energies

Editorial

Guest Editorial: Special Issue on Designs and Algorithms of Localization in Vehicular Networks

Sangwoo Lee [1,*] and Sunwoo Kim [2,*]

[1] Korea Aerospace Research Institute, Daejeon 34133, Korea
[2] Department of Electronics and Computer Engineering, Hanyang University, Seoul 04763, Korea
[*] Correspondence: lswoo@kari.re.kr (S.L.); remero@hanyang.ac.kr (S.K.)

We have been witnessing a paradigm shift in road transport systems over the last few years with the advent of autonomous vehicles and emerging road applications for road safety and traffic efficiency. Along with these changes, the role of vehicle localization has been significantly changing, as well as the requirements with respect to its applications.

For levels 0 to 2 with the driver in control, the location (position) information is considered application-layer information, which means its use is optional, used mostly for route guidance via a navigator equipped on the vehicle and for logistics management of regularly scheduled vehicles, and it is fully consumed by human beings (e.g., drivers and operators) who make decisions and actions during driving based on multidisciplinary knowledge. Thus, vehicle localization serves as a supportive function, and the requirements are very low—the users are satisfied with an accuracy of 5–10 m to know which road the vehicle is on—and even unclear on others including integrity, continuity, and availability, which are critical parameters for safety-critical applications. However, as the responsibility for driving is gradually transferred to a vehicle over level 3, vehicle localization plays a key role to empower understanding, prediction, decision making, and steering, which means that seamless localization with lane-level (submeter) accuracy is the most top-level requirement for such vehicles fulfilling lane-keeping/changing and acceleration/deceleration without the driver's input.

Since the Global Positioning System, widely known as GPS, of the United States (US) was opened for civilian use, Global Navigation Satellite Systems (GNSS) have been playing a major role for vehicle localization. However, several problems from surroundings such as signal blockage and multipaths are their inherent limitations. Many researchers have explored to complement GNSS and to satisfy the requirements for the advanced technologies by using different readings from the internal—odometer, inertial measurement unit, RADAR (RAdio Detection And Ranging) and LiDAR (Light Detection And Ranging)—and the external—WAVE (Wireless Access in Vehicular Environments) networks and mobile communications networks (e.g., 4G, 5G). Despite tremendous efforts, vehicle localization is still very challenging due to the tradeoffs among cost, complexity, and performance. According to the consumer study performed by Deloitte, consumers are unwilling to pay more than USD 500 for advanced technologies for safety, connectivity, infotainment, autonomy, and alternative engine solutions, while a commercial LiDAR sensor with 360-degree coverage, up to a range of few hundreds, and increased elevation required for level 4 automation costs tens of thousands US dollars.

The goal of this Special Issue is therefore to discuss the challenges and the state-of-art solutions for vehicular localization using a variety of sources that may fill the above-mentioned gap. The call for papers received a total of 11 papers from Republic of Korea (7), China (2), and Malaysia (2), where the number in bracket denotes the number of submissions from the corresponding country. Out of these, seven high-quality papers (acceptance ratio of nearly 64%) were accepted for the Special Issue on Designs and Algorithms of Localization in Vehicular Networks in *Energies* after extensive and rigorous peer-review.

Direction-of-arrival (DoA) is a valuable measure in vehicular networks—especially when the number of base-stations, acting as references for localization, is insufficient—and

check for updates

Citation: Lee, S.; Kim, S. Guest Editorial: Special Issue on Designs and Algorithms of Localization in Vehicular Networks. *Energies* **2022**, *15*, 2223. https://doi.org/10.3390/en15062223

Received: 8 February 2022
Accepted: 12 March 2022
Published: 18 March 2022

its importance has increased since the use of millimeter-wave with massive antennas have become practical. In the first article, titled "Wideband DoA Estimation on Co-Prime Array via Atomic Norm Minimization", Chung et al. [1] investigate a wideband DoA estimation problem in an underdetermined case where the number of signals exceeds the number of antennas. In order to solve the underdetermined DoA estimation problem, the authors present an atomic norm minimization-based algorithm with a co-prime array construction that increases the number of detectable signals, while preventing an unnecessary increase in complexity.

In the article by Chung et al. [2], titled "Super-Resolution DoA Estimation on a Co-Prime Array via Positive Atomic Norm Minimization", the resolution limit of the atomic norm minimization approach to DoA estimation is addressed. The authors highlight the DoA resolution is improved when the coefficients of the atoms are the positive real numbers in the atomic norm minimization and present a positive atomic norm minimization approach after deriving a novel optimization problem.

In the article titled "Off-Grid DoA Estimation on Non-Uniform Linear Array Using Constrained Hermitian Matrix", Chung et al. [3] address the drawback of off-grid DoA estimation, the application of which is limited to uniform linear arrays. Two off-grid DoA estimation algorithms are presented that can be applied to non-uniform linear arrays, for which the spacing between adjacent antennas is not constant. One is proposed for arbitrary linear array, of which the spacing is completely random. Another is for a symmetric linear array, of which the antenna elements are placed symmetrically with respect to the center, with the spacing between adjacent antennas being random. The authors highlight that the symmetric array outperforms the arbitrary array for cases where signals are sufficiently separated in the angular domain.

In the article by Chung et al. [4], "Off-Grid DoA Estimation via Two-Stage Cascaded Neural Network", the off-grid DoA estimation problem is studied from the perspective of neural networks. The authors first point out the gap between practice and underlying assumptions—the number of signals are fixed and DoA estimates are determined from an angular grid map—that are typically used in developing DoA estimation algorithms with neural networks. A novel DoA estimation algorithm based on a two-stage cascaded neural network is introduced, in which an initial DoA is mapped on the discrete angular grid with the convolutional neural network and the initial estimate is tuned by the deep neural network to reduce the mismatch from the grid map.

It is obvious that ranging sensors such as LiDAR and RADAR provide higher accuracy and precision than other sensors, but their range is limited to a few hundreds meters and become dramatically shorter in the case of blockage. Cooperative adaptive cruise control with sharing location information of connected vehicles is a key solution to break the limit but raises another issue of efficient spectrum use. The article by Hossain et al. [5], "Machine Learning-Based Cooperative Spectrum Sensing in Dynamic Segmentation Enabled Cognitive Radio Vehicular Network", deals with the cooperative spectrum-sensing problem in cognitive radio vehicular networks. The authors present a road network model that dynamically divides roads into multiple segments and sub-segments for more efficient management in density and further spectra. A novel cooperative spectrum-sensing algorithm is proposed based on the fuzzy, naïve Bayes, and tri-agent reinforcement learning algorithms.

Short-range networks are becoming more favorable to communications systems, such as 5G and beyond 5G, in order to achieve higher data rates with limited resources. In the article titled "A Theoretical Analysis of Mobility Detection in Connectivity-Based Localization for Short-Range Networks", Lee et al. [6] build a theoretical foundation of connectivity-based localization in short-range networks where explicit ranging measurements are not available. Connectivity-based localization provides a coarse-grained estimate but still effectively complements range-based localization for the search region and convergence time, which are critical factors for real implementations. The authors formulate the connectivity-based localization problem with defining mobility detection, miss detection, and false alarm probabilities and discuss the theoretical performance along with setting the mobility threshold and weight for each probability under the shadow fading channel.

In the final article, "Mathematical Analysis of Line Intersection and Shortest Distance Algorithms", Pradhan et al. [7] discuss two geometric approaches to trilateration, called the shortest distance algorithm and the line intersection algorithm, which are effective for networks where ranging is unavailable or less reliable. The fundamental technique of these two algorithms is to estimate the location based on intersection points of the circles drawn by distance measurements to the three nearest base-stations. The authors provide a mathematical analysis of two algorithms and show their superiority against the least squares estimation through simulations.

Funding: This work was supported by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government(NFA) (No.2019-0-01325, Developed of wireless communication tracking based location information system in disaster scene for fire-fighters and person who requested rescue).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to thank all the authors who submitted their precious work to this special issue in *Energies* and all the reviewers for their efforts and constructive comments. We would also like to the MDPI Publisher for the invitation to serve as guest editors of this special issue and are indebted to the editorial staff of *Energies* for the kind cooperation, patience, and committed engagement.

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

Abbreviations

The following abbreviations are used in this manuscript:

DoA	Direction-of-Arrival
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
LiDAR	Light Detection And Ranging
MDPI	Multidisciplinary Digital Publishing Institute
RADAR	RAdio Detection And Ranging
US	United States
WAVE	Wireless Access in Vehicular Environments

References

1. Chung, H.; Mi Park, Y.; Kim, S. Wideband DoA Estimation on Co-prime Array via Atomic Norm Minimization. *Energies* **2020**, *13*, 3235. [CrossRef]
2. Chung, H.; Park, Y.M.; Kim, S. Super-Resolution DoA Estimation on a Co-Prime Array via Positive Atomic Norm Minimization. *Energies* **2020**, *13*, 3609. [CrossRef]
3. Chung, H.; Joo, J.; Kim, S. Off-Grid DoA Estimation on Non-Uniform Linear Array Using Constrained Hermitian Matrix. *Energies* **2020**, *13*, 5775. [CrossRef]
4. Chung, H.; Seo, H.; Joo, J.; Lee, D.; Kim, S. Off-Grid DoA Estimation via Two-Stage Cascaded Neural Network. *Energies* **2021**, *14*, 228. [CrossRef]
5. Hossain, M.A.; Md Noor, R.; Yau, K.L.A.; Azzuhri, S.R.; Z'aba, M.R.; Ahmedy, I.; Jabbarpour, M.R. Machine Learning-Based Cooperative Spectrum Sensing in Dynamic Segmentation Enabled Cognitive Radio Vehicular Network. *Energies* **2021**, *14*, 1169. [CrossRef]
6. Lee, S.; Byun, I.; Kim, S.; Kim, S. A Theoretical Analysis of Mobility Detection in Connectivity-Based Localization for Short-Range Networks. *Energies* **2021**, *14*, 1162. [CrossRef]
7. Pradhan, S.; Hwang, S.S.; Lee, D. Mathematical Analysis of Line Intersection and Shortest Distance Algorithms. *Energies* **2021**, *14*, 1492. [CrossRef]