). The implementation of general international guides and standards on regional level in the field of metrology. *Journal of Physics: Conference Series*, 238, 012044. doi: 10.1088/1742-6596/238/1/012044
10. Cox, M. G. (2002). The evaluation of key comparison data. *Metrologia*, 39 (6), 589–595. doi: 10.1088/0026-1394/39/6/10
11. Cox, M. G. (2007). The evaluation of key comparison data: determining the largest consistent subset. *Metrologia*, 44 (3), 187–200. doi: 10.1088/0026-1394/44/3/005
12. Mana, G., Massa, E., Predescu, M. (2012). Model selection in the average of inconsistent data: an analysis of the measured Planck-constant values. *Metrologia*, 49 (4), 492–500. doi: 10.1088/0026-1394/49/4/492
13. Jeffery, A.-M. (2002). Final report on key comparison CCEM-K4 of 10 pF capacitance standards. *Metrologia*, 39 (1A), 01003–01003. doi: 10.1088/0026-1394/39/1a/3
14. Delahaye, F., Witt, T. J. (2002). Linking the results of key comparison CCEM-K4 with the 10 pF results of EUROMET. EM-K4. *Metrologia*, 39 (1A), 01005–01005. doi: 10.1088/0026-1394/39/1a/5
15. Johnson, L., Chua, W., Corney, A., Hsu, J., Sardjono, H., Lee, R. D. et al. (2009). Final report on the APMP comparison of capacitance at 10 pF: APMP.EM-K4.1. *Metrologia*, 46 (1A), 01003–01003. doi: 10.1088/0026-1394/46/1a/01003
16. Johnson, L., Chua, W., Corney, A., Hsu, J., Sardjono, H., Lee, R. D. et al. (2008). Final report on the APMP comparison of capacitance at 100 pF (APMP supplementary comparison APMP.EM-S7). *Metrologia*, 45 (1A), 01003–01003. doi: 10.1088/0026-1394/45/1a/01003
17. Velychko, O., Akhmadov, O. (2017). Final report on COOMET key comparison of capacitance at 10 pF (COOMET.EM-K4). *Metrologia*, 54 (1A), 01005–01005. doi: 10.1088/0026-1394/54/1a/01005
18. Velychko, O., Akhmadov, O. (2017). Final report on COOMET key comparison of capacitance at 100 pF (COOMET.EM-S4). *Metrologia*, 54 (1A), 01006–01006. doi: 10.1088/0026-1394/54/1a/01006
19. Velychko, O., Shevkun, S. (2015). Final report: COOMET supplementary comparison of capacitance at 10 pF and 100 pF (COOMET.EM-S13). *Metrologia*, 52 (1A), 01005–01005. doi: 10.1088/0026-1394/52/1a/01005
20. Guidelines on COOMET key comparison evaluation. COOMET R/GM/14:2016. Available at: [http://www.coomet.org/DB/isapi/cmt\\_docs/2016/5/2BMD10.pdf](http://www.coomet.org/DB/isapi/cmt_docs/2016/5/2BMD10.pdf)

21. Guidelines on COOMET supplementary comparison evaluation. COOMET R/GM/19:2016. Available at: [http://www.coomet.org/DB/isapi/cmt\\_docs/](http://www.coomet.org/DB/isapi/cmt_docs/)

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## ANALYSIS OF MASS-ENERGY BALANCE OF UNMANNED AIRCRAFT FUELED BY SOLAR ENERGY (p. 10-18)

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To understand the characteristics and principles of creation of an aircraft, fueled by solar energy, the fundamentals of providing mass-energy balance and its specificity were considered.

To create a mathematical model that describes interrelations between the basic parameters of an aircraft, fueled by solar energy, it was proposed to describe the main components in stages, namely:

- power, required for the implementation of a horizontal flight;
- total power consumption for performing of a flight, including take-off and maneuvers;
- magnitude of energy, generated during a flight;
- total take-off mass of an aircraft.

The principles of power supply of the aircraft systems under all flight modes were defined. Under the mode of a horizontal flight, there should be enough power, generated by solar panels, to fuel all systems. The power surplus is accumulated in the battery. Under the takeoff and landing modes, as well as during a maneuver, the current deficit of the generated power may be compensated for by power of the battery.

We described the factors that affect performance of solar panels of an aircraft, in particular shading, V-shape of a wing, geometry of aerodynamic profile, cloudiness, and orientation relative to the Sun. The model is proposed for determining the mass of an aircraft in general, which takes into account weight characteristics of the industrial components of an aircraft.

Results of the study might be used in the process of creation of aircraft, fueled by solar energy, at the stage of outline design.

We obtained a generalized analytical model of mass-energy balance of an aircraft, taking into account common operation modes and the laws of solar energy generation, which allows us to conduct analytical prediction of characteristics of prototypes. The model combines technological, operational, and design parameters, and is the basis for the formation of algorithm for choosing the parameters of an aircraft fueled by solar energy.

**Keywords:** mass-energy balance, aircraft fueled by solar energy, conditions of flight realization.

### References

1. Abbe, G., Smith, H. (2016). Technological development trends in Solar-powered Aircraft Systems. *Renewable and Sustainable Energy Reviews*, 60, 770–783. doi: 10.1016/j.rser.2016.01.053
2. Gao, X.-Z., Hou, Z.-X., Guo, Z., Chen, X.-Q. (2015). Reviews of methods to extract and store energy for solar-powered aircraft. *Renewable and Sustainable Energy Reviews*, 44, 96–108. doi: 10.1016/j.rser.2014.11.025
3. Gao, X.-Z., Hou, Z.-X., Guo, Z., Liu, J.-X., Chen, X.-Q. (2013). Energy management strategy for solar-powered high-altitude long-endurance aircraft. *Energy Conversion and Management*, 70, 20–30. doi: 10.1016/j.enconman.2013.01.007
4. Gao, X.-Z., Hou, Z.-X., Guo, Z., Fan, R.-F., Chen, X.-Q. (2013). The equivalence of gravitational potential and rechargeable battery for high-altitude long-endurance solar-powered aircraft on energy storage. *Energy Conversion and Management*, 76, 986–995. doi: 10.1016/j.enconman.2013.08.023
5. Barbosa, R., Escobar, B., Sanchez, V. M., Hernandez, J., Acosta, R., Verde, Y. (2014). Sizing of a solar/hydrogen system for high altitude long endurance aircrafts. *International Journal of Hydrogen Energy*, 39 (29), 16637–16645. doi: 10.1016/j.ijhydene.2014.05.152
6. Fazelpour, F., Vafaeipour, M., Rahbari, O., Shirmohammadi, R. (2013). Considerable parameters of using PV cells for solar-powered aircrafts. *Renewable and Sustainable Energy Reviews*, 22, 81–91. doi: 10.1016/j.rser.2013.01.016
7. Agarwal, R. K. (2015). Energy Optimization for Solar-Powered Aircraft. *Encyclopedia of Aerospace Engineering*, 1–17. doi: 10.1002/9780470686652.eae1010
8. Sukhov, V., Ivashchuk, A., Kozey, Y. (2016). Current state and prospects of planes on solar energy in Ukraine. *Journal of Mechanical Engineering the National Technical University of Ukraine "Kyiv Polytechnic Institute"*, 77, 5–14. doi: 10.20535/2305-9001.2016.77.71470
9. Sukhov, V., Kozey, Y., Getman, A. (2014). Aerodinamichne proektuvannya krila z sonjachnimi elementami [Aerodynamic design wing with solar cells]. *Information systems, mechanics and control*, 11, 111–119.
10. North, A. (2008). Design of solar powered airplanes for continuous flight. Switzerland, 196.
11. Trofimenko, A. (2012). Samolety na solnechnykh batareyah – novyi instrument dlya provedeniya issledovaniy v Antarktike: osobennosti, preimushhestva, perspektivy [Solar-powered aircraft – a new tool for conducting research in Antarctica: features, advantages, prospects]. *Ukrainian Antarctic Journal*, 10-11, 390–398.
12. Baldock, N., Mokhtarzadeh-Dehghan, M. R. (2006). A study of solar-powered, high-altitude unmanned aerial vehicles. *Aircraft Engineering and Aerospace Technology*, 78 (3), 187–193. doi: 10.1108/17488840610663648
13. Aeronautical meteorological code METAR. Meteocentr. Available at: <http://www.meteocenter.net/meteolib/metar.htm>
14. Hall, D. W., Hall, S. A. (1984). Structural Sizing of a Solar Powered Aircraft. United States, No. NASA-CR-172313, NAS 1.26:172313, LMSC-D878711, 105.
15. Stender, W. (1969). Sailplane Weight Estimation. Organisation Scientifique et Technique Internationale du Vol a Voile (OSITIV). Bern, 62.
16. Rehmet, M. A., Scholz, W., Voit-Nitschmann, R. (1995). Das Solarflugzeug Icare, Vorlauffer fur eine Kategorie Elektrisch Getriebener Flugzeuge. Germany, 99.
17. Solar Panel Manufacturers. ENF Solar definitive directory of solar companies and products. Available at: <https://www.ensolar.com/directory/panel>
18. Accumulators and Accessories. Hobbyking. Available at: [https://www.hobbyking.com/ru\\_ru/batteries/lipoly-all-brands.html](https://www.hobbyking.com/ru_ru/batteries/lipoly-all-brands.html)
19. Brushless motor for aircraft. Planeta Hobby. Available at: <https://www.modelistam.com.ua/elektrodivigateli-akessuary/beskollektornye-dlya-samoletov-c-238>

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## DEVELOPMENT OF A GEOMECHATRONIC COMPLEX FOR THE GEOTECHNICAL MONITORING OF THE CONTOUR OF A MINE WORKING (p. 19-25)

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While receiving information under dangerous conditions, at which human presence is difficult or impossible, widely spread are the mobile robotic complexes. Particularly important information to determine the stressed-strained state of the underground workings is data on their geometry. Establishing the values of convergence of underground workings will make it possible to locate dangerous areas and decrease the number of emergency cases. In order to design an experimental sample, we developed basic approaches to create geomechatronic complexes, which define the main tasks, the scope of application, and quality criteria. The motion of the complex along an underground working is accompanied by a spatial change in the position of a distance sensor, which must be considered when establishing the actual values of the profile of a working. As parameters that take into account a change in the position, we proposed six components, three displacements and three Euler angles, which are registered by a microelectronic gyroscope that registers the distance traveled. The proposed algorithm is a cyclical structure, which successively performs data registration from different sensors that define its position, data conversion, and data recording to a memory card. Implementation of the devised algorithm allows us to determine the geometry of a profile of the working with an accuracy of 0.5 cm.

**Keywords:** geomechatronic complex, coordinate system, profile of working, distance sensor, microcontroller.

### References

- Koshkarev, A. V., Burkov, V. N. (1998). *Geoinformatika. Tolkovanie osnovnykh terminov*. Moscow: GIS-Associaciya, 213.
- Isii, H., Inoueh, H., Simoyama, I. et. al. (1988). *Mekhatronika*. Moscow: Mir, 318.
- Likhachev, M., Ferguson, D., Gordon, G., Stentz, A., Thrun, S. (2008). Anytime search in dynamic graphs. *Artificial Intelligence*, 172 (14), 1613–1643. doi: 10.1016/j.artint.2007.11.009
- Siegwart, R., Nourbakhsh, I. (2004). *Introduction to Autonomous Mobile Robots*. MIT Press, 321.
- Bares, J. E. (1999). Dante II: Technical Description, Results, and Lessons Learned. *The International Journal of Robotics Research*, 18 (7), 621–649. doi: 10.1177/02783649922066475
- Durrant-Whyte, H., Majumder, S., Thrun, S., De Battista, M., Scheduling, S. (2001). A Bayesian algorithm for simultaneous localization and map building. In *Proceedings of the 10th International Symposium of Robotics Research (ISRR'01)*. Lorne, Australia.
- Parcheta, C. E., Pavlov, C. A., Wiltsie, N., Carpenter, K. C., Nash, J., Parness, A., Mitchell, K. L. (2016). A robotic approach to mapping post-eruptive volcanic fissure conduits. *Journal of Volcanology and Geothermal Research*, 320, 19–28. doi: 10.1016/j.jvolgeores.2016.03.006
- Gradeckiy, V. G., Knyaz'kov, M. M., Kravchuk, L. N. (2005). *Metody dvizheniya miniatyurnykh upravlyaemykh vnutritrubnykh robotov. Nano- i mikrosistemnaya tekhnika*, 9, 37–43.
- Cala, M., Stopkowicz, A., Kowalski, M., Blajer, M., Cyran, K., D'obyryn, K. (2016). Stability analysis of underground mining openings with complex geometry. *Studia Geotechnica et Mechanica*, 38 (1), 25–32. doi: 10.1515/sgem-2016-0003
- Grebyonkin, S. S., Samoylov, V. L., Petrenko, Yu. A. (2010). *Upravlenie sostoyaniem massiva gornyh porod. Doneck: "VIK"*, 191.
- Babiyuk, G. V., Puntus, V. F. (2015). *Kontrol' i diagnostika sostoyaniya podgotovitel'nykh vyrabotok na ugol'nyh shahtah. Zbirnik naukovih prac' DonDTU*, 1 (44), 4–13.
- Putz, S., Wiemann, T., Sprickerhof, J., Hertzberg, J. (2016). 3D Navigation Mesh Generation for Path Planning in Uneven Terrain. *IFAC-PapersOnLine*, 49 (15), 212–217. doi: 10.1016/j.ifacol.2016.07.734
- Schmuck, P., Scherer, S. A., Zell, A. (2016). Hybrid Metric-Topological 3D Occupancy Grid Maps for Large-scale Mapping. *IFAC-PapersOnLine*, 49 (15), 230–235. doi: 10.1016/j.ifacol.2016.07.738
- Yamanaka, S., Morioka, K. (2012). Mobile robot navigation using hybrid simplified map with relationships between places and grid maps. *IFAC Proceedings Volumes*, 45 (22), 616–621. doi: 10.3182/20120905-3-hr-2030.00145
- Pol, R. (1976). *Modelirovanie, planirovanie traektoriy i upravlenie dvizheniem robota-manipulyatora*. Moscow: Nauka, 104.
- Gradeckiy, V. G., Veshnikov, V. B., Kalinichenko, S. V., Kravchuk, L. N. (2001). *Upravlyamoe dvizhenie mobil'nykh robotov po proizvol'no orientirovannym v prostranstve poverhnostyam*. Moscow: Nauka, 360.
- Liu, J., Zhong, L., Wickramasuriya, J., Vasudevan, V. (2009). uWave: Accelerometer-based personalized gesture recognition and its applications. *Pervasive and Mobile Computing*, 5 (6), 657–675. doi: 10.1016/j.pmcj.2009.07.007
- Jang, I. J., Park, W. B. (2003). Signal processing of the accelerometer for gesture awareness on handheld devices. *The 12th IEEE International Workshop on Robot and Human Interactive Communication, 2003. Proceedings. ROMAN 2003*. doi: 10.1109/roman.2003.1251823

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## PREDICTING A TECHNICAL CONDITION OF RAILWAY AUTOMATION HARDWARE UNDER CONDITIONS OF LIMITED STATISTICAL DATA (p. 26-35)

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Here we report a method developed for the prediction of technical equipment of railway automation. It is based on the Student spread, the methods of maximum likelihood and unevenly accurate observations.

Development of the method for prediction was necessitated by a limited experience of operating the microelectronic systems of railway automation by domestic transportation enterprises. This led to a shortage of statistical data on their operation. Thus, the issue of the application of microstatistics for technical diagnosis of respective devices has become relevant.

As a result of the study we established that the basis for prediction may be formed by the principle of violation of the equivalence class of failure-free devices. The existence of a faulty device violates the integrity of the class. This makes it possible as a desired probability of failure of the device to determine the probability of its exiting the corresponding equivalence class. Under conditions of minimal statistical data, this approach has proved its suitability for micro-electronic equipment.

Thus, we obtain the possibility to predict technical condition of microelectronic equipment of railway automation under conditions of shortage of statistical data. The method has several disadvantages associated with deliberate understatement of values of confidence probability of failure-free work of devices. However, it lays the foundation for further improvement in the methodology of technical diagnosis of information-control systems on railway transport. This is executed with regard to the introduction of the newest modifications, not sufficiently tested as yet.

**Keywords:** microprocessor systems, railway automation, Student spread, method of maximum likelihood, microstatistics.

## References

- Karevs, V. (2015) Railway automation and telematics system's monitoring and diagnostic. Saarbrücken: LAP LAMBERT.
- Malovichko, V. V., Rybalka, R. V., Malovichko, N. V. et. al. (2012). Vyznachennia priorytetiv vyboru ob'ektiv diahnostuvannia ta kontroliu elektrichnoi tseentralizatsii z urakhuvanniam zatrymok poizdiv. Zbirnyk naukovykh prats Donetskohoho instytutu zaliznychnoho transportu, 31, 57–61.
- Kustov, V. F. (2016). Pidvyshchennia bezpeky rukhu poizdiv za rakhunok vykorystannia mikroprotsessornykh system zaliznychnoi avtomatyky. Informatsiino-keruiuchi systemy na zaliznychnomu transporti. Chornomorsk, 4, 28–29.
- Peter, B. (2005). The Concepts of IEC 61508. An Overview and Analysis. Bielefeld: RVS, 52.
- Griebel, S. (2008). Sicherheitsnormen im Umbruch. Revision der EN 5012X Suite. Siemens AG: Industry Sector, Mobility Division, 20.
- Traussing, R. (2004). Safety-Critical Systems: Processes, Standards and Certification. Analysis, Design and Implementation of Reliable Software. Paderborn: Universitat Paderborn, 17.
- Braband, Y., Khyrao, Yu., Liudeke, D. Vzaymosv'iaz mezhdru standartamy CENELEC v oblasti zheleznodorozhnoi syhnalizatsyy y druhykh standartamy po bezopasnosti. Informacionnaya bezopasnost' na transporte. Available at: <http://www.ibtrans.ru/upload/iblock/252/25224179d2f031147bf4a113e91b4411.pdf>
- Mehov, V., Sposhnikov, V., Spozhnikov, V. I., Urganskov, D. (2007). Concurrent Error Detection Based on Modulo Weight-Based Codes. Proceedings of 7th IEEE East-West Design & Test Workshop (EWDTW' 2007). Erevan, Armenia, 21–26.
- Gorelik, A. V., Taradin, N. A., Veselova, A. S. (2014). Model otsenki nad'yozhnosti i effektivnosti funktsionirovaniya ob'ektov transportnoy infrastruktury. Nauka i tehnika transporta, 1, 88–92.
- Sigorskiy, V. P. (1977). Matematicheskiy apparat inzhenera. Kyiv: Tehnika, 768.
- Moiseienko, V. I., Chehodaiev, B. V., Zotova, O. S. (2014). Methods of diagnosis of railway automation systems. Informatsiino-keruiuchi systemy na zaliznychnomu transporti, 4, 26–32.
- Panchenko, S., Siroklyn, I., Lapko, A., Kameniev, A., Zmii, S. (2016). Improvement of the accuracy of determining movement parameters of cuts on classification humps by methods of video analysis. Eastern-European Journal of Enterprise Technologies, 4 (3 (82)), 25–30. doi: 10.15587/1729-4061.2016.76103
- Tang, L. (2015). Reliability assessments of railway signaling systems: A comparison and evaluation of approaches. Trondheim: Norwegian University of Science and Technology, 81.
- Watanabe, Y., Matsumoto, Y. (2014). Online Failure Prediction in Cloud Datacenters. Fujitsu scientific & technical journal, 50 (1), 67–71.
- Svendsen, P. A. (2011). Online Failure Prediction in UNIX Systems. Kristiansand: University of Agder, 70.
- Kumar, R., Vijayakumar, S., Ahamed, S. (2013). Pat. No. US 2015/0067410 A1. Hardware failure prediction system. USA CPK G06F 11/004. No. US 14/144,823; declared: 31.12.2013; published: 05.03.2015, 14.
- Gavrilyuk, E. A., Mantserov, S. A., Panov, A. Yu. (2015). The failure prediction of automatic gas-compressor unit control systems on basis of technical state index and measure of risk. Fundamentalnye issledovaniya, 7, 309–313.
- Kovalev, A. V., Trushin, N. N., Salmikov, V. S. (2014). Prognozovanie tehniceskogo sostoyaniya tehnologicheskogo oborudovaniya. Izvestiya Tuls'kogo gosudarstvennogo universiteta. Tehnicheskie nauki, 11, 554–559.
- Efanov, D. V. (2016). Becoming and development prospects of concurrent error detection and monitoring systems of railway automation and remote control devices. Avtomatika na transporte, 2 (1), 124–148.
- Sansevich, V. K. (1996). Klassifikatsiya situatsiy na osnove otnosheniy mezhdru raznorodnyimi priznakami. Sbornik nauchnykh trudov. Orel: VIPS, 6, 53–57.
- Schut, D., Wisniewski, J. (2015). A global vision of railway development. Paris: International Union of Railways (UIC), 44.
- Pereira, J., Teixeira, P., Viegas, J. (2015). RAMS analysis of railway track infrastructure (Reliability, Availability, Maintainability, Safety). Paris: International Union of Railways (UIC), 44.
- Stewart, C., Luebke, C., Morrell, M., Goulding, L. (2015). Future of Rail 2050. London: Arup, 58.
- Kameniev, A. Yu. (2014). Reliability of combined proofs methods of microprocessor interlocking system of railway stations. Sovremennyye problemy transportnogo kompleksa Rossii, 4 (5), 61–66.
- Kameniev, O. Yu., Moiseienko, V. I., Haievskiy, V. V. (2016). Prohnozuvannia stanu mikroelektronnykh prystroiv zaliznychnoi avtomatyky pry obmezhenykh statystychnykh danykh. Informatsiino-keruiuchi systemy na zaliznychnomu transporti. Chornomorsk, 4, 37.
- Kustov, V. F., Kameniev, A. Yu. (2013). Uovershenstvovanie metodov ispytaniy mikroprotsessornoy tseentralizatsii na bezopasnost primeneniya. Aktualnyye voprosy razvitiya sistem zheleznodorozhnoy avtomatiki i telemehaniki, 103–118.
- Doslidzhennia funktsiinoi bezpechnosti ta elektromahnitnoi sumisnosti mikroprotsessornoi systemy elektrichnoi tseentralizatsii stantsii «Vuhilna» na etapi imitatsiynykh ta stendovyykh vyprovuban (2012). UkrDAZT. No. derzh. reyestr. 0112U006925; inv. No. 0713U007283, 139.



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**RESEARCH INTO THE USE OF SCRAMBLERS IN NARROWBAND COMMUNICATION SYSTEMS (p. 35-42)****Vitalii Kukush**Kharkiv National University of  
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One of the most important requirements for speech channel is to provide information security. Speech scrambling is one of the preferred methods for secure speech communications over the narrowband channels. That confirms the relevance of works focused on improvement and investigation of operation features of speech scrambling devices.

The article shows the advantages of using scramblers in narrowband voice communication systems and presents a detailed analysis of strength to hacking of communication channels secured by frequency-domain scrambling technique.

The investigation of strength to hacking is based on the developed digital signal processing algorithm which realizes the band scrambler. The developed algorithm does not require synchronization between the scrambler and the descrambler which is achieved by using of sliding window FFT technique.

Presented experimental results show that the lowest level of the scrambled signal residual intelligibility can be achieved when low frequency bands of speech spectrum are permuted with high frequency ones. Also the article shows that if amount of bands is less than 32 the scrambled signal can be hacked by a simple frequency spectrum inversion in the entire frequency band of the signal.

During scrambling with amount of bands greater than 32, there are variants of band permutation that ensure the level of residual intelligibility near 10–20 % and that is secured against hacking by the spectrum inversion.

For a real-time speech communication system, the maximum number of scrambler bands is limited by two factors: the delay time for the scrambling-descrambling process and inserted distortions. It was shown that the maximum amount of bands should be less or equal to 256 for scrambling time delay of 128 ms, communication channel bandwidth of 4 kHz and the level of distortions that causes reduction of intelligibility not lower than 90 %.

The presented information can be used in development of frequency-domain scramblers and for selection scrambler keys, which are optimal by the criteria of strength to hacking, minimum of residual intelligibility and level of inserted distortions.

**Keywords:** scrambling, band scrambler, fast Fourier transform, sliding window, residual intelligibility.

**References**

- Torokin, A. A. (2005). *Inzhenerno-tehnicheskaja zashhita informacii*. Moscow: Gelios ARV, 960.
- Lenkov, S. V., Peregudov, D. A., Horoshko, V. A.; Horoshko, V. A. (Ed.) (2008). *Metody i sredstva zashhity informacii*. Vol. 2. *Informacionnaja bezopasnost'*. Kyiv: Ariy, 344.
- Srinivasan, A., Selvan, P. (2012). Review of analog audio scrambling methods for residual intelligibility. *Innovation Systems Design and Engineering*, 3 (7), 22–38.
- Konahovich, G. F., Klimchuk, V. P., Pauk, S. M., Potapov, V. G. (2008). *Zashhita informacii v telekommunikacionnyh sistemah*. Kyiv: Ariy, 344.
- Gorbenko, I. D., Zamula, A. A., Presnyakov, I. N. (1997). *Principy zashhity rechevyh soobshheniy v kommunikacionnyh sistemah: ucheb. posobie*. Kharkiv: KNURE, 116.
- Jayakurami, J., Dhanya, G. (2016). A review of analog speech scrambling for secure communication. *Progress in science and engineering research journal*, 2, 194–198.
- Lim, Y. C., Lee, J. W., Foo, S. W. (2009). Quality Analog Scramblers Using Frequency-Response Masking Filter Banks. *Circuits, Systems and Signal Processing*, 29 (1), 135–154. doi: 10.1007/s00034-009-9113-8
- Weinstein, S. B. (1980). Sampling based techniques for voice scrambling. *Proc. Int. Conf. Commun.*, 16.2.1–16.2.6.
- Lee, L. S., Harn, Y. P., Chen, Y. C. (1980). A simple sample value scrambler using FFT algorithms for secure voice communications. *Proc. Nat. Telecommun. Conf.*, 49.4.1–49.4.5.
- Verchyk, D. Ju., Kukush, V. D. (2016). Osobennosti tehniceskoy realizacii i primeneniya algoritmov skremblirovaniya rechi. *Radioelektronika i molodezh' v XXI veke*. Kharkiv: KNURE, 3, 81–82.
- De Andrade, J. F., de Campos, M. L. R., Apolinario, J. A. (2008). Speech privacy for modern mobile communication systems. 2008 IEEE International Conference on Acoustics, Speech and Signal Processing. doi: 10.1109/icassp.2008.4517975
- Matsunaga, A., Koga, K., Ohkawa, M. (1989). An analog speech scrambling system using the FFT technique with high-level security. *IEEE Journal on Selected Areas in Communications*, 7 (4), 540–547. doi: 10.1109/49.17718
- Jayakurami, J., Dhanya, G. (2016). An efficient voice scrambling technique for next generation communication systems. *International Journal of Engineering and Technology*, 8 (1), 293–299.
- Tseng, D.-C., Chiu, J.-H. (2008). An OFDM-Based Speech Encryption System without Residual Intelligibility. *IEICE Transactions on Information and Systems*, E91-D (11), 2742–2745. doi: 10.1093/ietisy/e91-d.11.2742
- Lee, L.-S., Chou, G.-C., Chang, C.-S. (1984). A New Frequency Domain Speech Scrambling System Which Does Not Require Frame Synchronization. *IEEE Transactions on Communications*, 32 (4), 444–456. doi: 10.1109/tcom.1984.1096078
- Lee, J. W., Lim, Y. C. (2008). Efficient fast filter bank with a reduced delay. *APCCAS 2008 – 2008 IEEE Asia Pacific Conference on Circuits and Systems*. doi: 10.1109/apccas.2008.4746299
- Sapozhkov, M. A. (1978). *Elektroakustika*. Moscow: Svyaz', 272.
- Rukovodstvo po proektirovaniyu sistem zvukovogo obespecheniya na stroyashchikhsya i rekonstruiuemyykh obektakh g. Moskvy (2000). *Besplatnaya biblioteka standartov i normativov*. Available at: <http://www.docload.ru/Basesdoc/8/8269/index.htm>
- Flanagan, D. L. (1968). *Analiz, sintez i vospriyatie rechi*. Moscow: Svyaz', 396.
- Heckl, M., Muller, H. A. (Eds.) (1980). *Spravochnik po tehniceskoy akustike*. Leningrad: Sudostroenie, 440.
- Olifer, V. G., Olifer, N. A. (2010). *Komp'yuternye seti. Principy, tehnologii, protokoly*. Saint Petersburg: Piter, 944.
- Sklar, B. (2003). *Cifrovaya svyaz'. Teoreticheskie osnovy i prakticheskoe primeneniye*. Moscow: Izdatel'skij dom «Vil'yams», 1104.
- Kondoz, A. M. (2004). Digital speech: coding for low bit rate communication systems. John Wiley & Sons Ltd, 459. doi: 10.1002/0470870109
- Basics of the STI-measuring method. Available at: <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.501.8775>

25. Ifeachor, E. C., Jarvis, B. W. (2004). *Cifrovaya obrabotka signalov: prakticheskiy podhod*. Moscow: Izdatel'skiy dom «Vil'yams», 992.

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**DEVELOPMENT OF A SYSTEM FOR THE DETECTION OF CYBER ATTACKS BASED ON THE CLUSTERING AND FORMATION OF REFERENCE DEVIATIONS OF ATTRIBUTES (p. 43-52)**

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Adaptive system of cyber attack detection, which is based on the improved algorithms for splitting the feature space into clusters, was developed. The procedure of recognition was improved by using the simultaneous clustering and formation of verifying admissible deviations for the attributes of anomalies and cyber attacks.

The proposed modifications of the algorithm for splitting the feature space into clusters in the process of implementation of the procedure of recognition of anomalies and cyber attacks, in contrast to the existing ones, allow us to form simultaneously the reference tolerances when processing complex attributes of recognition objects (RO). This provides the possibility, at every step of training an adaptive recognition system, to change the verifying admissible deviations for all attributes of anomalies and cyber attacks simultaneously. The proposed algorithms make it possible to prevent possible cases of absorption of one RO class of basic attributes of anomalies and cyber attacks by another class. Predicate expressions for ASR that is capable of self-learning were obtained.

Verification of the proposed algorithms was carried out on the simulation models in MatLab and Simulink. It was proved that the proposed algorithms for the clustering of RO attributes make it possible to receive effective learning matrices for ASR as a part of intelligent systems for cyber attack detection.

**Keywords:** system of cyber attack detection, cyber security, clustering of attributes, verifying admissible deviations.

## References

- Khan, L., Awad, M., Thuraisingham, B. (2006). A new intrusion detection system using support vector machines and hierarchical clustering. *The VLDB Journal*, 16 (4), 507–521. doi: 10.1007/s00778-006-0002-5
- Ranjan, R., Sahoo, G. (2014). A New Clustering Approach for Anomaly Intrusion Detection. *International Journal of Data Mining & Knowledge Management Process*, 4 (2), 29–38. doi: 10.5121/ijdkp.2014.4203
- Feily, M., Shahrestani, A., Ramadass, S. (2009). A Survey of Botnet and Botnet Detection. 2009 Third International Conference on Emerging Security Information, Systems and Technologies. doi: 10.1109/secuware.2009.48
- Mahmood, T., Afzal, U. (2013). Security Analytics: Big Data Analytics for cybersecurity: A review of trends, techniques and tools. 2013 2nd National Conference on Information Assurance (NCIA). doi: 10.1109/ncia.2013.6725337
- Dua, S., Du, X. (2016). *Data Mining and Machine Learning in Cybersecurity*. UK, CRC press, 256.
- Zhang, S., Caragea, D., Ou, X. (2011). An Empirical Study on Using the National Vulnerability Database to Predict Software Vulnerabilities. *Database and Expert Systems Applications*, 217–231. doi: 10.1007/978-3-642-23088-2\_15
- Lee, K.-C., Hsieh, C.-H., Wei, L.-J., Mao, C.-H., Dai, J.-H., Kuang, Y.-T. (2016). Sec-Buzzer: cyber security emerging topic mining with open threat intelligence retrieval and timeline event annotation. *Soft Computing*, 21 (11), 2883–2896. doi: 10.1007/s00500-016-2265-0
- Buczak, A. L., Guven, E. (2016). A Survey of Data Mining and Machine Learning Methods for Cyber Security Intrusion Detection. *IEEE Communications Surveys & Tutorials*, 18 (2), 1153–1176. doi: 10.1109/comst.2015.2494502
- Petit, J., Shladover, S. E. (2015). Potential Cyberattacks on Automated Vehicles. *IEEE Transactions on Intelligent Transportation Systems*, 16 (2), 546–556. doi: 10.1109/tits.2014.2342271
- Lakhno, V. A., Kravchuk, P. U., Pleskach, V. L., Stepanenko, O. P., Tishchenko, R. V., Chernyshov, V. A. (2017). Applying the functional effectiveness information index in cybersecurity adaptive expert system of information and communication transport systems. *Journal of Theoretical and Applied Information Technology*, 95 (8), 1705–1714.
- Dovbysh, A. S., Martynenko, S. S., Kovalenko, A. S., Budnyk, N. N. (2011). Information-extreme Algorithm for Recognizing Current Distribution Maps in Magnetocardiography. *Journal of Automation and Information Sciences*, 43 (2), 63–70. doi: 10.1615/jautomatinfscien.v43.i2.60
- Ameer Ali, M., Karmakar, G. C., Dooley, L. S. (2008). Review on Fuzzy Clustering Algorithms. *IETECH Journal of Advanced Computations*, 2 (3), 169–181.
- Guan, Y., Ghorbani, A. A., Belacel, N. (2003). Y-means: a clustering method for intrusion detection. *CCECE 2003 – Canadian Conference on Electrical and Computer Engineering. Toward a Caring and Humane Technology (Cat. No.03CH37436)*. doi: 10.1109/ccece.2003.1226084
- Halkidi, M., Batistakis, Y., Vazirgiannis, M. (2001). On Clustering Validation Techniques. *Journal of Intelligent Information Systems*, 17 (2/3), 107–145. doi: 10.1023/a:1012801612483
- Gamal, M. M., Hasan, B., Hegazy, A. F. (2011). A Security Analysis Framework Powered by an Expert System. *International Journal of Computer Science and Security (IJCSS)*, 4 (6), 505–527.
- Lakhno, V., Mohylnyi, H., Donchenko, V., Smahina, O., Pyroh, M. (2016). A model developed for teaching an adaptive system of recognising cyberattacks among non-uniform queries in information systems. *Eastern-European Journal of Enterprise Technologies*, 4 (9 (82)), 27–36. doi: 10.15587/1729-4061.2016.73315
- Riadi, I., Istiyanto, J. E., Ashari, A., Subanar, N. (2012). Log Analysis Techniques using Clustering in Network Forensics. *(IJCSIS) I International Journal of Computer Science and Information Security*, 10 (7).
- Lakhno, V., Tkach, Y., Petrenko, T., Zaitsev, S., Bazylevych, V. (2016). Development of adaptive expert system of informa-

tion security using a procedure of clustering the attributes of anomalies and cyber attacks. *Eastern-European Journal of Enterprise Technologies*, 6 (9 (84)), 32–44. doi: 10.15587/1729-4061.2016.85600

19. Kiss, I., Genge, B., Haller, P. (2015). A clustering-based approach to detect cyber attacks in process control systems. 2015 IEEE 13th International Conference on Industrial Informatics (IN-DIN). doi: 10.1109/indin.2015.7281725
20. Dovbysh, A. S., Budnik, N. N., Moskalenko, V. V. (2012). Informatsionno-ekstremalnyy algoritm optimizatsii parametrov giperellipsoidnykh konteynerov klassov raspoznavaniya. *Problemy upravleniya i informatiki*, 5, 111–119.
21. Lee, S. M., Kim, D. S., Lee, J. H., Park, J. S. (2012). Detection of DDoS attacks using optimized traffic matrix. *Computers & Mathematics with Applications*, 63 (2), 501–510. doi: 10.1016/j.camwa.2011.08.020
22. Gao, P., Wang, M., Chow, J. H., Ghiocel, S. G., Fardanesh, B., Stefopoulos, G., Razanousky, M. P. (2016). Identification of Successive “Unobservable” Cyber Data Attacks in Power Systems Through Matrix Decomposition. *IEEE Transactions on Signal Processing*, 64 (21), 5557–5570. doi: 10.1109/tsp.2016.2597131
23. Lakhno, V., Kazmirchuk, S., Kovalenko, Y., Myrutenko, L., Zhmurko, T. (2016). Design of adaptive system of detection of cyber-attacks, based on the model of logical procedures and the coverage matrices of features. *Eastern-European Journal of Enterprise Technologies*, 3 (9 (81)), 30–38. doi: 10.15587/1729-4061.2016.71769
24. Dovbysh, A. S., Velikodnyi, D. V., Simonovski, J. V. (2015). Optimization of the parameters of learning intellectual system of human signature verification. *Radioelectronic and computer systems*, 2, 44–49.
25. Akhmetov, B., Lakhno, V., Boiko, Y., Mishchenko, A. (2017). Designing a decision support system for the weakly formalized problems in the provision of cybersecurity. *Eastern-European Journal of Enterprise Technologies*, 1 (2 (85)), 4–15. doi: 10.15587/1729-4061.2017.90506
26. Callegari, C., Gazzarrini, L., Giordano, S., Pagano, M., Pepe, T. (2012). Improving PCA-based anomaly detection by using multiple time scale analysis and Kullback-Leibler divergence. *International Journal of Communication Systems*, 27 (10), 1731–1751. doi: 10.1002/dac.2432
27. Chinh, H. N., Hanh, T., Thuc, N. D. (2013). Fast Detection of Ddos Attacks Using Non-Adaptive Group Testing. *International Journal of Network Security & Its Applications*, 5 (5), 63–71. doi: 10.5121/ijnsa.2013.5505

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## EXAMINING THE LEARNING FIRE DETECTORS UNDER REAL CONDITIONS OF APPLICATION (p. 53-59)

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Theoretical analysis revealed that in order to create learning fire detectors, capable of adjusting to unknown conditions of application, it is expedient to consider the criterion of equality of probabilities of false detection and skipping a fire as a criterion of guaranteed fire detection. By using such detection criterion, it is possible to provide guaranteed fire detection under conditions of the absence of a priori information about statistics of the recorded data. The algorithms and structural circuits of the learning fire detectors were developed for the case of discrete and continuous data recording by sensors. Their distinguishing feature is the possibility of application under indeterminate conditions when there is no a priori information about the type of distribution laws of the recorded data, as well as their capability to adapt to previously unknown and changing application conditions and to provide guaranteed fire detection in this case. It was shown that the main limitation in the implementation of such algorithms is the need to use additional instructions from a trainer about the existence or the absence of a fire on the object. To overcome this limitation, it is proposed to apply the hypothesis about sufficient rarity of events related to a fire on the protected sites. This made it possible to use the registered information about the absence of fire as the instructions from a trainer. In this case, the resulting modified algorithm and the structural circuit of the proposed fire detector that matches it do not require instructions from a trainer and, in this sense, a detector becomes a self-learning fire detector.

Results of examining the fire detectors, performed based on the example of real dynamics of the mean temperature of medium when alcohol is ignited and burned, demonstrated their high efficiency. In comparison with fire detectors that comply with the requirements of standard EN 54-5:2003, the examined self-learning fire detectors possess an essential gain in time (exceeding 170 times) of the guaranteed fire detection on the site under uncertain conditions. The ability of self-learning fire detectors to adapt to previously unknown conditions allows their application under non-stationary conditions in order to detect complex fires.

**Keywords:** learning fire detector, guaranteed fire detection, a priori uncertainty of detection condition.

## References

1. Poulsen, A., Jomaas, G. (2011). Experimental Study on the Burning Behavior of Pool Fires in Rooms with Different Wall Linings. *Fire Technology*, 48 (2), 419–439. doi: 10.1007/s10694-011-0230-0
2. Oppelt, U. (2006). Improvement on fire detectors by using multiple sensors. *Fire & Safety*. Available at: <http://www.securitysa.com/regular.aspx?pkregularid=2502>
3. Ding, Q., Peng, Z., Liu, T., Tong, Q. (2014). Multi-Sensor Building Fire Alarm System with Information Fusion Technology Based on D-S Evidence Theory. *Algorithms*, 7 (4), 523–537. doi: 10.3390/a7040523
4. Cheng, C., Sun, F., Zhou, X. (2011). One fire detection method using neural networks. *Tsinghua Science and Technology*, 16 (1), 31–35. doi: 10.1016/s1007-0214(11)70005-0
5. Pospelov, B. B., Andronov, V. A. (2015). Improving Efficiency Monitoring Systems for Potentially Dangerous Objects Based on Optimization of Group Detection Sensors. *Civil Engineering and Architecture*, 3 (4), 69–72. doi: 10.13189/cea.2015.030401



6. Andronov, V., Pospelov, B., Rybka, E. (2017). Development of a method to improve the performance speed of maximal fire detectors. *Eastern-European Journal of Enterprise Technologies*, 2 (9 (86)), 32–37. doi: 10.15587/1729-4061.2017.96694
7. Cestari, L. A., Worrell, C., Milke, J. A. (2005). Advanced fire detection algorithms using data from the home smoke detector project. *Fire Safety Journal*, 40 (1), 1–28. doi: 10.1016/j.fire-saf.2004.07.004
8. Radonja, P., Stankovic, S. (2009). Generalized profile function model based on neural networks. *Serbian Journal of Electrical Engineering*, 6 (2), 285–298. doi: 10.2298/sjee0902285r
9. Tsai, Y. C. (2007). The Design and Implementation of Early Fire Detection and Hierarchical Evacuation Alarm System, Master Thesis. Graduate Institute of Networking and Communication Engineering, Taiwan.
10. Ristic, J., Radosavljevic, D. (2011). Decision algorithms in fire detection systems. *Serbian Journal of Electrical Engineering*, 8 (2), 155–161. doi: 10.2298/sjee1102155r
11. Andronov, V., Pospelov, B., Rybka, E. (2016). Increase of accuracy of definition of temperature by sensors of fire alarms in real conditions of fire on objects. *Eastern-European Journal of Enterprise Technologies*, 4 (5 (82)), 38–44. doi: 10.15587/1729-4061.2016.75063

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#### OPTIMIZATION OF THERMAL MODES AND COOLING SYSTEMS OF THE INDUCTION TRACTION ENGINES OF TRAMS (p. 59-67)

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We developed a procedure for the optimization of thermal modes and parameters of the cooling system of induction traction engines of tram carriages. The procedure includes the following basic steps. The optimization of operating modes of an induction traction drive by the criterion of effectiveness of its work under different modes. The optimization of motion modes of a tram carriage along a track section with the assigned motion schedule and profile based on the curves of the motion of a tram carriage, optimal by the criterion of energy consumption, using the method of Hamilton-Jacobi-Bellman. The optimization of parameters of the cooling fan of traction engines by the criterion of efficiency of a cooling system using the Weyl method by the generalized golden section. It is proposed to conduct determining of operating modes of a traction drive in advance based on the solution to the problem of conditional optimization of its modes. In order to determine the optimal operating modes of a traction drive, we selected a combined

method: global search is executed by genetic algorithm with a one-point crossover and by selection on the principle of roulette. At the final stage of an optimization procedure, optimum refining is carried out using the Nelder–Mead method. When a tram carriage moved along a track section, we defined the following. We determined the optimal modes of motion of the tram carriage T-3 VPA with induction traction engines for a track section with the assigned motion schedule. It was found that, compared with the basic design, efficiency of the cooling system increased by 27.6 %, which corresponds to a reduction in the proposed criterion of efficiency. Based on the results of modeling a traction engine with an optimal fan, it was established that the largest overheating is observed in the frontal part of the stator winding. The temperature is 139.6 °C at second 3363 from starting the motion and it does not exceed a permissible value of 140 °C.

**Keywords:** tram carriage, induction engine, optimal operating modes, cooling fan.

#### References

1. Liubarskyi, B. G. (2015). Ratsionalni shvydkisni rezhymy rukhu prymiskogo elektropoizdu z asynkhronnymy tiagovymy dvygunamy. *Visnyk Natsionalnogo tekhnichnogo universytetu «Kharkivskiy politekhnichnyi Instytut»*, 8 (1127), 86–92.
2. Mizuno, S., Noda, S., Matsushita, M., Koyama, T., Shiraishi, S. (2013). Development of a Totally Enclosed Fan-Cooled Traction Motor. *IEEE Transactions on Industry Applications*, 49 (4), 1508–1514. doi: 10.1109/tia.2013.2256872
3. Nakahama, T., Suzuki, K., Hashidume, S., Ishibashi, F., Hirata, M. (2006). Cooling Airflow in Unidirectional Ventilated Open-Type Motor for Electric Vehicles. *IEEE Transactions on Energy Conversion*, 21 (3), 645–651. doi: 10.1109/tec.2006.877364
4. Cuiping, L., Yulong, P., Ronggang, N., Shukang, C. (2011). Analysis of 3D static temperature field of water cooling induction motor in mini electric vehicle. 2011 International Conference on Electrical Machines and Systems. doi: 10.1109/icems.2011.6073618
5. Nakahama, T., Biswas, D., Kawano, K., Ishibashi, F. (2006). Improved Cooling Performance of Large Motors Using Fans. *IEEE Transactions on Energy Conversion*, 21 (2), 324–331. doi: 10.1109/tec.2006.874245
6. Boglietti, A., Cavagnino, A., Staton, D., Shanel, M., Mueller, M., Mejuto, C. (2009). Evolution and Modern Approaches for Thermal Analysis of Electrical Machines. *IEEE Transactions on Industrial Electronics*, 56 (3), 871–882. doi: 10.1109/tie.2008.2011622
7. Jinxin, F., Chengning, Z., Zhifu, W., Strangas, E. G. (2010). Thermal analysis of water cooled surface mount permanent magnet electric motor for electric vehicle. International Conference on Electrical Machines and Systems (ICEMS).
8. Huang, Z., Nategh, S., Lassila, V., Alakula, M., Yuan, J. (2012). Direct oil cooling of traction motors in hybrid drives. 2012 IEEE International Electric Vehicle Conference. doi: 10.1109/iev.2012.6183163
9. Desale, R., Deshmukh, N. K. (2006). Prediction of air delivery, noise, and power consumption of fan for TEFC electric motors. *J. Sci. Ind. Res.*, 65, 344–348.
10. Rama Krishna, S., Rama Krishna, A., Ramji, K. (2011). Reduction of motor fan noise using CFD and CAA simulations. *Applied Acoustics*, 72 (12), 982–992. doi: 10.1016/j.apacoust.2011.06.008
11. Kondo, M., Miyabe, M., Manabe, S. (2014). Development of a High Efficiency Induction Motor and the Estimation of En-



- ergy Conservation Effect. Quarterly Report of RTRI, 55 (3), 138–143. doi: 10.2219/rtriqr.55.138
12. Kondo, M. (2009). Energy-Saving Effect of High Efficient Traction Motors in Electric Train. RTRI Report, 23 (11), 29–34.
  13. Nikovski, D., Lidicky, B., Zhang, W., Kataoka, K., Yoshimoto, K. (2012). Markov decision processes for train run curve optimization. 2012 Electrical Systems for Aircraft, Railway and Ship Propulsion. doi: 10.1109/esars.2012.6387473
  14. Ma, Y. (2008). Dynamic programming and the HJB equation. Optimal Control Lecture Notes, 121–149.
  15. Xie, M. Q., Nie, L. (2009). Research on Periodic Train Working Diagram Model. Journal of China Railway Society, 31, 7–13.
  16. Cezario, C. A., Silva, H. P. (2010). Electric motor winding temperature prediction using a simple two-resistance thermal circuit. COMPEL – The international journal for computation and mathematics in electrical and electronic engineering, 29 (5), 1325–1330. doi: 10.1109/icelmach.2008.4800135
  17. Santos, S., Antunes, C. (2012). CFD and Thermography Techniques Applied in Cooling Systems Designs. Applied Computational Fluid Dynamics, 135–154. doi: 10.5772/26311
  18. Ding, Y., Zhou, F., Bai, Y., Li, R. (2009). A correction model of loaded train's grade resistance calculation. 5th Advanced Forum on Transportation of China (AFTC 2009). doi: 10.1049/cp.2009.1626
  19. Mou, W. T., Dong, Y. (2010). Train Operation Adjustment Model and Three Swarms Cooperative Particle Swarm Optimization Algorithm Research. Railway Operation Technology Journal, 16, 13–15.
  20. Liubarskyi, B. G. (2014). Optimizatsiya rezhimov roboty tyagovogo asinhronnogo privoda. Elektriika, 6, 5–10.
  21. Petrenko, O. M., Domanskyi, I. V., Liubarskyi, B. G. (2016). Metodika optimizatsiyi rezhimiv roboti asinhronnogo tyagovogo privodu ruhomogo skladu. Mekhanika ta mashynobuduvannya, 1, 59–67.
  22. Severin, V. P. (2009). Vektornaia optimizatsiia system avtomaticheskogo upravleniia geneticheskimi algoritmami. Tekhnicheskaiia elektrodinamika. Silovaia elektronika i energoeffektivnost, 80–85.
  23. Afanasov, A. M. (2014). Opredelenie magnitnykh poter v tiagovykh dvigatel'nykh elektropodvizhnogo sostava magistralnogo i promyshlennogo transporta. Zbir. nauk. prats' Donets'koho instytutu zaliznychnoho transportu, 39, 71–77.
  24. General Considerations for IGBT and IPM. Mitsubishi Application Notes. Available at: [http://www.mitsubishielectric.com/semiconductors/files/manuals/powermos3\\_0.pdf](http://www.mitsubishielectric.com/semiconductors/files/manuals/powermos3_0.pdf)
  25. Ivahno, V. V., Zamaruev, V. V., Ilina, O. V. (2014). Vybór i raschet silovykh poluprovodnikovyykh priborov poluprovodnikovogo preobrazovatelya elektricheskoi energii. Kharkiv: NTU «KhPI», 72.
  26. Kappen, H. J. (2011). Optimal control theory and the linear Bellman equation. Bayesian Time Series Models, 363–387. doi: 10.1017/cbo9780511984679.018
  27. Petrenko, O. M. (2017). Optymizatsiia parametriv ventyliatora asynkhronnogo tiagovogo dvyguna tramvainogo vagonu. Systemy upravlinnia, navigatsii ta zviazku, 1, 64–68.
  28. Petrenko, O. M., Liubarskyi, B. G., Glebova, M. L. (2017). Matematychna model teplovogo stanu tiagovykh asynkhronnykh dvyguniv tramvainykh vagoniv. Systemy upravlinnia, navigatsii ta zviazku, 2, 46–50.
  29. Petrushin, V. S., Yakimets, A. M., Kalenik, O. V. (2008). Osobennosti teplovykh raschetov neustanovivshihsiya rezhimov roboty reguliruemyykh asinhronnykh dvigateley. Elektromashinostroenie i elektrooborudovanie, 71, 47–51.

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## A METHOD FOR LOCALIZING A REFERENCE OBJECT IN A CURRENT IMAGE WITH SEVERAL BRIGHT OBJECTS (p. 68-74)

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To ensure the effective functioning of the correlation-extreme navigation systems (CENSs), a method is developed to localize a reference object (RO) in a current image (CI) with several bright objects. The peculiarity of the method consists in converting the CI to a binary unit by determining the average value of the background and setting it for the threshold of the image quantization, which in turn determines the amount of probabilities of errors of the first and second kinds as well as entails assigning the objects of the viewing surface (VS) and the backgrounds to two classes: the RO and the background. The CI model is represented by the brightness values of the corresponding objects and backgrounds of the VS in the differentiation elements. In the model of the current image, the RO has the highest brightness. Other objects that are similar in brightness and commensurate with the RO are categorized as false. The reference image (RI) is set by the contrast mark and the geometrical shape of the object, and it is binary. An algorithm has been developed for localizing the RO in an image by searching for a fragment of a binary CI with a maximum value of units that coincides with the RI. The peculiarity of the algorithm consists in adapting the application procedure for the threshold conversion of a CI with an unknown value of the signal-noise ratio. A method has been developed to clarify the maximum value of the DF and to determine the coordinates of the RO in the field of the CI matrix. The method consists in the summation of the number of units of different sections and finding the highest value of the DF. The highest value of the DF coincides with the full match between the CI and the RI. An analytical expression has been obtained for the estimation of the probability of localizing the RO. The expression establishes dependence of the probability of localizing the RO on the parameters that are specified in the stages of solving the problem of localizing the RO, which are the identification, the multi-threshold selection, and the specification of the maximum DF. By modeling the process of forming the DF, numerical estimates have been obtained for the probability of localizing the RO. The research results indicate the feasibility of using the proposed method in a CENS in relation to a VS with several bright objects.

**Keywords:** current image, identification and selection of a multi-threshold reference object, unimodal decision function.

## References

1. Tarshyn, V. A., Sotnikov, A. M., Sidorenko, R. G., Megelbey, V. V. (2015). Preparation of reference patterns for high-fidelity correlation-extreme navigation systems on basis of forming of paul fractal dimensions. *Systemy Ozbroiennia i Viiskova Tekhnika*, 2 (42), 142–144.
2. Tarshyn, V. A., Sotnikov, A. M., Sidorenko, R. G. (2015). Preparation of reference patterns for high-fidelity cross-correlation-extreme systems of navigation on basis of the use direct cross-correlation analysis. *Nauka i Tekhnika Povitrianykh Syl Zbroinykh Syl Ukrainy*, 2 (19), 69–73.
3. Vorobiov, O., Savchenko, V., Sotnikov, A., Tarshyn, V., Kurtseitov, T. (2017). Development of radioisotopic-plasma technology for the protection of radio electronic means from powerful electromagnetic radiation. *Eastern-European Journal of Enterprise Technologies*, 1 (5 (85)), 16–22. doi: 10.15587/1729-4061.2017.91642
4. Pahomov, A. A., Potapov, A. A. (2015). Obrabotka iskazhennykh atmosferoy izobrazheniy, poluchennykh aviacionnymi kompleksami. *Radiotekhnika*, 5, 144–145.
5. Fernandes, L. A. F., Oliveira, M. M. (2008). Real-time line detection through an improved Hough transform voting scheme. *Pattern Recognition*, 41 (1), 299–314. doi: 10.1016/j.patcog.2007.04.003
6. Fursov, V. A., Bibikov, S. A., Yakimov, P. Yu. (2013). Localization of objects contours with different scales in images using Hough transform. *Komp'yuternaya Optika*, 37 (4), 496–502.
7. Maji, S., Malik, J. (2009). Object detection using a max-margin Hough transform. 2009 IEEE Conference on Computer Vision and Pattern Recognition. doi: 10.1109/cvpr.2009.5206693
8. Katulev, A. N., Kolonskov, A. A., Hramichev, A. A., Yagol'nikov, S. V. (2014). Adaptivniy metod i algoritm obnaruzheniya malokontrastnykh ob'ektov optiko-ehlektronnym sredstvom. *Opticheskiy Zhurnal*, 2, 29–39.
9. Gnilitskii, V. V., Insarov, V. V., Chernyavskii, A. S. (2010). Decision making algorithms in the problem of object selection in images of ground scenes. *Journal of Computer and Systems Sciences International*, 49 (6), 972–980. doi: 10.1134/s1064230710060158
10. Bogush, R., Maltsev, S. (2007). Minimax Criterion of Similarity for Video Information Processing. 2007 Siberian Conference on Control and Communications. doi: 10.1109/sibcon.2007.371310
11. Potapov, A. A. (2013). Fractal paradigm and fractal-scaling methods in fundamentally new dynamic fractal signal detectors. 2013 International Kharkov Symposium on Physics and Engineering of Microwaves, Millimeter and Submillimeter Waves. doi: 10.1109/msmw.2013.6622151