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Map Generation and Localization based on Height Variance of LiDAR Point Cloud for Autonomous Driving

Ryo Yanase[1)] Miya Kawaseki[1)] Mohammad Aldibaja[1)] Keisuke Yoneda[1)] Naoki Suganuma[1)]

1) Kanazawa University, Kakuma-cho, Kanazawa, Ishikawa, 920-1192, Japan (E-mail: ryanase@staff.kanazawa-u.ac.jp)

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Self-localization is a very important technology for autonomous vehicles. For example, path planning is calculated based on the vehicle's position, and if the estimated position differs significantly from the original location, the vehicle may behave unexpectedly. Thus, the vehicle's position must be accurately estimated because it is involved in decision-making and operation. Global Navigation Satellite System (GNSS) is one of the most popular methods of self-localization. It is possible to measure the absolute position by receiving signals from multiple satellites.

Therefore, position estimation by GNSS stand-alone is not very safe for autonomous driving. In many cases, a technique called map-matching is used to correct the GNSS position. This method identifies the current position by matching the map with the surrounding environment. Map formats and matching methods depend on the sensors used to recognize the surrounding environment. The main sensors installed in automated vehicles include LiDAR (Light Detection and Ranging), millimeter-wave radar, and cameras. LiDAR is a sensor that measures the distance to an object and the intensity of the reflected infrared laser beam by irradiating it with an infrared laser. The commonly used 3D-LiDAR can obtain a three-dimensional object shape as a point cloud. Compared to other sensors, LiDAR has higher ranging accuracy and can measure the position of an object with an error of only a few centimeters. Because of these features, many self-localization methods using LiDAR have been proposed, and actual results of their use in public road tests have been reported. Although these methods for highly accurate position estimation have been proposed, there is a problem that the matching between the map and sensor data is not calculated correctly during snowfall because the road shapes and road surface patterns are significantly different from those during normal conditions. Considering that LiDAR can provide a 3D point cloud, there is a large possibility of obtaining the shapes of relatively tall objects such as telegraph poles, since they are rarely completely covered, even during snowfall. Therefore, by using LiDAR point clouds to detect and map only pole-like objects, it is expected to be possible to estimate locations that are relatively unaffected by snow and other factors. A similar idea has been proposed to extract pole-shaped objects from a point cloud or use the pole's point cloud to estimate its position. However, aligning 3D point clouds is computationally more costly than matching 2D images. Moreover, previous studies have not examined the effectiveness of this method in snowy environments, so the effectiveness of these methods for position estimation in snowy conditions has not been demonstrated.

This paper proposes a new feature extraction and image generation method based on height variance as a map generation and self-localization method using pole-like objects. The effectiveness of this method is verified by comparing the generated map images and the accuracy of position estimation under normal and snowy conditions.

A tall object such as a pole can be observed by LiDAR as a point cloud with a spread shape in the height direction. In other words, a pole-like object will have a large variance in the height direction of the point cloud. Thus, if the height variance is large at a point, the probability of the existence of an object there can be regarded as high. Based on the idea, the probability of an object's existence is mapped onto a two-dimensional plane as a feature for matching based on its height variance. Using this method, equivalent features were extracted and images were generated for normal and snowy conditions as shown in Fig.1. Furthermore, the results of the accuracy evaluation has shown that the vehicle position can be estimated with less influence from weather conditions.

(a) Normal condition. (b) Snowy condition.

Fig. 1 Camera images under normal/snowy condition.