Efficient Map Management Scheme for LiDAR-based Vehicle Localization

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***Abstract*— Since large-scale of point cloud is widely utilized in the autonomous vehicles, it becomes important to manage a huge amount of point cloud data. Moreover, the point cloud data for vehicle localization should be processed in real time. Therefore, this paper proposes an easy and efficient point cloud map management scheme for vehicle localization using image format. This paper also introduces a method to load the map in real time according to the location of the vehicle. The proposed method was verified using the large-scale point cloud data provided by Singapore Land Authority (SLA). Then, localization of the vehicle is successfully tested by using the proposed map.**

I. Introduction

Since autonomous vehicles have widely developed, a vehicle localization becomes one of important issues for navigation. Because LiDAR sensors are one of the sensors commonly mounted on autonomous vehicles, it is important to handle point cloud data generated by LiDAR sensors. In particular, city-level point cloud data should be processed in real time to operate autonomous vehicles. Therefore, this paper proposes a method to manage an enormous amount of point cloud easily and effectively using image format.

The most common point cloud data processing is voxelization. However, this method is not easy to handle the vast amount of point clouds for localization of autonomous vehicle. Thus, the point cloud map is generally simplified to 2D grid map for localization. J. Levinson *et al.* [1] proposed a precision vehicle localization using a elevation map and its intensity data of LiDAR sensor. For using a localization method using vertical information of point cloud, multi-resolution Gaussain mixture maps algorithm [2] was proposed to include all the vertical information into a grid cell as Gaussain mixture model. R. Triebel *et al.* [3] also proposed a multi-level surface map to handle multi-level road such as bridges and interchanges. However, these approaches have limitations to utilize in general application because they contain only particular information. Therefore, this paper proposes a general format that can easily and efficiently store and manage enormous point cloud data. The main contributions of this paper are follows:

This paper is a short summary of a part of [4].

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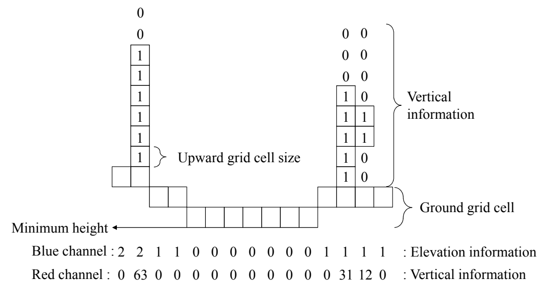


Fig. 1. The concept of map representation method that includes a elevation map (blue channel) and vertical information (red channel).

- Efficient compression of point cloud data.
- By storing in image format, it is convenient to manage such as save/load and modify.
- It is useful for efficient memory use and real-time operation by loading the location-based surrounding map in real time.

II. The Map Representation

This section describes to extract essential elements from point cloud for localization of vehicle. First and foremost information for vehicle localization is a elevation map and intensity information of a road. As point cloud projects with z-axis to 2D grid cells, a elevation map is generated by selecting a minimum height value among the all height values in a grid cell. By saving each intensity information of each elevation grid value, a intensity map is generated. The other important information is vertical information. The vertical information have several data within each grid cell when projecting point cloud into a grid cell. Since essential vertical information is below a certain height from the road, upward grid cells are stacked on the elevation map to represent vertical information.

In this paper, a image format is utilized for effective store and management in real-time. The image format generally is composed of three channels (RGB) of eight bytes. The elevation map and its intensity map simply save into blue and green channels by converting to eight bytes, respectively. The elevation map is saved into 0-255 range by binary quantization step by a grid cell size as set to 0 for a minimum elevation value of the map. Thus, the maximum height range of eight bytes is $255 \times$ *the grid cell size* (*e.g.* 25.5 m $= 255 \times 0.1$ m). The intensity map also converts to 0-255 range by binary quantization. The upward grid cell of vertical information are stacked on the elevation map as shown in Fig. 1. The maximum number of upward grid cells is eight

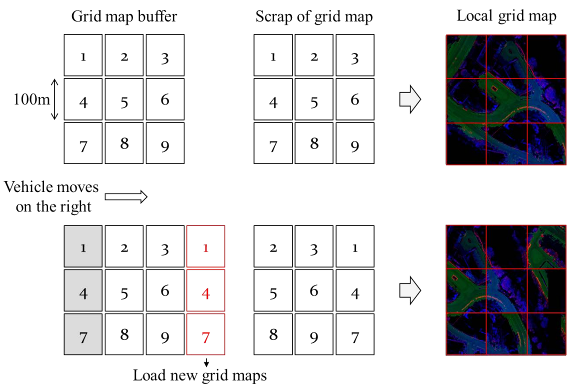


Fig. 2. The concept of the dynamic map management when the vehicle moves on the right.

since one channel has eight bytes. Therefore, 00001100 in binary as shown in right side of Fig 1 converts to 12 in decimal system. Similarly, 00011111 and 00111111 in binary are 31 and 61, respectively. As the binary data is saved in a red channel, the vertical information is stored in a image format. If adding more channels for vertical information, more upward grid cells can be allocated.

III. Dynamic Map Management

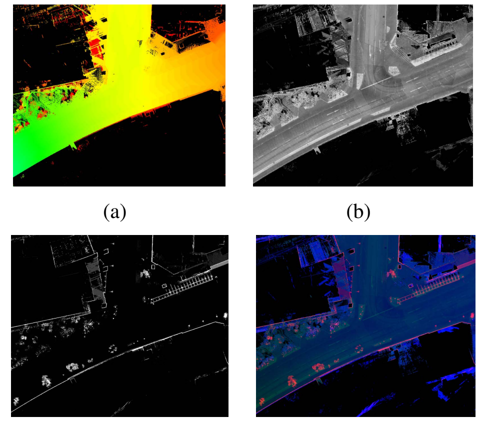
This section introduces a effective dynamic map management using image patches. The size of a image patch is decided by considering a range of sensor system (*e.g.* 1000 pixel $\times$ 0.1 m resolution = 100 m). The each image patch is saved as a PNG (Portable Network Graphics) format with a origin point and a minimum height value of the image patch. To generate a local map near a vehicle, nine patches are loaded on grid map buffers as shown Fig.2. When the vehicle moves to the right patch from the middle patch, new three near patches are loaded on the left map buffers. Instead of rearranging all the near patches, only the indicators of patches are shifted to reduce unnecessary image patches loading. The final local grid map is generated for localization by reordering grid map buffers using indicators.

IV. Experiments and Results

The results of a elevation map, its intensity map, and a height map are shown in Fig. 3. The result of the combination of all the maps into RGB channels is shown in Fig. 3(d). The total size of point cloud data in experiment area is 30.5GB, which consists of 6,292,573,705 points. The proposed method is compressed the point cloud as 380 image patches with 218.2MB. The results of some image patches are shown in Fig. 4. The grid map is reconstructed by image patches as shown in Fig. 5. The proposed method is demonstrated by MCL (Monte Carlo localization) with the local map through 19.9 km way in city area, see details in [4].

V. Conclusions

This paper proposed a effective data extraction method from enormous point cloud by considering a image format.



(a) (b) (c) (d)

Fig. 3. (a) the elevation map represented by height map color. (b) its intensity map. (c) the vertical map, (d) the image format to combine with all the maps.

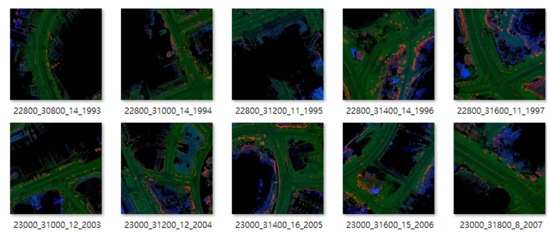


Fig. 4. The result of a image patches.

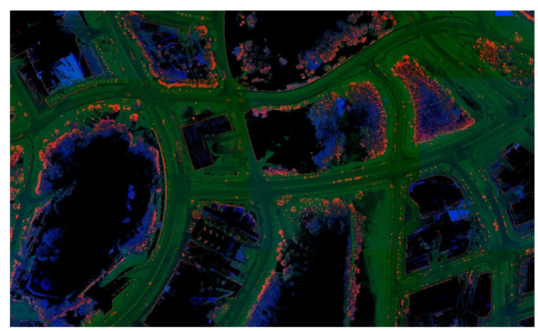


Fig. 5. The restructured grid map by the image patches.

A dynamic map management is proposed to generate a local map for real-time localization using image patches. The proposed method can cover in a huge city area.

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