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Road-Feature Extraction using Point Cloud and 3D LiDAR Sensor for Vehicle Localization

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***Abstract*—This paper proposes a novel road-feature extraction method from a point cloud and a LiDAR (Light Detection and Ranging) sensor for vehicle localization. For a robust localization of a vehicle, it is important to extract unchanging features. Road markings such as lines, arrows, and crosses are effective features for localization in a road environment. Thus, this paper describes a method to extract road marking features from intensity information of both point cloud and a LiDAR sensor. The proposed method is effective for an uncalibrated LiDAR sensor. In addition, it is compatible for real-time localization by extracting only essential features from the road. The proposed method is demonstrated by an autonomous vehicle test conducted in a 2.8 km loop near One-north, Singapore.**

***Keywords*—Road-feature extraction, localization, multi-layer LiDAR, autonomous vehicle**

1. Introduction

The importance of vehicle localization increases with the rapid development of self-driving vehicles. The multi-layer LiDAR sensor, a popular sensor placed on the vehicle, can provide 3D environmental information. Since the LiDAR sensor has high reliability, it is widely used for purposes of localization [1-5] as well as perception [6].

The LiDAR sensor helps recognize black and white objects by providing intensity information which is a reflection of strength. Thus, the intensity information is generally utilized for localization [1]. However, it is hard to employ without calibration due to issues related to sensitivity [1]. Although there is extensive research on calibrating the sensor [7, 8], the calibration is difficult and troublesome. Therefore, this paper proposes a road-feature extraction method for vehicle localization without calibration. The most robust features on the road include road markings such as lines, arrows, and crosses. Thus, road marking features are extracted from an uncalibrated, multi-layer LiDAR sensor and point cloud. One advantage of the proposed method is that the sensors for map generation and localization don't have to the same.

The proposed method is tested in a 2.8 km loop near One-north, Singapore. A 32-channel LiDAR sensor and an established point cloud are used to verify the proposed algorithm. To verify the effectiveness of the proposed method, the MCL(Monte Carlo Localization) algorithm [9] is utilized in real time.

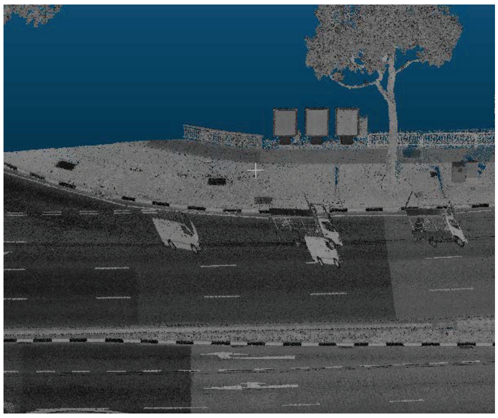
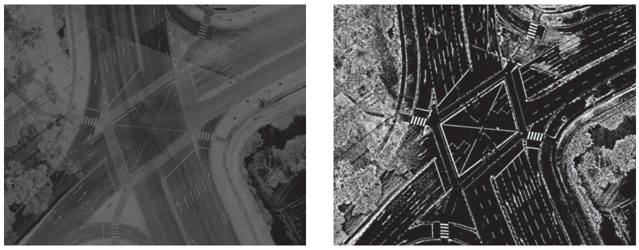


Fig. 1. Intensity representation of a delicate point cloud collected in advance.



(a) (b)

Fig. 2. (a) Top view of road intensity information of grid map. (b) Extracted road marking features from point cloud.

2. Proposed Method

2.1. Extraction of Road-Features from Point Cloud

A delicate point cloud is made in advance as shown in Fig. 1. To extract road marking features, traversable areas should first be detected. To find the areas, an elevation grid map [3] is generated from the 3D point cloud. Since a traversable area has small height differences from the surrounding areas, a traversable cell on the grid map is found by calculating the height differences from the surrounding cells. A top view of road intensity information of the grid map is shown in Fig. 2(a). As shown in the figure, the actual road intensity information contains various values because of color differences. Thus, an adaptive-threshold image processing

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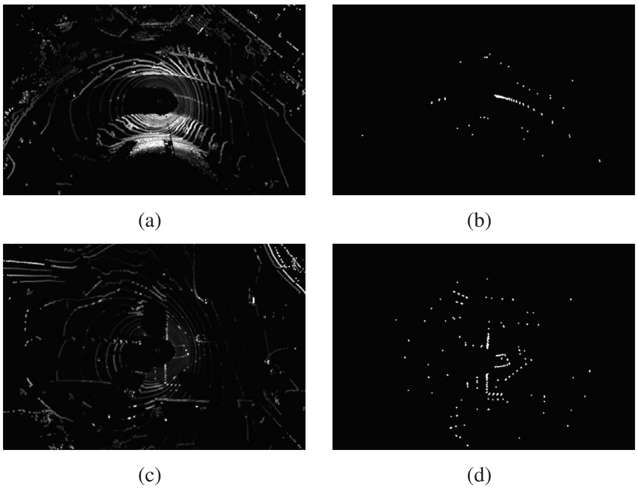

Fig. 3. (a) Uncalibrated raw intensity data of a multi-layer LiDAR sensor on a curved road. (b) Extracted road-feature from the LiDAR sensor on a curved road. (c) Uncalibrated raw intensity data of a multi-layer LiDAR sensor on an intersection. (d) Extracted road-feature from the LiDAR sensor on the intersection.

method is utilized to extract road marking features as shown in Fig. 2(b).

2.2. Extraction of Road-Features from Multi-layer LiDAR

In general, a multi-layer LiDAR sensor should be calibrated to use its intensity information. This section introduces a simple method to extract road-features from an uncalibrated multi-layer LiDAR sensor. Since each layer of the multi-layer LiDAR sensor has different characteristics, it is necessary to extract the features layer by layer. To make geometric uniform of each layer, a voxel grid filter algorithm is utilized. Since the each layer contains scanning data of 360 degrees like a ring, the road-features are extracted by applying a ring-based 1D adaptive threshold method to each layer. The uncalibrated raw intensity data are shown on the left side of Fig. 3 and the results of the extracted road-features are shown on the right side of Fig. 3.

2.3. MCL Algorithm using Extracted Features

Using the proposed extracted features, an MCL algorithm is utilized for vehicle localization. The steps of MCL include prediction, calculation of weight, and resampling steps. The vehicle is predicted by a wheel odometry and gyro sensor according to a probabilistic robot model [9]. The weight of each particle is calculated by correlations between the extracted features from the point cloud and the multi-layer LiDAR sensor. In the resampling step, a SIS (Sequential Importance Sampling) method is utilized.

3. Experiments and Conclusions

The experiments are conducted by an autonomous vehicle in a 2.8 km loop near One-north, Singapore. The autonomous vehicle is equipped with a 32-channel LiDAR (Velodyne 32E), GPS (Xsens MTi-900), IMU (KVH-1775), and wheel odometry. The point cloud data were provided by SLA (Singapore Land Authority). The results of the MCL algorithm using the proposed feature extraction method is shown in Fig. 4 and the mean of x, y, and θ errors are 0.125 m, 0.129 m, and 0.195 degree, respectively. The proposed method is performed in real time and is proven by performing localization successfully without any failure in the 2.8 km loop.

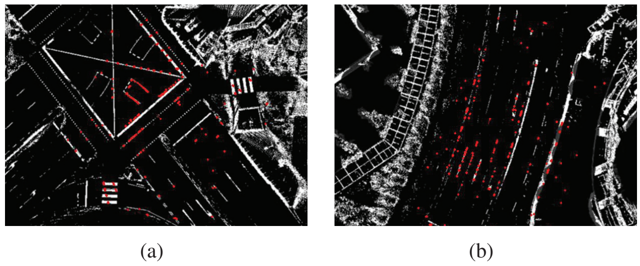

Fig. 4. Localization result using the proposed feature on the intersection (a) and a curved road (b). Red and white dots denote extracted features from a LiDAR sensor and point cloud, respectively.

This paper proposed a road-feature extraction method for localization without intensity calibration. The effectiveness of the proposed method was demonstrated by applying an MCL algorithm in real time.

Acknowledgment

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