Spatial Similarity-based Multiple LiDAR Synchronization and Data Falsification Detection for Reliable 3D Mapping

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ABSTRACT

Light detection and ranging (LiDAR) scanners are sensors that can acquire time-series shape information as point clouds of real 3D space. The LiDAR scanners can be used for digital twins as infrastructure for sensing urban spaces. The digital twin is a concept for solving urban issues based on a cycle consisting of acquiring physical space information with sensors, recoding it in digital space, simulating city behavior, and feeding the simulation result back into physical space. Here, spatial coverage is an important element for 3D mapping to obtain highly accurate simulation results in digital twinning and for optimal self-driving. However, the improvement of coverage is not easy because of the spare arrangement of LiDARs in the city, because urban spaces have many obstructions. So, we focus on the integration of many LiDARs in self-driving cars and autonomous mobile robots would be useful to improve coverage. However, multiple LiDAR synchronization has also issues, and the time consistency of scan data is also an important element of 3D mapping. Time synchronization is not easy even under normal circumstances because the time accuracy of the sensors varies depending on the time source, from nanosecond-level GNSS to hundreds of milliseconds-level NTP. Furthermore, there are currently concerns about LiDAR spoofing and data cracking, so the reliability of the data needs to be guaranteed. Therefore, in this study, we propose a reliability guarantee methodology based on the spatial similarity between a highly reliable LiDAR scanner and a less reliable LiDAR scanner. In this study, verification was conducted under various conditions in an environment that included moving objects. In addition, point cloud cracking was performed by inserting AI-generated point clouds to verify the change in spatial similarity. Through the feasibility study of time synchronization of LiDARs, we clarified that the accuracy of time synchronization is affected by the number of features and the scanning pattern of the LiDAR scanner, leading to a decrease in accuracy. Furthermore, the feasibility of detecting LiDAR spoofing was also revealed. Future challenges include improving stability and processing speed in situations that lead to a decrease in accuracy. This study will contribute to the realization of secure 3D map creation and digital twins.

Keywords: digital twin, time synchronization, LiDAR spoofing, point clouds