DEVELOPMENT OF METHODOLOGICAL FOUNDATIONS FOR DESIGNING A CLASSIFIER OF THREATS TO CYBERPHYSICAL SYSTEMS (p. 6–19)

Olexander Shmatko

National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0002-2426-900X

Svitlana Balakireva

Ivan Kozhedub Kharkiv National Air Force University, Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0003-2535-0798

Andrii Vlasov

Ivan Kozhedub Kharkiv National Air Force University, Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0001-6080-237X

Nataliya Zagorodna

Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine

ORCID: http://orcid.org/0000-0002-1808-835X

Olha Korol

Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0002-8733-9984

Oleksandr Milov

Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0001-6135-2120

Oleksii Petrov

Ivan Kozhedub Kharkiv National Air Force University, Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0002-3062-9286

Serhii Pohasii

Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0002-4540-3693

Khazail Rzayev

Azerbaijan State Oil and Industry University, Baku, Azerbaijan

ORCID: http://orcid.org/0000-0001-9272-4302

Vladyslav Khvostenko

Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine

ORCID: http://orcid.org/0000-0002-6436-4159

The emergence of a full-scale quantum computer questions the stability of almost all symmetric and asymmetric cryptography algorithms. At the same time, the rapid growth of computing resources of IT and "G" technologies contributes to an increase in attacks on information and communication (ICS) and cyberphysical systems (CPS). These systems are the core of modern critical cybernetic information systems (CCIS). In such conditions, the primary task of maintaining the required level of security is the classification of modern threats that are integrated with social engineering methods and acquire signs of synergy and hybridity. The paper proposes a synergistic model of threats to ICS/CPS, which takes into account the focus of threats on synergy and hybridity, and the combined impact of security components: information security (IS), cybersecurity (CS), security of information (SI). This approach allows developing methodological foundations for building a unified classifier of threats to cyberphysical systems, forming sets of critical threats, critical points in the ICS/CPS infrastructure elements, based on minimal computing, human and economic costs. The developed methodology for determining the category of an attacker allows systematizing an attacker and, based on the analysis of weighting factors, forming a matrix of correspondence between the capabilities of attackers of various categories and technical means of information security (TMIS). These actions significantly reduce the risk of an attack by certain categories of attackers and allow for planning in the formation of both the IS policy and the corresponding protection profiles.

Keywords: synergetic model of threats, classifier of threats of cyberphysical systems, information security, cybersecurity.

References

1. Alguliyev, R., Imamverdiyev, Y., Sukhostat, L. (2018). Cyberphysical systems and their security issues. Computers in Industry, 100, 212–223. doi: https://doi.org/10.1016/j.compind.2018.04.017
2. Cárdenas, A. A., Amin, S., Lin, Z.-S., Huang, Y.-L., Huang, C.-Y., Sastry, S. (2011). Attacks against process control systems. Proceedings of the 6th ACM Symposium on Information, Computer and Communications Security - ASIACCS '11. doi: https://doi.org/10.1145/1966913.1966959
3. Gollmann, D. (2013). Security for Cyber-Physical Systems. Lecture Notes in Computer Science, 12–14. doi: https://doi.org/10.1007/978-3-642-36046-6_2
4. Cardenas, A., Amin, S., Sinopoli, B., Giani, A., Perrig, A., Sastry, S. (2009). Challenges for securing cyber physical systems. Workshop on future directions in cyber-physical systems security.
5. Pfleeger, C. P., Pfleeger, S. L. (2006). Security in Computing. Prentice Hall, 880.
6. Cebula, J. J., Young, L. R. (2010). A taxonomy of operational cyber security risks. Technical report, DTIC Document.
7. Kang, D.-J., Lee, J.-J., Kim, S.-J., Park, J.-H. (2009). Analysis on cyber threats to SCADA systems. 2009 Transmission & Distribution Conference & Exposition: Asia and Pacific. doi: https://doi.org/10.1109/td-asia.2009.5357008
8. Nicholson, A., Webber, S., Dyer, S., Patel, T., Janicke, H. (2012). SCADA security in the light of Cyber-Warfare. Computers & Security, 31 (4), 418–436. doi: https://doi.org/10.1016/j.cose.2012.02.009
9. Guide for conducting risk assessments (2012). NIST. doi: https://doi.org/10.6028/nist.sp.800-30r1
10. Cyber threat source descriptions. US-CERT. Available at: https://ics-cert.us-cert.gov/content/cyber-threat-source-descriptions
11. Milov, O., Korol, O., Khvostenko, V. (2019). Development of the classification of the cyber security agents bounded rationality. Control, Navigation and Communication Systems. Academic Journal, 4 (56), 82–90. doi: https://doi.org/10.26906/sunz.2019.4.082
12. Yevseiev, S. (2017). Intruder model of access rights in the automated banking system based on a synergistic approach. Naukovotekhnichnyi zhurnal "Informatsiyna bezpeka", 2 (26), 110–120.
13. Kravets, D. (2009). Feds: Hacker disabled offshore oil platforms' leak-detection system. Available at: https://www.wired.com/2009/03/feds-hacker-dis/
14. Chattopadhyay, A., Prakash, A., Shafique, M. (2017). Secure Cyber-Physical Systems: Current trends, tools and open research prob-

lems. Design, Automation & Test in Europe Conference & Exhibition (DATE), 2017. doi: https://doi.org/10.23919/date.2017.7927154

15. Dell security annual threat report. Available at: https://proconics.co.za/wp-content/uploads/2017/10/2425.pdf

16. Walker, J. J. (2012). Cyber Security Concerns for Emergency Management. Emergency Management. doi: https://doi.org/10.5772/34104

17. Ali, N. S. (2016). A four-phase methodology for protecting web applications using an effective real-time technique. International Journal of Internet Technology and Secured Transactions, 6 (4), 303. doi: https://doi.org/10.1504/ijitst.2016.10003854

18. Park, K.-J., Zheng, R., Liu, X. (2012). Cyber-physical systems: Milestones and research challenges. Computer Communications, 36 (1), 1–7. doi: https://doi.org/10.1016/j.comcom.2012.09.006

19. Hansman, S., Hunt, R. (2005). A taxonomy of network and computer attacks. Computers & Security, 24 (1), 31–43. doi: https://doi.org/10.1016/j.cose.2004.06.011

20. Goel, S., Chen, V. (2005). Information security risk analysis – a matrix-based approach. Proceedings of the Information Resource Management Association (IRMA) International Conference. San Diego.

21. Kjaerland, M. (2006). A taxonomy and comparison of computer security incidents from the commercial and government sectors. Computers & Security, 25 (7), 522–538. doi: https://doi.org/10.1016/j.cose.2006.08.004

22. Blackwell, C. (2010). A security ontology for incident analysis. Proceedings of the Sixth Annual Workshop on Cyber Security and Information Intelligence Research - CSIIRW '10. doi: https://doi.org/10.1145/1852666.1852717

23. Yevseiev, S., Karpinski, M., Shmatko, O., Romashchenko, N., Gancarczyk, T. (2019). Methodology of the cyber security threats risk assessment based on the fuzzy-multiple approach. 19th International Multidisciplinary Scientific GeoConference (SGEM 2019). Sofia, 437.

24. Pollock, G. M., Atkins, W. D., Schwartz, M. D., Chavez, A. R., Urrea, J. M., Pattengale, N. et. al. (2010). Modeling and simulation for cyber-physical system security research, development and applications. doi: https://doi.org/10.2172/1028942

25. Ahmad, R., Yunos, Z. (2012). A dynamic cyber terrorism framework. International Journal of Computer Science and Information Security, 10 (2), 149–158.

26. Loukas, G., Gan, D., Vuong, T. (2013). A taxonomy of cyber attack and defence mechanisms for emergency management networks. 2013 IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops). doi: https://doi.org/10.1109/percomw.2013.6529554

27. Framework for Improving Critical Infrastructure Cybersecurity. Version 1.0 (2014). National Institute of Standards and Technology. Available at: http://securityaffairs.co/Downloads/cybersecurity-framework-021214-final.pdf

28. Hughes, J., Cybenko, G. (2014). Three tenets for secure cyber-physical system design and assessment. Cyber Sensing 2014. doi: https://doi.org/10.1117/12.2053933

29. Buchyk, S. (2016). The methodology of analysis of risks of tree that identifiers the state informative resources. Ukrainian Information Security Research Journal, 18 (1), 81–89. doi: https://doi.org/10.18372/2410-7840.18.10116

30. Yevseiev, S., Rzayev, K., Mammadova, T., Samedov, F., Romashchenko, N. (2018). Classification of cyber cruise of informational resources of automated banking systems. Cybersecurity: Education, Science, Technique, 2 (2), 47–67. doi: https://doi.org/10.28925/2663-4023.2018.2.4767

31. Chen, L., Jordan, S., Liu, Y.-K., Moody, D., Peralta, R., Perlner, R., Smith-Tone, D. (2016). Report on Post-Quantum Cryptography. NIST. doi: https://doi.org/10.6028/nist.ir.8105

32. Nurdinov, R. A., Batova, T. N. (2013). Approaches and methods of rationale choosing of information protection facilities. Sovremennye problemy nauki i obrazovaniya, 2, 395. Available at: https://www.elibrary.ru/item.asp?id=21285749

33. Katorin, Yu. F., Nurdinov, R. A., Zaytseva, N. M. (2015). Model' kolichestvennoy otsenki riskov bezopasnosti informatsionnoy sistemy. Vestnik mezhdunarodnyh nauchnyh konferentsiy, 12 (16), 77–86. Available at: https://www.elibrary.ru/item.asp?id=25663945

34. Howard, J. (1997). An Analysis of Security Incidents on the Internet 1989–1995. Pennsylvania. Available at: https://resources.sei.cmu.edu/asset_files/WhitePaper/1997_019_001_52455.pdf

OBSERVED TIME DIFFERENCE OF ARRIVAL BASED POSITION ESTIMATION FOR LTE SYSTEMS: SIMULATION FRAMEWORK AND PERFORMANCE EVALUATION (p. 20–28)

Abdulrhman Kh. Alhafid
College of Engineering, University of Mosul, Mosul, Iraq
ORCID: http://orcid.org/0000-0002-2475-8049

Sedki Younis
College of Electronics Engineering, Ninevah University, Mosul, Iraq
ORCID: http://orcid.org/0000-0003-2917-5747

Precise user equipment (UE) location is paramount for the reliable operation of location-based services provided by mobile network operators and other emerging applications. In this paper, the Long Term Evolution (LTE) network positioning performance based on mobile assist Observed Time Difference of Arrival (OTDoA) method is considered. The received signal time difference (RSTD) measurements are estimated by the UE using dedicated position reference signal (PRS) transmitted in the downlink frame where the reported time measurements are used by the network for location calculation. A simulation framework for the position estimation in LTE networks is presented where the LTE downlink communication link is implemented. The correlation-based method for the time of arrival measurement is used for the implementation of OTDoA. The simulation framework provides different configurations and adjustments for the system and network parameters for evaluating the performance of LTE positioning using OTDoA over multipath fading channels. Different simulation scenarios are conducted to identify the influence of various parameters of LTE system and positioning procedure setup on the positioning accuracy. Simulation results demonstrated that the positioning accuracy is highly affected by the channel fading condition where the accuracy of time of arrival measurements is deteriorated in severe fading environments; however, the positioning accuracy can be significantly improved by increasing the positioning sequences involved in the estimation process either in the frequency domain or in the time domain.

Keywords: LTE, Positioning, Estimation, OTDoA, Time of arrival, Correlation, Monte-Carlo simulation, Multilateration, fading channels, geolocation.

References

1. Frattasi, S., Rosa, F. D. (2017). Mobile Positioning and Tracking. John Wiley & Sons. doi: https://doi.org/10.1002/9781119068846

2. Xu, W., Dammann, A., Laas, T. (2019). Where are the Things of the Internet? Precise Time of Arrival Estimation for IoT Positioning. The Fifth Generation (5G) of Wireless Communication. doi: https://doi.org/10.5772/intechopen.78063

3. Campos, R. S. (2017). Evolution of Positioning Techniques in Cellular Networks, from 2G to 4G. Wireless Communica-

tions and Mobile Computing, 2017, 1–17. doi: https://doi.org/10.1155/2017/2315036

4. Rufa, J. R., Atkins, E. M. (2013). OTDOA/GPS Fusion for Urban UAS Navigation using Particle Filtering Techniques. AIAA Guidance, Navigation, and Control (GNC) Conference. doi: https://doi.org/10.2514/6.2013-4878

5. Shamaei, K., Khalife, J., Kassas, Z. M. (2018). A joint TOA and DOA approach for positioning with LTE signals. 2018 IEEE/ION Position, Location and Navigation Symposium (PLANS). doi: https://doi.org/10.1109/plans.2018.8373368

6. Sivers, M., Fokin, G. (2015). LTE Positioning Accuracy Performance Evaluation. Internet of Things, Smart Spaces, and Next Generation Networks and Systems, 393–406. doi: https://doi.org/10.1007/978-3-319-23126-6_35

7. Lin, X., Bergman, J., Gunnarsson, F., Liberg, O., Razavi, S. M., Razaghi, H. S. et. al. (2017). Positioning for the Internet of Things: A 3GPP Perspective. IEEE Communications Magazine, 55 (12), 179–185. doi: https://doi.org/10.1109/mcom.2017.1700269

8. Del Peral-Rosado, J. A., Lopez-Salcedo, J. A., Seco-Granados, G., Zanier, F., Crisci, M. (2012). Evaluation of the LTE positioning capabilities under typical multipath channels. 2012 6th Advanced Satellite Multimedia Systems Conference (ASMS) and 12th Signal Processing for Space Communications Workshop (SPSC). doi: https://doi.org/10.1109/asms-spsc.2012.6333065

9. Radnosrati, K. (2018). On Timing-Based Localization in Cellular Radio Networks. No. 1808. Doctor's degree Thesis, Linköping University. doi: https://doi.org/10.3384/lic.diva-148074

10. Kong, S.-H., Kim, B. (2016). Error Analysis of the OTDOA From the Resolved First Arrival Path in LTE. IEEE Transactions on Wireless Communications, 15 (10), 6598–6610. doi: https://doi.org/10.1109/twc.2016.2586469

11. Gadka, P. (2014). New First - Path Detector for LTE Positioning Reference Signals. UBICOMM 2014: The Eighth International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies, 99–104.

12. Ryden, H., Razavi, S. M., Gunnarsson, F., Kim, S. M., Wang, M., Blankenship, Y. et. al. (2015). Baseline performance of LTE positioning in 3GPP 3D MIMO indoor user scenarios. 2015 International Conference on Location and GNSS (ICL-GNSS). doi: https://doi.org/10.1109/icl-gnss.2015.7217158

13. Lee, K., Hwang, W., Ryu, H., Choi, H.-J. (2017). New TDOA-Based Three-Dimensional Positioning Method for 3GPP LTE System. ETRI Journal, 39 (2), 264–274. doi: https://doi.org/10.4218/etrij.17.0116.0554

14. Hu, S., Berg, A., Li, X., Rusek, F. (2017). Improving the Performance of OTDOA Based Positioning in NB-IoT Systems. GLOBECOM 2017 - 2017 IEEE Global Communications Conference. doi: https://doi.org/10.1109/glocom.2017.8254510

15. Hu, S., Li, X., Rusek, F. (2019). On Time-of-Arrival Estimation in NB-IoT Systems. 2019 IEEE Wireless Communications and Networking Conference (WCNC). doi: https://doi.org/10.1109/wcnc.2019.8885551

16. Berg, A. (2017). OTDOA based positioning in NB-IoT. Lund University.

17. Radnosrati, K., Hendeby, G., Fritsche, C., Gunnarsson, F., Gustafsson, F. (2017). Performance of OTDOA positioning in narrowband IoT systems. 2017 IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC). doi: https://doi.org/10.1109/pimrc.2017.8292365

18. Aatique, M. (1997). Evaluation of TDOA techniques for position location in CDMA systems. Virginia, 125.

19. Del Peral-Rosado, J. A. (2014). Evaluation of the LTE positioning capabilities in realistic navigation channels. Universitat Autònoma de Barcelona.

20. 3GPP TS 36.211 V12.3.0. (2014). LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 12.3.0 Release 12).

21. 3GPP TS 36. 116 V13.0.1. (2016). LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Relay radio transmission and reception. (3GPP TS 36.116 version 13.0.1 Release 13).

DEVELOPMENT OF TYPICAL "STATE" SOFTWARE PATTERNS FOR CORTEXM MICROCONTROLLERS IN REAL TIME (p. 29–38)

Pavlo Katin
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-2542-9976

Viacheslav Chmelov
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
ORCID: http://orcid.org/0000-0003-3369-2675

Vladimir Shemaev
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
ORCID: http://orcid.org/0000-0003-1629-6689

There are real-time technical systems that require high speed of software solutions. At the same time, it is necessary to ensure the unification of the source code, the quality of software maintenance, and mathematical modeling at a relatively low cost of software and hardware solution. Such hardware can be implemented on the basis of mass microcontrollers of the Cortex-M architecture.

The software part of these microcontrollers data could be implemented on the basis of a real-time operating system (RTOS). This study has found that the application of RTOS leads to a speed-related constraint. Simple software solutions are complex at unification, support, and have difficulties with mathematical modeling.

To address these shortcomings, typical State software patterns have been developed for an auxiliary controller within a circuit of controlling mechanisms or sensors based on the Cortex-M architecture microcontroller in real time, in a procedural paradigm. A feature of these patterns is the higher speed of the software solution compared to the solutions based on RTOS.

The developed patterns make it possible to unify the source code for the Cortex-M architecture microcontrollers from different manufacturers, improve maintenance, and adapt it to the mathematical model of the finite state machine.

The study results were tested using the STM32F103 microcontroller employing the Cortex microcontroller software interface system (CMSIS) library. This allows the result obtained to be extended to MCs made by other manufacturers, which ensures the practical value of the developed patterns.

Keywords: real time, master controller, finite state machine, Cortex-M microcontroller, State design pattern.

References

1. Real Time Operating Systems Lecture (2001). MIT. Available at: http://web.mit.edu/16.070/www/year2001/RTOS27.pdf

2. Real Time Operating Systems. Part II (2001). MIT. Available at: http://web.mit.edu/16.070/www/year2001/RTOS28.pdf

3. Saini, P., Bansal, A., Sharma, A. (2015). Time Critical Multitasking For Multicore Microcontroller Using Xmos® Kit. International Journal of Embedded Systems and Applications, 5 (1), 01–18. doi: https://doi.org/10.5121/ijesa.2015.5101

4. Sadgrove, M. (2011). Microcontroller interrupts for flexible control of time critical tasks in experiments with laser cooled atoms. Available at: https://arxiv.org/pdf/1104.0064.pdf

5. Execution time analysis. Rapita Systems. Available at: https://www.rapitasystems.com/products/features/execution-time-analysis

6. Chen, Z., Chen, J., Zhou, S. (2019). Embedded electronic scale measuring system based on STM32 single chip microcomputer. 2019 Chinese Automation Congress (CAC). doi: https://doi.org/10.1109/cac48633.2019.8997317

7. Bessmertnyy, R. S., Katin, P. Y. (2019). Use of high-performance microcontroller for improving economic efficiency of jem production. Standartyzatsiya. Sertyfikatsiya. Yakist, 3 (115), 69–77.

8. Zhu, W., Wang, Z., Zhang, Z. (2020). Renovation of Automation System Based on Industrial Internet of Things: A Case Study of a Sewage Treatment Plant. Sensors, 20 (8), 2175. doi: https://doi.org/10.3390/s20082175

9. Kasthuri Arachchi, S. P., Shih, T. K., Hakim, N. L. (2020). Modelling a Spatial-Motion Deep Learning Framework to Classify Dynamic Patterns of Videos. Applied Sciences, 10 (4), 1479. doi: https://doi.org/10.3390/app10041479

10. Gamma, E., Helm, R., Johnson, R., Vlissides, J., Booch, G. (1994). Design Patterns: Elements of Reusable Object-Oriented Software. Published by Addison-Wesley Professional, 416. Available at: http://www.uml.org.cn/c++/pdf/DesignPatterns.pdf

11. Katin, P. (2017). Development of variant of software architecture implementation for low-power general purpose microcontrollers by finite state machines. EUREKA: Physics and Engineering, 3, 49–54. doi: https://doi.org/10.21303/2461-4262.2017.00361

12. Solodovnikov, A. (2016). Developing method for assessing functional complexity of software information system. EUREKA: Physics and Engineering, 5, 3–9. doi: https://doi.org/10.21303/2461-4262.2016.00157

13. Dietrich, C., Hoffmann, M., Lohmann, D. (2015). Back to the Roots: Implementing the RTOS as a Specialized State Machine. The 11th Annual Workshop on Operating Systems Platforms for Embedded Real-Time Applications, 7–12. Available at: https://people.mpi-sws.org/~bbb/events/ospert15/pdf/ospert15-p7.pdf

14. Beynon, W. M. (1980). On the structure of free finite state machines. Theoretical Computer Science, 11 (2), 167–180. doi: https://doi.org/10.1016/0304-3975(80)90044-4

15. Adamczyk, P. The Anthology of the Finite State Machine Design Patterns. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.95.838&rep=rep1&type=pdf

16. Andresen, K., Møller-Pedersen, B., Runde, R. K. (2015). Combined Modelling and Programming Support for Composite States and Extensible State Machines. Proceedings of the 3rd International Conference on Model-Driven Engineering and Software Development. doi: https://doi.org/10.5220/0005237302310238

17. Prasanna, Ch. S. L., Venkateswara Rao, M. (2012). Implementation of a Scalable μC/OS-II Based Multitasking Monitoring System. International Journal of Computer Science And Technology, 3 (2), 86–89. Available at: http://ijcst.com/vol32/1/prasanna.pdf

18. RM0008 Reference manual STM32F101xx, STM32F102xx, STM32F103xx, STM32F105xx and STM32F107xx advanced Arm®-based 32-bit MCUs. Available at: https://www.st.com/resource/en/reference_manual/cd00171190-stm32f101xx-stm32f102xx-stm32f103xx-stm32f105xx-and-stm32f107xx-advanced-arm-based-32-bit-mcus-stmicroelectronics.pdf

19. Bloh, A. Sh. (1975). Graf shemy i ih primenenie. Minsk: Visheyshaya shkola, 294.

STUDYING ACOUSTIC EMISSION BY FITTING THE DESTRUCTION MODELS OF A COMPOSITE ACCORDING TO THE OR CRITERION AND MISES CRITERION (p. 39–45)

Sergii Filonenko
National Aviation University, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-9250-1640

Anzhelika Stakhova
National Aviation University, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-5171-6330

This paper reports the established patterns of change in the acoustic emission signals by approximating the models of the destruction of a composite material in the form of a bundle of fibers according to the OR criterion and Mises criterion. It has been shown that increasing the coefficient that characterizes the ratio of the size of the elements of the composite material leads to that the pattern of change in the equivalent stresses according to the OR criterion is approaching the pattern of change by Mises criterion. At a certain value of the coefficient, according to the OR criterion, the equivalent stresses are aligned with a minimal deviation from each other. However, this alignment is limited to a specific change period.

We have established patterns of change in the number of elements, which remain, as well as the signals of acoustic emission according to the OR criterion with the regularity of their change approaching that based on the Mises criterion. It has been shown that at the best approximation of the equivalent stresses according to the criteria there is a good agreement of the patterns of change in the number of a composite's elements, remaining in time, and the parameters for the formed signals of acoustic emission with their minimal deviation. It has been determined that the deviations in the parameters of acoustic emission signals are due to the difference in the rate of change in the equivalent stresses in proportion to approaching the time when a composite material starts breaking according to the OR criterion and Mises criterion.

It has been determined that with the increasing deformation rate of a composite material, the patterns of change in the equivalent stresses approaching those based on the OR criterion and Mises criterion, the number of the remaining elements in the composite over time, and the parameters of acoustic emission signals are maintained. However, these patterns are observed at smaller intervals of time. The results obtained could be used in the study of the destructive processes of composite materials, taking into consideration the influence of various factors.

Keywords: acoustic emission, composite material, signal parameters, destruction criteria, equivalent stresses.

References

1. Turcotte, D. L., Newman, W. I., Shcherbakov, R. (2003). Micro and macroscopic models of rock fracture. Geophysical Journal International, 152 (3), 718–728. doi: https://doi.org/10.1046/j.1365-246x.2003.01884.x

2. Kun, F., Carmona, H. A., Andrade, J. S., Herrmann, H. J. (2008). Universality behind Basquin's Law of Fatigue. Physical Review Letters, 100 (9). doi: https://doi.org/10.1103/physrevlett.100.094301

3. Danku, Z., Kun, F. (2014). Record breaking bursts in a fiber bundle model of creep rupture. Frontiers in Physics, 2. doi: https://doi.org/10.3389/fphy.2014.00008

4. Kovács, K., Hidalgo, R. C., Pagonabarraga, I., Kun, F. (2013). Brittle-to-ductile transition in a fiber bundle with strong heterogeneity. Physical Review E, 87 (4). doi: https://doi.org/10.1103/physreve.87.042816

5. Bosia, F., Pugno, N., Lacidogna, G., Carpinteri, A. (2008). Mesoscopic modeling of Acoustic Emission through an energetic approach. International Journal of Solids and Structures, 45 (22-23), 5856–5866. doi: https://doi.org/10.1016/j.ijsolstr.2008.06.019

6. Pugno, N., Bosia, F., Carpinteri, A. (2009). Size effects on the strength of nanotube bundles. Measurement Science and Technology, 20 (8), 084028. doi: https://doi.org/10.1088/0957-0233/20/8/084028

7. Oskouei, A. R., Ahmadi, M. (2009). Fracture Strength Distribution in E-Glass Fiber Using Acoustic Emission. Journal of Composite Materials, 44 (6), 693–705. doi: https://doi.org/10.1177/0021998309347963

8. Hader, A., Boughaleb, Y., Achik, I., Sbiaai, K. (2013). Failure kinetic and scaling behavior of the composite materials: Fiber Bundle Model with the local load-sharing rule (LLS). Optical Materials, 36 (1), 3–7. doi: https://doi.org/10.1016/j.optmat.2013.07.035

9. Lennartz-Sassinek, S., Danku, Z., Kun, F., Main, I. G., Zaiser, M. (2013). Damage growth in fibre bundle models with localized load sharing and environmentally-assisted ageing. Journal of Physics: Conference Series, 410, 012064. doi: https://doi.org/10.1088/1742-6596/410/1/012064

10. Capelli, A., Reiweger, I., Lehmann, P., Schweizer, J. (2018). Fiber-bundle model with time-dependent healing mechanisms to simulate progressive failure of snow. Physical Review E, 98 (2). doi: https://doi.org/10.1103/physreve.98.023002

11. Capelli, A., Reiweger, I., Schweizer, J. (2018). Acoustic emission signatures prior to snow failure. Journal of Glaciology, 64 (246), 543–554. doi: https://doi.org/10.1017/jog.2018.43

12. Pradhan, S., Kjellstadli, J. T., Hansen, A. (2019). Variation of Elastic Energy Shows Reliable Signal of Upcoming Catastrophic Failure. Frontiers in Physics, 7. doi: https://doi.org/10.3389/fphy.2019.00106

13. Yamada, Y., Yamazaki, Y. (2019). Avalanche Distribution of Fiber Bundle Model with Random Displacement. Journal of the Physical Society of Japan, 88 (2), 023002. doi: https://doi.org/10.7566/jpsj.88.023002

14. Abaimov, S. G. (2017). Non-equilibrium Annealed Damage Phenomena: A Path Integral Approach. Frontiers in Physics, 5. doi: https://doi.org/10.3389/fphy.2017.00006

15. Danku, Z., Ódor, G., Kun, F. (2018). Avalanche dynamics in higher-dimensional fiber bundle models. Physical Review E, 98 (4). doi: https://doi.org/10.1103/physreve.98.042126

16. Monterrubio-Velasco, M., Rodríguez-Pérez, Q., Zúñiga, R., Scholz, D., Aguilar-Meléndez, A., de la Puente, J. (2019). A stochastic rupture earthquake code based on the fiber bundle model (TREMOL v0.1): application to Mexican subduction earthquakes. Geoscientific Model Development, 12 (5), 1809–1831. doi: https://doi.org/10.5194/gmd-12-1809-2019

17. Raischel, F., Kun, F., Herrmann, H. J. (2005). Simple beam model for the shear failure of interfaces. Physical Review E, 72 (4). doi: https://doi.org/10.1103/physreve.72.046126

18. Raischel, F., Kun, F., Herrmann, H. J. (2006). Local load sharing fiber bundles with a lower cutoff of strength disorder. Physical Review E, 74 (3). doi: https://doi.org/10.1103/physreve.74.035104

19. Michlmayr, G., Cohen, D., Or, D. (2013). Shear-induced force fluctuations and acoustic emissions in granular material. Journal of Geophysical Research: Solid Earth, 118 (12), 6086–6098. doi: https://doi.org/10.1002/2012jb009987

20. Filonenko, S., Kalita, V., Kosmach, A. (2012). Destruction of composite material by shear load and formation of acoustic radiation. Aviation, 16 (1), 1–9. doi: https://doi.org/10.3846/16487788.2012.679831

Viktor Kharchenko
O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-1209-609X

Ivan Kostenko
O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-8170-7432

Borys Liubarskyi
National Technical University
«Kharkiv Polytechnic Institute», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-2985-7345

Viktor Shaida
National Technical University
«Kharkiv Polytechnic Institute», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-4281-5545

Maksym Kuravskyi
Ivan Kozhedub Kharkiv National Air Force University, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-9360-6850

Oleksandr Petrenko
O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-4027-4818

Switching to the new type of a traction drive, from direct to alternating current, cannot be performed instantly in public transportation. The reason is the large fleet of vehicles and associated costs. In most countries in Europe and Asia, this process takes years.

Therefore, the fleet of trolleybuses develops in two directions simultaneously. The first is the purchase of new trolleybuses, that is, the renewal of fleet with modern machines with an alternating current traction motor. The second is the overhaul and modernization of "outdated" machines, in order to improve their performance. Most "obsolete" trolleybuses are equipped with direct current traction motors of serial or mixed excitation. It is possible to achieve substantial energy savings and to improve the characteristics of the traction electric drive with such engines by using a pulse control system and by optimizing control algorithms.

The goal of this study is to increase energy efficiency and to improve the characteristics of the trolleybus traction electric drive, equipped with a direct current motor of mixed excitation. This is accomplished by improving this drive's control system based on the pulse control system via DC-DC.

The feasibility of the tractive electric drive has been tested through imitation and physical modeling. A mathematical model of the DC motor with mixed excitation has also been improved. A special feature of this model is taking into consideration the saturation of the elements of a magnetic wire of the traction motor based on the preliminary performed calculations of a magnetic field using a finite element method. By combining these components, the improved mathematical model of the entire trolleybus electric drive has been built.

The operation of the trolleybus electric drive under a start mode has been simulated. The results have confirmed the increase in the energy efficiency of the traction electric drive by reducing the loss for excitation. The comparison has proven that the losses of energy

decreased from 0.587 MJ (0.163 kWh) to 0.531 (0.1475 kWh) MJ, by 9.54 %.

References

1. Hutyria, S., Yahlinskyi, V., Chanchin, A., Khomiak, Y., Popov, V. (2020). Evolution of trolley-bus: directions, indicators, trends. Diagnostyka, 21 (1), 11–26. doi: https://doi.org/10.29354/diag/116080

2. Grijalva, E. R., López Martínez, J. M. (2019). Analysis of the Reduction of CO2 Emissions in Urban Environments by Replacing Conventional City Buses by Electric Bus Fleets: Spain Case Study. Energies, 12 (3), 525. doi: https://doi.org/10.3390/en12030525

3. Tica, S., Filipovic, S., Zivanovic, P., Bajcetic, S. (2011). Development of Trolleybus Passenger Transport Subsystems in Terms of Sustainable Development and Quality of Life in Cities. International Journal for Traffic and Transport Engineering, 1 (4), 196–205.

4. Stepanov, P. (2019). Characteristics of construction and operation of trolleybus systems in the world. Prace Komisji Geografii Komunikacji PTG, 22 (3), 64–72. doi: https://doi.org/10.4467/2543859xpkg.19.018.11284

5. Grzelec, K., Birr, K. (2016). Development of trolleybus public transport in gdynia as part of a sustainable mobility strategy. Scientific Journal of Silesian University of Technology. Series Transport, 92, 53–63. doi: https://doi.org/10.20858/sjsutst.2016.92.6

6. Lyagushkin, A., Yankivskiy, D., Vel'mozhko, A. (2019). Na kakih trolleybusah ezdyat ukraintsy. Passazhirskiy Transport. Available at: https://traffic.od.ua/blogs/antonlyagushkin/1217504

7. Zavada, J., Blašković Zavada, J., Miloš, K. (2012). Conditions for Implementing Trolleybuses in Public Urban Transport. PROMET - Traffic&Transportation, 22 (6), 467–474. doi: https://doi.org/10.7307/ptt.v22i6.212

8. Bogodistiy, P. (2016). Sovremenniy trolleybus: opisaniya ustroystva i printsipa raboty. Nauka i Tehnika. Available at: https://naukatehnika.com/sovremennyij-trollejbus.html

9. Karpliuk, L., Panchenko, B. (2012). Osoblyvosti zastosuvannia chastotnokerovanoho asynkhronnoho elektropryvodu dlia tiahovykh mekhanizmiv. Visnyk Natsionalnoho universytetu «Lvivska politekhnika»: Elektroenerhetychni ta elektromekhanichni systemy, 736, 49–53. Available at: http://ena.lp.edu.ua:8080/bitstream/ntb/15815/1/9-Karplyuk-49-53.pdf

10. Sharyakov, V. (2014). Dvadtsat' let vnedreniya asinhronnogo elektroprivoda na gorodskom elektrotransporte. Control Engineering Rossiya, 3 (51), 67–69. Available at: https://controleng.ru/wp-content/uploads/5167.pdf

11. Bartłomiejczyk, M., Połom, M., Jakimovska, K. (2013). Application of principal component and hierarchical cluster analysis in classifying defects of trolleybuses. Przeglad Elektrotechniczny, 89 (8), 48–51. Available at: http://www.pe.org.pl/articles/2013/8/10.pdf

12. Lyagushkin, A., Yankivskiy, D. (2020). Kak v proshlom godu obnovlyalis' trolleybusnye parki Ukrainy. Odesskiy Kur'er. Available at: https://uc.od.ua/news/traffic/1222426

13. Lyagushkin, A., Vel'mozhko, A. (2019). Proekt EIB «Gorodskoy obshchestvenniy transport v Ukraine»: kakih uspehov dobilis' goroda. Passazhirskiy Transport. Available at: https://traffic.od.ua/blogs/antonlyagushkin/1220877

14. Mwambeleko, J. J., Kulworawanichpong, T., Greyson, K. A. (2015). Tram and trolleybus net traction energy consumption comparison. 2015 18th International Conference on Electrical Machines and Systems (ICEMS). doi: https://doi.org/10.1109/icems.2015.7385399

15. Cherny, M., Kachimov, V. (2009). Implementation of energy efficient equipment and technologies at the rolling stock city electric Ukraine.

16. Nicholson, T. J. (2008). DC & AC traction motors. IET Professional Development Course on Electric Traction Systems. doi: https://doi.org/10.1049/ic:20080505

17. Andreychenko, V. P., Donets, A. V., Gerasimenko, V. A. (2012). Povyshenie energoeffektivnosti na gorodskom elektricheskom transporte. Komunalne hospodarstvo mist, 107, 412–417.

18. Hamacek, Š., Bartłomiejczyk, M., Hrbáč, R., Mišák, S., Stýskala, V. (2014). Energy recovery effectiveness in trolleybus transport. Electric Power Systems Research, 112, 1–11. doi: https://doi.org/10.1016/j.epsr.2014.03.001

19. Sładkowski, A. (Ed.). (2020). Ecology in Transport: Problems and Solutions. Springer. doi: https://doi.org/10.1007/978-3-030-42323-0

20. Biryukov, V. V., Porsev, E. G. (2018). Tyagoviy elektricheskiy privod. Novosibirsk: Izd-vo NGTU, 312.

21. Gor, C. P., Shah, V. A., Gor, M. P. (2016). Electric vehicle drive selection related issues. 2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES). doi: https://doi.org/10.1109/scopes.2016.7955554

22. Kulagin, D., Chernetskiy, B. (2015). The choice of traction motors for building systems for mobile electrical systems. Technology audit and production reserves, 2 (1 (22)), 9–12. doi: http://doi.org/10.15587/2312-8372.2015.39931

23. Thakar, D. U., Patel, R. A. (2019). Comparison of Advance and Conventional Motors for Electric Vehicle Application. 2019 3rd International Conference on Recent Developments in Control, Automation & Power Engineering (RDCAPE). doi: https://doi.org/10.1109/rdcape47089.2019.8979092

24. Biryukov, V. V., Kalugin, M. V., P'yanyh, A. N. (2013). K opredeleniyu moshchnosti tyagovogo dvigatelya transportnogo sredstva. Transport: nauka, tehnika, upravlenie, 8, 43–46.

25. Bartłomiejczyk, M., Mirchevski, S., Jarzebowicz L., Karwowski, K. (2017). How to choose drive's rated power in electrified urban transport? 2017 19th European Conference on Power Electronics and Applications (EPE'17 ECCE Europe). doi: https://doi.org/10.23919/epe17ecceeurope.2017.8098948

26. Bitar, Z., Sandouk, A., Jabi, S. A. (2015). Testing the Performances of DC Series Motor Used in Electric Car. Energy Procedia, 74, 148–159. doi: https://doi.org/10.1016/j.egypro.2015.07.536

27. Apostolidou, N., Papanikolaou, N. (2018). Energy Saving Estimation of Athens Trolleybuses Considering Regenerative Braking and Improved Control Scheme. Resources, 7 (3), 43. doi: https://doi.org/10.3390/resources7030043

28. Brazis, V., Latkovskis, L., Grigans, L. (2010). Simulation of Trolleybus Traction Induction Drive with Supercapacitor Energy Storage System. Latvian Journal of Physics and Technical Sciences, 47 (5). doi: https://doi.org/10.2478/v10047-010-0023-0

29. Hurtova, I., Sejkorova, M., Verner, J., Šarkan, B. (2018). Comparison of electricity and fossil fuel consumption in trolleybuses and buses. Engineering for Rural Development, 2079–2084. doi: https://doi.org/10.22616/erdev2018.17.n342

30. Mukha, A. M., Kostin, M. O., Kurylenko, O. Y., Tsyplia, H. V. (2017). Enhancing the operational efficiency of direct current drive based on use of supercondenser power storage units. Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport, 5 (71), 48–60. doi: https://doi.org/10.15802/stp2017/114624

31. Jandura, P., Kubin, J., Hubka, L. (2017). Electric energy monitoring for applying an energy storage systems in trolleybus DC traction. 2017 IEEE International Workshop of Electronics, Control, Measurement, Signals and Their Application to Mechatronics (ECMSM). doi: https://doi.org/10.1109/ecmsm.2017.7945904

Municipal economy of cities, 88, 263–266. Available at: https://khg.kname.edu.ua/index.php/khg/article/view/1604/1596

32. Pavlenko, T., Shavkun, V., Petrenko, A. (2017). Ways to improve operation reliability of traction electric motors of the rolling stock of electric transport. Eastern-European Journal of Enterprise Technologies, 5 (8 (89)), 22–30. doi: https://doi.org/10.15587/1729-4061.2017.112109

33. Andrienko, P. D., Shilo, S. I., Kaplienko, A. O., Nemudriy, I. Yu. (2007). Issledovanie dinamiki seriesnogo elektrodvigatelya s razlichnymi impul'snymi shemami regulirovaniya. Elektrotekhnika i elektroenerhetyka, 1, 4–8.

34. Poluyanovich, N. K., Voloshenko, Yu. P., Shushanov, I. I. (2013). Mathematical model of the traction electric drive with pulse-width management for research of the mode of start-up. Izvestiya Yuzhnogo federal'nogo universiteta. Tehnicheskie nauki, 4 (141), 125–130.

35. Bogdan, N. B., Safonov, A. I., Mazanik, K. I. (2001). Sovremennye sistemy upravleniya tyagovymi elektrodvigatelyami gorodskogo elektricheskogo transporta. Energetika. Izvestiya vysshih uchebnyh zavedeniy i energeticheskih obedineniy SNG, 4, 22–30.

36. Chan, C. C., Cheng, M. (2013). Vehicle Traction Motors vehicle traction motors. Transportation Technologies for Sustainability, 1103–1132. doi: https://doi.org/10.1007/978-1-4614-5844-9_800

37. Veltman, A., Pulle, D. W. J., De Doncker, R. W. (2016). Fundamentals of Electrical Drives. Power Systems. doi: https://doi.org/10.1007/978-3-319-29409-4

38. Deev, S. G., Levykina, V. I. (2000). Energosberegayushchee upravlenie dvigatelem postoyannogo toka. Radioelektronika, informatyka, upravlinnia, 1, 139–142.

39. Andrienko, P. D., Shylo, S. I., Kaplienko, O. O., Shevchenko, N. M. (2011). Doslidzhennia reostatno-rekuperatyvnoho halmuvannia u systemi impulsnoho rehuliuvannia seriesnoho elektrodvyhuna. Elektryfikatsiya transportu, 2, 6–9.

40. Luchko, A. R., Strakolist, E. V. (2008). Utochnennaya imitatsionnaya model' tyagovogo elektrodvigatelya postoyannogo toka so smeshannym vozbuzhdeniem. Elektrotekhnika i elektroenerhetyka, 1, 31–36.

41. Shavelkin, A., Gerasimenko, V., Kostenko, I., Movchan, A. (2016). Modeling of traction electric drive with dc series motors. Eastern-European Journal of Enterprise Technologies, 1 (2 (79)), 42–48. doi: https://doi.org/10.15587/1729-4061.2016.60322

42. Drubetskyi, A. Yu. (2017). Approximation of universal magnetic characteristic for modelling electric traction machines. Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport, 1 (67), 106–116. doi: https://doi.org/10.15802/stp2017/94031

43. Andriychenko, V. P., Donets, O. V., Kostenko, I. O. (2012). Vdoskonalennia systemy keruvannia rukhomym skladom elektrychnoho transportu z vykorystanniam DC-DC peretvoriuvacha. Komunalne hospodarstvo mist, 103, 489–497.

44. Kharchenko, V. F., Daleka, V. K., Andriichenko, V. P., Kostenko, I. O. (2010). Pat. No. 60109 UA. Method for field reduction of traction electric motor of compound excitation type. No. u201013973; declareted: 23.11.2010; published: 10.06.2011, Bul. No. 11.

45. Andreychenko, V., Zakurday, S., Kostenko, I. (2014). Improvement of the method used for control of starting direkt-currentrailway motor. Eastern-European Journal of Enterprise Technologies, 1 (8 (67)), 31–35. doi: https://doi.org/10.15587/1729-4061.2014.20123

46. Kostenko, I. A., Petrenko, A. N. (2015). The control algorithm DC-DC converter device for field weakening. Visnyk Natsionalnoho tekhnichnoho universytetu "KhPI". Seriya: Problemy udoskonalennia elektrychnykh mashyn i aparativ. Teoriya i praktyka, 42 (1151), 31–33.

47. Shavelkin, A., Kostenko, I. (2015). Realization of the mode of weakening of a magnetic field in the traction DC electric drive. Visnyk Kharkivskoho natsionalnoho avtomobilno-dorozhnoho universytetu, 69, 53–60.

48. Soroka, K. A., Andreychenko, V. P., Kostenko, I. A. (2016). Analysis of Operation Mode Trolleybus Traction Motors with DC-DC Converter by Mathematical Modeling Package MATLAB. Transport: nauka, tehnika, upravlenie, 3, 47–51.

49. Abhishek, S. (2014). Speed Control of Dc Motor Using Chopper. International Journal of Engineering, Management & Sciences (IJEMS), 1 (10), 5–8. Available at: https://www.academia.edu/9451929/International_Journal_of_Engineering_Management_and_Sciences_Vol._1_Issue_10_October_2014

50. Forouzesh, M., Siwakoti, Y. P., Gorji, S. A., Blaabjerg, F., Lehman, B. (2017). Step-Up DC–DC Converters: A Comprehensive Review of Voltage-Boosting Techniques, Topologies, and Applications. IEEE Transactions on Power Electronics, 32 (12), 9143–9178. doi: https://doi.org/10.1109/tpel.2017.2652318

51. Vilberger, M. E., Vislogusov, D. P., Kotin, D. A., Kulekina, A. V. (2017). Bidirectional DC-DC conversion device use at system of urban electric transport. IOP Conference Series: Earth and Environmental Science, 87, 032053. doi: https://doi.org/10.1088/1755-1315/87/3/032053

52. Grygar, D., Koháni, M., Štefún, R., Drgoňa, P. (2019). Analysis of limiting factors of battery assisted trolleybuses. Transportation Research Procedia, 40, 229–235. doi: https://doi.org/10.1016/j.trpro.2019.07.035

53. Manjesh, Manjunatha, K. C., Bhoi, A. K., Sherpa, K. S. (2017). Design and Development of Buck-Boost Regulator for DC Motor Used in Electric Vehicle for the Application of Renewable Energy. Advances in Smart Grid and Renewable Energy, 33–37. doi: https://doi.org/10.1007/978-981-10-4286-7_4

54. Ramalingam, N., Sathishkumar, S., Balasubramani, K., Boobalan, C., Naveen, S., Sridhar, N. (2016). Chopper Fed Speed Control of DC Motor Using PI Controller. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), 11 (3), 65–69. Available at: https://www.researchgate.net/publication/315684733_Chopper_Fed_Speed_Control_of_DC_Motor_Using_PI_Controller

55. Katke, S. P., Rangdal, S. M. (2015). Speed Control of DC Motor Using Microcontroller. International Journal of Scientific Research in Science and Technology, (1) 2, 62–67. Available at: http://ijsrst.com/IJSRST151227

56. Kostenko, I. O., Kharchenko, V. F., Khvorost, M. V. (2018). Calculation of the magnetic characteristics of the traction dc motor with combined excitation for trolley buses. Electrification of transport, 15, 117–123.

57. Kostenko, I. (2018). Improvement of the method of calculation of mechanical characteristics of a traction motor of direct current with combined excitation. Technology Audit and Production Reserves, 4 (1 (42)), 4–10. doi: https://doi.org/10.15587/2312-8372.2018.141384

58. Chernyh, I. V. (2008). Modelirovanie elektrotehnicheskih ustroystv v MATLAB, SimPowerSystems i Simulink. Moscow: DMK Press, Sankt-Peterburg: Piter, 288.

DEVELOPMENT OF A WI-FI CONTROLLED MOBILE VIDEO DEVICE ON THE ARDUINO NANO BASIS (p. 55–60)

Olga Sergeyeva
Ukrainian State University of Chemical Technology,
Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-6634-7694

Victoria Lisenko
Ukrainian State University of Chemical Technology,
Dnipro, Ukraine
ORCID: http://orcid.org/0000-0001-8736-1033

Tatiana Dubovik
Ukrainian State University of Chemical Technology,
Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-2359-2569

Mykola Patalakha
Ukrainian State University of Chemical Technology,
Dnipro, Ukraine
ORCID: http://orcid.org/0000-0002-6860-851X

The development of a Wi-Fi-controlled video machine using Arduino NANO is described. The connection diagram of Arduino NANO and additional modules is presented. The relevance of the topic under development is emphasized by the increasing demand for the use of remotely controlled video devices.

A Wi-Fi-controlled video device (machine) was developed, which is powered by a battery that is connected to the charge controller module with microUSB. Possible battery life is 5-6 hours without recharging.

In the process of developing a Wi-Fi-controlled video machine, a large amount of work was carried out, including adding the necessary libraries for the correct writing of programs and determining the necessary conditions for the functioning of the device. Program (sketch) for controlling the engines of the machine is also developed; the main components for creating the device are identified.

For the mobile camera application to work, it is necessary to download the JoyLite application from the AppStore or PlayMarket; after which the smartphone "connects" to the Wi-Fi network and the SANNCE HD 720p camera.

In the software part of the development of a Wi-Fi-controlled video machine using Arduino NANO in the Arduino IDE software environment, the program (sketch) was developed for the SANNCE HD 720p "JoyLite" mobile application. This program configures the signals from the stepper motors of the camera to asynchronous motors of the machine, as well as adjusting the speed of the wheels.

During the tests of the device, it turned out that the Wi-Fi-controlled video machine has a sensitivity to speed impacts, namely, the speed should exceed 255 r/s.

The developed Wi-Fi-controlled video machine can be used in various fields. For example, the device can be used in systems such as "Smart Home" or in security systems, or be implemented as a training project in the course of robotics.

Keywords: Wi-Fi, microcontroller, Arduino NANO, video machine, remotely controlled devices, JoyLite application, Arduino IDE, three-wheeled platform, camera stepper motor, camera, battery.

References

1. Astapkovich, A. M., Vostrikov, A. A., Sergeev, M. B., Chudinovskiy, Yu. G. (2002). Information and control Internet-based systems. Informatsionno-upravlyayushchie sistemy, 1, 12–18.

2. Wortmann, F., Flüchter, K. (2015). Internet of Things. Business & Information Systems Engineering, 57 (3), 221–224. doi: https://doi.org/10.1007/s12599-015-0383-3

3. Shim, J., Ko, J., Shim, J. (2014). A Study on Training Courses Development and Analysis for Improving the Creativity using Arduino. Journal of Korea Multimedia Society, 17 (4), 514–525. doi: https://doi.org/10.9717/kmms.2014.17.4.514

4. Morón, C., Ferrández, D., Saiz, P., Vega, G., Díaz, J. (2017). New Prototype of Photovoltaic Solar Tracker Based on Arduino. Energies, 10 (9), 1298. doi: https://doi.org/10.3390/en10091298

5. Sergeyeva, O. V., Robuck, E. A., Pavlenko, N. Y., Dubovik, T. N. (2019). Applications of computer systems based on the Arduino microprocessor system in chemical laboratory. The Eurasian Union of Scientists (ESU), 12 (69 (5)), 34–38.

6. Faugel, H., Bobkov, V. (2013). Open source hard- and software: Using Arduino boards to keep old hardware running. Fusion Engineering and Design, 88 (6-8), 1276–1279. doi: https://doi.org/10.1016/j.fusengdes.2012.12.005

7. Ocak, M. A. (2018). Where does Arduino's power come from?: An extended literature review. Journal of Learning and Teaching in Digital Age, 3 (1), 21–34.

8. Langbridge, J. A. (2014) Arduino™ Sketches: Tools and Techniques for Programming Wizardry. John Wiley & Sons Inc. doi: https://doi.org/10.1002/9781119183716

9. Xia, F., Yang, L. T., Wang, L., Vinel, A. (2012). Internet of Things. International Journal of Communication Systems, 25 (9), 1101–1102. doi: https://doi.org/10.1002/dac.2417

10. Pahuja, R., Kumar, N. (2014). Android Mobile Phone Controlled Bluetooth Robot Using 8051 Microcontroller. International Journal of Scientific Engineering and Research, 2 (7), 14–17.

11. Juang, H.-S., Lurrr, K.-Y. (2013). Design and control of a two-wheel self-balancing robot using the arduino microcontroller board. 2013 10th IEEE International Conference on Control and Automation (ICCA). doi: https://doi.org/10.1109/icca.2013.6565146

12. Kulkarni, C., Grama, S., Suresh, P. G., Krishna, C., Antony, J. (2014). Surveillance Robot Using Arduino Microcontroller, Android APIs and the Internet. 2014 First International Conference on Systems Informatics, Modelling and Simulation, 83–87. Available at: https://ijssst.info/Vol-15/No-5/data/5198a083.pdf

13. Azeta, J., Bolu, C. A., Hinvi, D., Abioye, A. A., Boyo, H., Anakhu, P., Onwordi, P. (2019). An Android Based Mobile Robot for Monitoring and Surveillance. Procedia Manufacturing, 35, 1129–1134. doi: https://doi.org/10.1016/j.promfg.2019.06.066

14. Chan, T.-F., Shi, K. (2011). Applied Intelligent Control of Induction Motor Drives. John Wiley & Sons. doi: https://doi.org/10.1002/9780470825587

15. Driving Motors - DC & Stepper (2006). Interfacing with C++, 197–271. doi: https://doi.org/10.1007/3-540-33581-1_8