ISSN 0735-2727, Radioelectronics and Communications Systems, 2019, Vol. 62, No. 2, pp. 61–71. © Allerton Press, Inc., 2019.
Russian Text © S.Ya. Zhuk, I.O. Tovkach, Yu.Yu. Reutskaya, 2019, published in Izvestiya Vysshikh Uchebnykh Zavedenii, Radioelektronika, 2019, Vol. 62, No. 2, pp. 81–92.

Adaptive Filtration of Radio Source Movement Parameters Based on Sensor Network TDOA Measurements in Presence of Anomalous Measurements

S. Ya. Zhuk*, I. O. Tovkach, and Yu. Yu. Reutskaya*****

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
**ORCID: 0000-0002-0046-8450*
***ORCID: 0000-0002-5989-6126, e-mail: tovkach.igor@gmail.com*
****ORCID: 0000-0003-1954-9100*

Received April 25, 2018
Revised January 14, 2019
Accepted January 24, 2019

Abstract—The methods based on TDOA measurements find wide application for localization of radio sources using wireless sensor networks. The need of taking into account the presence of anomalous measurement results often occurs in real conditions. Their appearance means a significant malfunction of sensor network components that results in divergence of traditional algorithms of Kalman filtration of radio source movement parameters. Based on the mathematical tools of mixed Markov processes in discrete time domain, the optimal and quasioptimal algorithms of adaptive filtration of radio source movement parameters were synthesized on the basis of TDOA measurements of sensor network in the presence of anomalous measurements. The optimal algorithm describes the evolution of joint a posteriori probability density of the vector of movement parameters and switching variables determining the type of measurement errors of network sensors. The quasioptimal algorithm obtained by linearization of the measurement equation involves the implementation of sequential technique of incoming data processing and performance of the Gaussian approximation of a posteriori probability density of radio source movement parameters. For the case considered in this paper using the statistical simulation, the developed quasioptimal algorithm makes it possible to recognize the appearance of anomalous errors of measurements with probability close to unity and eliminate their impact on the accuracy of determining the radio source movement parameters.

DOI: 10.3103/S073527271902002X

INTRODUCTION

The problem of passive localization of radio emission sources (RAS) is quite common in the field of environment monitoring, liquidation of aftermaths of natural disasters, in intelligent transport and security systems [1–3]. The RAS location can be determined by using wireless sensor networks (WSN) [4–7] that became an important field of research in recent years.

WSN have started to be actively applied in different fields, such as emergency relief operations, autonomous supervision and monitoring of industrial processes and the environment (monitoring of wild animals), monitoring and control of mobile objects, etc. In performing the emergency relief operations, WSN ensure the possibility of position-finding of members of rescue teams (e.g., fire-fighting team), and also technical equipment (e.g., robots), that makes easier the attainment of target goals. An important feature of WSN is the possibility of tracking mobile objects (targets).

One of the main approaches to passive localization of RAS is based on using TDOA measurements containing information about the time difference of arrival of signals obtained by different sensors and the WSN reference sensor. In his case, the synchronization of RAS and WSN sensors is not required making it possible to apply this approach to the localization of unknown targets [8–13].

The accuracy of determining RAS coordinates on the basis of TDOA measurements depends on measurement errors of the time of signal reception by the sensor network transducers. It is known [14] that under real conditions the need often arises to take into account along with ordinary (normal) measurement results the presence of anomalous (rough) measurements. The measurements with anomalous errors can be

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

The initial version of this paper in Russian is published in the journal "Izvestiya Vysshikh Uchebnykh Zavedenii. Radioelektronika," ISSN 2307-6011 (Online), ISSN 0021-3470 (Print) on the link http://radio.kpi.ua/article/view/S002134701902002X with DOI: 10.20535/S002134701902002X.

REFERENCES

1. M. Emery, M. Denko, "IEEE 802.11 WLAN based real-time location tracking in indoor and outdoor environments," *Proc. of Canadian Conf. on Electrical and Computer Engineering*, CCECE'07, 22-26 Apr. 2007, Vancouver, Canada (IEEE, 2007), pp. 1062–1065. DOI: 10.1109/CCECE.2007.271.
2. E. Xu, Z. Ding, S. Dasgupta, "Target tracking and mobile sensor navigation in wireless sensor networks," *IEEE Trans. Mobile Comput.* **12**, No. 1, 177 (Jan. 2013). DOI: 10.1109/TMC.2011.262.
3. A. J. Sinclair, T. A. Lovell, J. Darling, "RF localization solution using heterogeneous TDOA," *IEEE Aerospace Conf.*, 7-14 Mar. 2015, Big Sky, USA (IEEE, 2015). DOI: 10.1109/AERO.2015.7119256.
4. S. Mahfouz, F. Mourad-Chehade, P. Honeine, J. Farah, H. Snoussi, "Target tracking using machine learning and Kalman filter in wireless sensor networks," *IEEE Sensors J.* **14**, No. 10, 3715 (Oct. 2014). DOI: 10.1109/JSEN.2014.2332098.
5. F. Liu, H. Li, Z. Yang, "Estimation method based on deep neural network for consecutively missing sensor data," *Radioelectron. Commun. Syst.* **61**, No. 6, 258 (2018). DOI: 10.3103/S0735272718060043.
6. Mohammad Abu Alsheikh, Shaowei Lin, Dusit Niyato, Hwee-Pink Tan, "Machine learning in wireless sensor networks: Algorithms strategies and applications," *IEEE Commun. Surveys & Tutorials* **16**, No. 4, 1996 (2014). DOI: 10.1109/COMST.2014.2320099.
7. Alon Amar, Geert Leus, "A reference-free time difference of arrival source localization using a passive sensor array," *IEEE Sensor Array and Multichannel Signal Processing Workshop*, 4-7 Oct. 2010, Jerusalem, Israel (IEEE, 2010), pp. 157–160. DOI: 10.1109/SAM.2010.5606725.

8. X. Zhang, J. Huang, Y. Wang, Y. Zhou, "An efficient estimator for target localization in a multistation redundancy system without matrix inversion," *J. Sensors* **2018**, 1 (2018). DOI: 10.1155/2018/6362939.
9. Jose L. Rullan-Lara, Guillaume Sanahuja, Rogelio Lozano, Sergio Salaza, Ramon Garcia-Hernandez, Jose A. Ruz-Hernandez, "Indoor localization of a quadrotor based on WSN: a real-time application," *Int. J. Advanced Robotic Systems* **10**, No. 1 (2013). DOI: 10.5772/53748.
10. N. El Gemayel, S. Koslowski, F. K. Jondral, J. Tschan, "A low cost TDOA localization system: Setup, challenges and results," *Proc. of 10th Workshop on Positioning, Navigation and Communication*, WPNC, 20-21 Mar. 2013, Dresden Germany (IEEE, 2013), pp. 1-4. DOI: 10.1109/WPNC.2013.6533293.
11. Noha El Gemayel, Holger Jakel, Friedrich K. Jondral, "Error analysis of a low cost TDoA sensor network," *Proc. of IEEE/ION Position, Location and Navigation Symp.*, 5-8 May 2014, Monterey, USA (IEEE, 2014), pp. 1140-1145. DOI: 10.1109/PLANS.2014.6851484.
12. Pengwu Wan, Zan Li, Benjian Hao, "Time delay estimation of co-frequency signals in TDOA localization based on WSN," *Proc. of Int. Conf. on Computer, Information and Telecommunication Systems*, CITS, 6-8 Jul. 2016, Kunming, China (IEEE, 2016). DOI: 10.1109/CITS.2016.7546399.
13. Ahmed Makki, Abubakr Siddig, Mohamed Saad, Joseph R. Cavallaro, Chris J. Bleakley, "Indoor localization using 802.11 time differences of arrival," *IEEE Trans. Instrumentation Meas.* **65**, No. 3, 614 (Mar. 2016). DOI: 10.1109/TIM.2015.2506239.
14. A. I. Kupriyanov, A. V. Sakharov, *Theoretical Foundations of Electronic Warfare: Training Manual* [in Russian] (Vuzovskaya Kniga, Moscow, 2007).
15. A. A. Sirota, E. A. Kirsanov, "The neural-network and statistical algorithms for estimating coordinates of a source of radio radiation in multi-position radio systems in the presence of abnormal errors of primary parameter measurement," *Radioelectron. Commun. Syst.* **49**, No. 4, 13 (2006). URI: http://radioelektronika.org/article/view/S0735272706040030.
16. He You, Xiu Jianjuan, Guan Xin, *Radar Data Processing with Applications* (Wiley, 2016). DOI: 10.1002/9781118956878.
17. I. O. Tovkach, S. Ya. Zhuk, "Recurrent algorithm for TDOA localization in sensor networks," *J. Aerosp. Technol. Manag.* **9**, No. 4, 489 (2017). DOI: 10.5028/jatm.v9i4.727.
18. P. A. Evlanov, S. Ya. Zhuk, "Integration of meters with failures," *Radioelectron. Commun. Syst.* **33**, No. 7, 49 (1990). URI: http://radioelektronika.org/article/view/S073527271990070111.
19. V. I. Tikhonov, V. N. Kharisov, *Statistical Analysis and Synthesis of Radiotechnical Devices and Systems* [in Russian], 3rd ed. (Goryachaya Liniya–Telekom, Moscow, 2014).
20. A. P. Trifonov, Yu. S. Shinakov, *Joint Distinction of Signals and Estimation of their Parameters against the Background of Interferences* [in Russian] (Media, Moscow, 2012).
21. S. Ya. Zhuk, "Synthesis of digital detector-meters for mixed Markovian processes," *Radioelectron. Commun. Syst.* **32**, No. 11, 29 (1989). URI: http://radioelektronika.org/article/view/S073527271989110063.
22. I. O. Tovkach, S. Ya. Zhuk, "Adaptive filtration of radio source movement parameters with complex use of sensor network data based on TDOA and RSS methods," *Radioelectron. Commun. Syst.* **60**, No. 12, 528 (2017). DOI: 10.3103/S0735272717120020.