IEEE Trans. on Vehicular Technology
Special Section on
"Indoor localization, tracking, and mapping with heterogeneous technologies"

GUEST EDITORIAL

Position has always represented fundamental information in vehicular systems, whose accurate availability opens the way to enhanced system performance and functionalities, such as automated guided vehicles and people-movers. While satellite-based positioning systems (generally referred to as Global Navigation Satellite Systems, namely GNSS, including GPS, GLONASS, and Galileo) provide position information that is accurate enough for most applications in outdoor environments, they usually do not work well in close or harsh environments. Therefore, other localization technologies must be considered. In some scenarios, such as inside buildings and unexplored caves, even the map of the environment might not be available. Thus, the localization processes have to be executed in parallel to mapping (i.e., simultaneous localization and mapping, or SLAM for short), making the problem even more challenging. Different from outdoor applications and the reliance on GNSS, for indoor applications, there is no single dominant technology that can meet a sufficiently wide range of requirements. As a result, a plethora of solutions have been investigated in the last decade. A current trend in indoor localization and tracking is to use a combination of standards, low-cost, and already deployed technologies and resort to statistical fusion of the information they provide.

For people who work in the field of vehicular technology, it is strategically important to understand the potentialities and limitations of indoor positioning. Unfortunately, most of the research on indoor positioning is widely scattered because it has been carried out by different communities ranging from robotics, signal processing, and vehicular technology, to computer science. This makes the distillation of key results difficult, especially for those researchers who are new to this topic. This has motivated us to propose this Special Section entitled "*Indoor localization, tracking, and mapping with heterogeneous technologies*". The goal here is to bring contributions from different communities to a wide range of professionals in the Vehicular Technology community with the focus on the integration and fusion of indoor localization and mapping techniques. It is intended to facilitate the understanding of the technology, to identify future research and development directions, and to accelerate the adoption of the technology into real life.

We have received 51 paper submissions. We would like to take this opportunity to thank all authors for submitting their works to this special section. After thorough and careful reviews, followed by extensive discussions among Guest Editors and the Editor-in-Chief, we have accepted 12 papers for this special section.

The Special Section is opened by the survey paper "*Indoor Tracking: Theory, Methods, and Technologies*", authored by the Guest Editors. The paper introduces the readers to the general problems on indoor tracking and provides a comprehensive survey on main challenges, technologies and the most advanced statistical tools that are available in the current literature.

The following three papers address the integration of measurements coming from heterogeneous sensors with the purpose of improving the localization accuracy.
Specifically, in "*Integrated Indoor Navigation System for Ground Vehicles with Automatic 3D Alignment and Position Initialization*", Atia et al. introduce an autonomous indoor navigation system based on the integration of inertial sensors, LiDAR, received signal strength from WLAN signals, odometry, and occupancy floor maps. The multi-sensor integration is performed by a multi-rate EKF and validated in an experimental setting with sub-meter accuracy. In "*Indoor positioning using ultra-wideband and inertial measurements*", Kok et al. propose a method for indoor positioning by combining measurements from accelerometers and gyroscopes with time of arrival measurements from an ultra-wideband system. They also present an algorithm for calibration of the ultra-wideband system. It is shown that accurate position estimates can be obtained even in challenging settings with large number of outliers. Zampella et al., in "*Indoor Positioning using efficient Map Matching, RSS measurements and an improved motion model*", present a foot-mounted Pedestrian Dead Reckoning (PDR) system that integrates measurements from inertial sensors, received signal strength, map matching, and a motion model. This fusion is performed by a two-level structure, including a particle filter in charge of the integration. The experimental results validate the approach, showing meter accuracy.

Cooperation is one of the most effective methods to improve the performance and robustness of localization algorithms especially when working in adverse propagation conditions. The paper by Nguyen et al. entitled "*Least-Square Cooperative Localization*" investigates the fundamental limits in cooperative localization in the presence of spatial randomness of network nodes and arbitrary ranging bias. The authors quantify the deviation of localization accuracy from the theoretical limit for different versions of the least-square (LS) algorithm. They also propose a simple distributed algorithm for LS cooperative localization. Wu et al. propose, in "*A Time-Reversal Paradigm for Indoor Positioning System*", to use the unique multipath profile at each location by time-reversal radio transmission. The method works with a minimum of one access point, for which the system creates a database of channel impulse responses that are used in the on-line positioning stage. Experiments are conducted with a prototype, validating the proposed methodology and achieving centimeter localization accuracy. In "*Distance-based Interpolation and Extrapolation Methods for RSS-based Localization with Indoor Wireless Signals*", Talvitie et al. consider to use incomplete fingerprinting databases to study the performance of a number of interpolation and extrapolation techniques for the missing data problem. The work is supported by experimental results from WLAN measurements, concluding that joint interpolation and extrapolation techniques can improve horizontal accuracy and floor detection probability. A novel method that enables a device-free localization by an array of sensors is proposed in "*Signal Eigenvector-based Device-Free Passive Localization using Array Sensor*" by Jihoon et al. The method is based on multiclass support vector machines and outlier mitigation. The experimental results show that the proposed method has localization accuracy that is better than that of the Nuzzer system.

The simultaneous localization and mapping problem is addressed in the paper by Zhou et al. entitled "*StructSLAM: Visual SLAM with Building Structure Lines*". The authors propose a visual SLAM method using structure building lines as novel features complemented with the point features. This method, validated by using both synthetic and real-world scenes, provides a superior performance with respect to conventional visual SLAM approaches that might fail in indoor environments that typically lack point features.

The last three papers cover the topic of passive localization and imaging using radars. In "*X-Ray Vision with WiFi Power Measurements Using Rytov Wave Models*" by Depatla et al., the problem of autonomous high-resolution imaging and localization of a completely unknown area using unmanned vehicles based on simple WiFi measurements is investigated. A theoretical and experimental framework for this problem based on Rytov wave models, sparse signal processing, and robotic path planning is developed. Blind methods for selecting representative observations based on features extracted from the received waveforms are proposed by Bartoletti et al. in "*Blind Selection of Representative Observations for Sensor Radar Networks*". The methods offer improved localization accuracy in the presence of obstacles with lower complexity.In "*Parasitic exploitation of WiFi signals for indoor radar surveillance*" by Pastina et al., existing WiFi signals are exploited as waveforms of opportunity to detect and track moving targets based on the passive radar principle. Experimental results demonstrate the effective applicability of this principle for improving internal and external security of private/public premises using very inexpensive and non-invasive technology.

We would like to thank all the reviewers for their hard work and for all their suggestions and comments, leading to improvements of the accepted papers. We would also like to extend our special thanks to the Editor-in-Chief of the IEEE Trans. on Vehicular Technology, Dr. Yuguang Fang, and his staff for their assistance, patience and useful suggestions during the finalization of this issue. Last but not least, we thank the European Network of Excellence NEWCOM# for having created the fertile background of professional relationships that inspired this Special Section.

Given the vast amount of research that is being carried out worldwide in indoor localization and mapping technologies, we are well aware that this Special Section can be no more than a sample of recent advances in the field. Nevertheless, we hope that it will represent a useful starting point and stimulus for further research on localization technologies.

Guest Editors,

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