energies

Editorial

On the Navigation, Positioning and Wireless Communication of the Companion Robot in Outdoor Conditions

Karolina Krzykowska-Piotrowska *,† and Mirosław Siergiejczyk †

Faculty of Transport, Warsaw University of Technology, ul. Koszykowa 75, 00-662 Warsaw, Poland; miroslaw.siergiejczyk@pw.edu.pl
* Correspondence: karolina.krzykowska@pw.edu.pl
† The authors contributed equally to this work.

Citation: Krzykowska-Piotrowska, K.; Siergiejczyk, M. On the Navigation, Positioning and Wireless Communication of the Companion Robot in Outdoor Conditions. *Energies* **2022**, *15*, 4936. https://doi.org/10.3390/en15144936

Received: 23 June 2022
Accepted: 30 June 2022
Published: 6 July 2022

1. Introduction

The dynamic process of demographic aging is an important reason for the systematic increase in the share of people with reduced mobility in Polish society. According to EUROSTAT forecasts, by 2100, Polish society will become the oldest of all nationalities in the European Union (EU), and the demographic dependency ratio will increase during this period from approximately 27% to 63%. In this context, in addition to activities focused on pro-natalist policy, a key challenge is ensuring the quality of life of people with reduced mobility. To achieve this, the widespread use of reliable, fast, learning and precisely navigated companion robots is being pursued. The precise satellite navigation of companion robots is one of the most important challenges facing their designers. This is related to a wide range of supporting activities facing this type of device. The social and psychological challenges and barriers must not be overlooked. However, it is important to emphasize the importance of aspects related to the precision of the companions' robots and their safe use, which are a derivative of their precise navigation. Therefore, activities that adapt robots to the implementation of new tasks are extremely important. The robot's positioning and navigation should be distinguished, including a determination of the permissible error in its position in an urbanized and closed environment. This aspect is of particular importance in the context of navigation in which the signal is defined by the accuracy, availability, continuity and integrity of the signal.

Although scientists have been designing robots to support the elderly or physically disabled for years, designing robots that can perform tasks requiring accurate movements over a few centimeters is still a big challenge. There are existing publications on robot navigation in the literature; for example, the monograph edited by Matveev, Savkin, Hoy and Wang from 2016, which is primarily a detailed and unified study presenting the latest achievements in this field. The book extends its scope to include obstacles that are subject to general movements, including rotations and deformations, i.e., changes in shape and size, and devotes a lot of attention to reactive algorithms and rigorous mathematical research into the proposed navigation solutions, showing the correlation between mathematics and robotics. This is similar to the publication by Möller et al., from 2021, recognizes that the design of a societal robot that can act as a companion must consider different areas of research. The article mainly deals with the navigational aspect of the robot and provides an overview of existing solutions in relevant research areas, as well as a perspective on possible future directions. Autonomous navigation in a diverse environment, in contact with people, employees with different roles, schedules and access restrictions, requires robots to adapt to socially accepted rules. Likewise, the speed with which they gett close to people, both to establish communication and to get around, must conform to social conventions. Currently used algorithms do not consider the social complexity of real environments and their relation to the time of day or the activities performed in these scenarios. In Calderit et al.'s 2021 article, a new framework of robot navigation was introduced, with the concept of time-dependent social mapping. The article describes how the interaction areas change over time and how they affect human's conscious navigation. The literature also presents various mobile robotic platform concepts for specific activities, depending on the age of the people with which they work. Looking at the literature analysis and the state of the issue at present, it is possible to clearly indicate the research gap in the area of robot navigation: robot satellite navigation that considers the reduction in a number of errors and disturbances in the satellite signal. This navigation would be used to carry out precise tasks supporting people and influencing their quality of life. The similar structure of satellite navigation systems makes it possible to distinguish some general directions of activities for up to a year. These mainly include technical changes to the space and ground segments, which will aim to improve the stability of the satellites, increase the power of transmitted signals, extend the satellite lifetime, broadcast new signals with additional frequencies, increase the accuracy of measurements (especially in conditions of large urban development and other limiting signal transmission), incorporate the transmission of ionospheric corrections into the basic beacon, increase the signal immunity to interference, and ensure communication between satellites within a given system.

2. A Short Review of the Contributions in This Special Issue

The purpose of this Special Issue is to cover issues related to navigation, positioning, and wireless communication, with particular application to companion robots, including methods and issues that may have a direct or indirect impact on the completion of tasks by such robots, e.g., communication with road infrastructure (robot-to-infrastructure (R2I)), communication with pedestrians, communication interfaces, risk analysis, cybersecurity issues, and reliability aspects. There were eight submissions to the Special Issue of which four received positive reviews and were accepted for publication.

In Reference [1], the issue of noises in double-differenced GNSS observations was analyzed. The authors claim that precise data-processing from the GNSS reference station network is based on a combination of double-differenced carrier phase and code observations, which allows for most of the measurement errors to be removed or reduced. On the other hand, creating observation differences between two receivers and two satellites increases the measurement noise of the observations by a factor of 2. That is why, in this paper, the authors prepared a complex analysis of the noise type in double-differenced GNSS (GPS, GLONASS and Galileo) observations, both carrier phase and code observations, with a 1-s sampling interval. A couple of methods were used for the research, such as the Autocorrelation Function (ACF) method, the Lomb–Scargle (L-S) periodogram method, and the Allan Variance (AVAR) method. The weekly set of measurement data was analyzed. The results were as follows:

- Depending on the system and type of observation, the noise level and type of noise are significantly different;
- Among the code measurements, the lowest noise levels were obtained for the GPS C5Q and Galileo C7Q/C8Q observations, with the standard deviations not exceeding $\pm$10 cm;
- The noisiest observations were obtained for the GLONASS C1C and C2C signals, which had standard deviations of about $\pm$90 cm and $\pm$45 cm.

Reference [2] aims to analyze the space segment (BDS-2 and BDS-3) of the BeiDou Navigation Satellite System (BDS), focusing on the occurrence of periodic, repetitive signals in the clock products, and determine whether the signals coincide with the orbital periods or their multiples. A couple of tools were used for analysis, such as the Lomb–Scargle (L-S) power spectrum (to determine the periods present in the BDS clock products), and continuous wavelet transform (CWT) (to produce a time−frequency representation showing the more complex behaviour of the satellite clock products). The results were as follows:

- The BDS-2 satellite clocks have significantly higher noise than the satellite clocks of BDS-3;
- The number of designated periods is higher, but their reliability is significantly lower;

- BDS-3 satellites have only been in operation for a very short time; thus, this was the first analysis to include their data.

With reference to the topic of this issue, in Reference [3], a comparative analysis of the GNSS, LiDAR Point Clouds, DTMs, databases, maps, and historical sources was prepared to identify the position of mountains peaks. The global navigation satellite system (GNSS) geodetic measurements were used as a reference for this research. The GNSS measurements were carried out with Xiaomi Mi 8 smartphones and the raw recorded data were further used for calculations in the post-processing mode. Some other data sources included global and local databases, models and topographic maps. A comparison of Polish and Slovak point clouds for two peaks were presented in the article, with the results showing that there is a possibility of using large-area laser scanning to determine the maximum heights of mountain peaks.

In Reference [4], the safe communication between the companion robot and infrastructure is discussed, as the authors see a list of challenges in the robot's communication with the environment, which are widely described in the literature. The threats that scientists believe have the most significant impact can be identified as follows: denial-of-service (DoS) attacks, satellite signal spoofing, external eavesdropping, spamming, broadcast tampering, and man-in-the-middle attacks. The idea presented in the paper was to show the possibility of using a communication model from transportation, which is adapted for robots (robot-to-infrastructure (R2I) model). A risk analysis was carried out, determining the likelihood of potential threats occurring, their consequences, and the ability to detect these threads. Finally, specific methods of responding to the occurring threats are proposed, considering the cybersecurity aspects. Their critical new approach was the proposal to use communication and protocols that were previously dedicated to transport (IEEE 802.11p WAVE, dedicated short-range communications (DSRC)).

3. Conclusions

The precise satellite navigation of companion robots is one of the most important challenges facing their designers. This is related to the wide range of support activities that this type of device faces, which includes accompanying their users in everyday activities such as moving around, taking medications, and shopping, or aiding in activities related to personal hygiene. In EU countries, adapting the satellite navigation of the companion robot to the provision of services for people with reduced mobility is a breakthrough in scientific research. This is due to its pioneering nature, both in terms of the satellite navigation itself and the social aspect of the use of this type of device.

Author Contributions: Conceptualization, K.K.-P. and M.S.; methodology, K.K.-P. and M.S.; validation, K.K.-P. and M.S.; formal analysis, K.K.-P. and M.S.; investigation, K.K.-P. and M.S.; resources, K.K.-P. and M.S.; writing—original draft preparation, K.K.-P. and M.S.; writing—review and editing, K.K.-P. and M.S.; visualization, K.K.-P. and M.S.; supervision, K.K.-P. and M.S.; project administration, K.K.-P. and M.S.; funding acquisition, K.K.-P. and M.S. All authors have read and agreed to the published version of the manuscript.

Funding: Research was partially funded by the Centre for Priority Research Area Artificial Intelligence and Robotics of Warsaw University of Technology within the Excellence Initiative: Research University (IDUB) Programme (Contract No. 1820/29/Z01/POB2/2021). Research work partially co-financed by the state budget under the program of the Minister of Education and Science (POLAND) called "Science for Society" project number NdS/536964/2021/2021 amount of funding PLN 1,557,100 total value of the project PLN 1,557,100.

Acknowledgments: Many thanks to the distinguished authors for contributing to this issue.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Prochniewicz, D.; Kudrys, J.; Maciuk, K. Noises in Double-Differenced GNSS Observations. *Energies* **2022**, *15*, 1668. [CrossRef]
2. Kudrys, J.; Prochniewicz, D.; Zhang, F.; Jakubiak, M.; Maciuk, K. Identification of BDS Satellite Clock Periodic Signals Based on Lomb-Scargle Power Spectrum and Continuous Wavelet Transform. *Energies* **2021**, *14*, 7155. [CrossRef]
3. Szombara, S.; Róg, M.; Kozioł, K.; Maciuk, K.; Skorupa, B.; Kudrys, J.; Lepeška, T.; Apollo, M. The Highest Peaks of the Mountains: Comparing the Use of GNSS, LiDAR Point Clouds, DTMs, Databases, Maps, and Historical Sources. *Energies* **2021**, *14*, 5731. [CrossRef]
4. Krzykowska-Piotrowska, K.; Dudek, E.; Siergiejczyk, M.; Rosiński, A.; Wawrzyński, W. Is Secure Communication in the R2I (Robot-to-Infrastructure) Model Possible? Identification of Threats. *Energies* **2021**, *14*, 4702. [CrossRef]