(28) EXTRACTION OF CROSSROADS AREA UTILIZING MMS DATA

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As the development of social productivity, land transportation has become more and more important. To fulfill the increasing need of land transportation and reduce the CO2 emission, more and more large-size truck has been utilized in Japan. Nevertheless, due to the large size and heavy load, these trucks may be unable to pass certain areas. Therefore, a review process is needed to guarantee that trucks can smoothly pass the urban area. On the other side, review usually takes a significantly long time, which causes heavy damage to the social productivity. One effective solution of this situation is to develop an automatic system that can calculate the passability automatically by inputting the truck size data and road data. The truck data can be achieved by the manufacturer immediately while the road data is difficult to measure effectively. Mobile Mapping System (MMS) is widely used to obtain the road data, but the origin data is too large and includes lots of unnecessary data and noise. The purpose of this study is to develop an automatic process to extract the basic shape a crossroads area from the original MMS data in Naruto City, Tokushima Prefecture by utilizing random sample consensus (RANSAC) and slope filtering. After that, the extracted shape can be used to calculate the width of the crossroads area in four directions.

Key Words : *land transportation, terrestrial LiDAR, MMS data, RANSAC, road extraction*

1. INTRODUCTION

Due to the increasing need of land transportation, more and more large-size trucks are put into use in Japan. Nevertheless, such kind of oversized truck cannot move smoothly in the urban area due to several reasons. One of the most important reason is that due to their large size, the turning radius can be significantly wide compared with regular vehicles, which cause the problem while turning in the crossroads. Hence, special vehicle passage permit system was established[1)].

Currently, the review system is mainly done manually, which causes a great waste of time. According to the data of Japan Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the average review time in August, 2019 is 35.7 days[2)]. To eliminate such damage to the social productivity caused by the inefficient review system, it will be promising to develop an automatic review system. On the other side, the digital transformation of road data is being promoted positively, which provides a possible solution to realize the automatic review system.

However, the original data cannot be used directly because of the unnecessary points and noises. Hence, the object of this study is to eliminate the unnecessary element such as constructions or vehicles on the road, and extract the attributes of crossroads area from the original data utilizing random sample consensus (RANSAC) algorithm and slope filtering. The final output will be the floor plan of the crossroads area and the width of each road.

2. STUDY AREA

Study area is as shown in **Fig.1**, which is an area in Naruto City, Tokushima Prefecture. The original data was obtained by Ministry of Land, Infrastructure, Transport and Tourism, Japan. It has an area of 243.9 m × 193.3 m. The maximum and minimum coordinates are shown in **Table 1**. This area contains two main roads which are nearly perpendicular to

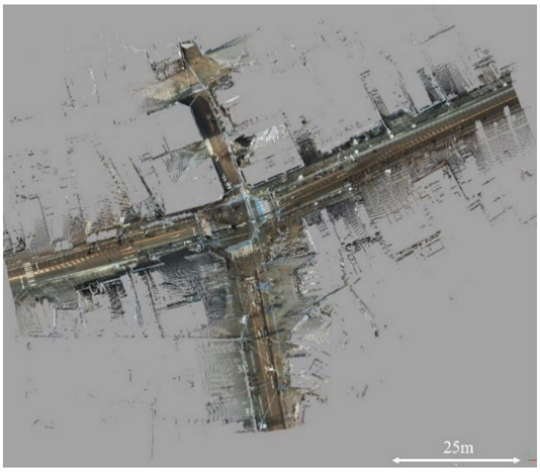

Fig.1 Original data of study area

Table 1 Range of the study area in the Plane Rectangular Coordinate IV

Direction	Minimum (m)	Maximum (m)
X	131351.2	131595.1
Y	102178.1	102371.4

each other. Center of the crossroads area are surrounded by four zebra zone.

3. METHODOLOGY

Process of the extraction is illustrated in **Fig.2**. Firstly, a RANSAC plane filter is adapted to extract all the elements which are close to the road plane so that most unnecessary elements which are higher than the road plane can be eliminated. Next, a RGB filter is applied to extract the zebra zone. In this case, each zebra zone also consists of a bicycle zone, which is also took into consideration. The purpose of extracting zebra zone is because that they can generally determine the area of the crossroads if we can find the line that pass through each zebra zone. After that, we can obtain a more specific crossroads zone but still with many noises. The final step is to apply a slope filter to separate the road points and other points such as constructions or sidewalk. As a result, we can obtain the floor plan of the crossroads area, and the width for each direction can also be calculated directly.

(1) Extraction of road plane

This step aims to extract the general road plane for further processing utilizing RANSAC, which is an effective tool to fit model with lots of noises developed by Martin and Robert[3]. The basic concept is as follows. Randomly choosing 3 points $P_1(x_1, y_1, z_1)$, $P_2(x_2, y_2, z_2)$, $P_3(x_3, y_3, z_3)$. The normal vector of this plane can be calculated as:

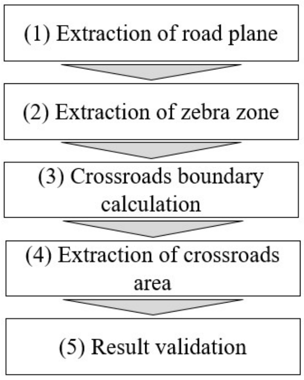

Fig.2 Flow chart of extraction process

$$\vec{n} = \overrightarrow{P_1P_2} \times \overrightarrow{P_1P_3} \tag{1a}$$

$$\vec{n} = \begin{bmatrix} \vec{i} & \vec{j} & \vec{k} \\ x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ x_3 - x_1 & y_3 - y_1 & z_3 - z_1 \end{bmatrix} \tag{1b}$$

$$\vec{n} = a\vec{i} + b\vec{j} + c\vec{k} \tag{1c}$$

$$\vec{n} = (a, b, c) \tag{1d}$$

Equation of the plane can be derived as follows:

$$ax + by + cz + d = 0 \tag{2}$$

After obtain the equation of the plane, we then need to calculate the distance between this plane and all the other points. Assume there is a point $Q(x_0, y_0, z_0)$, the distance between Q_0 and plane is D. Take a random point on the plane $P(x, y, z)$, the angle between $\overrightarrow{PQ}$ and $\vec{n}$ is θ, then distance D can be calculated as:

$$D = \left|\overrightarrow{PQ}\right| \cdot \cos\theta = \frac{\overrightarrow{PQ} \cdot \vec{n}}{|\vec{n}|} \tag{3a}$$

$$D = \frac{ax_0 + by_0 + cz_0 + d}{\sqrt{a^2 + b^2 + c^2}} \tag{3b}$$

Then a threshold T is determined, if D is smaller than T, this point is called an inlier. The algorithm will be repeated several times and the model which maximize the number of inliers will be considered as the final output. In this case, threshold T is set as 0.5 m and the iteration time is 100 times. The result is shown as **Fig.3**.

(2) Extraction of zebra zone

The extraction of zebra zone is mainly based on the color feature, which is a white stripe area. In this case, zebra zone also consists of a blue bicycle zone. Based on the color feture, these two areas can be extracted.

Nevertheless, there are still many isolated noise points. To eliminate such area, the data set is projected to a plane and divided into grids of 0.2 m × 0.2 m. Grids that has a density less than 20 points / grid is considered as isolated points, thus

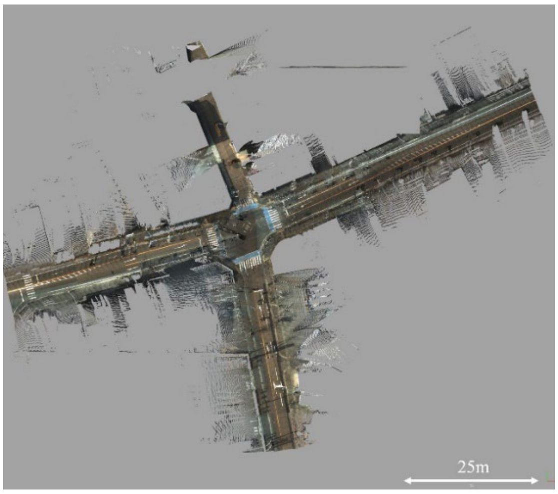

Fig.3 Extraction of road plane

eliminated. The kept points are represented by the center points of each grid. The result is shown in **Fig.4** ($(R+G+B)/3 > 240$ or $B > 120$).

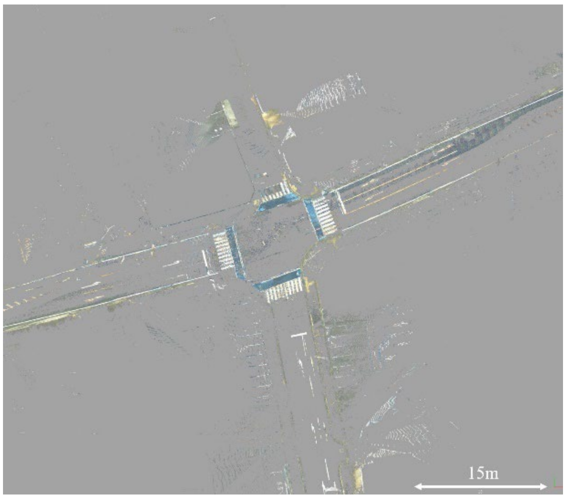

Fig.4 Extraction of zebra zone

(3) Crossroads' boundary calculation

Since the zebra zone is almost parallel to the road, this characteristic can be used to extract the boundary of the crossroads area. After the previous process, the zebra zone has become the densest area compared with other clusters. Considering the shape of zebra zone is rectangle, RANSAC can be applied to extract such specific area. As shown in **Fig.5**, two red points are randomly picked to determine a straight line. Along this line, we can determine a rectangular area and the points inside this area are considered as inliers. If the range of this rectangular area are set suitably, the zebra zone can be extracted and the boundary line can also be determined. In this case, the size of rectangular area is set as 12 m × 4 m.

(4) Etraction of crossroads area floor plan

After determined the boundaries of the crossroads

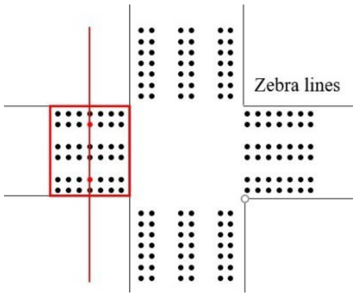

Fig.5 Boundary extraction of crossroads area

area, we can extract a more specific area from the original data, and then conduct the extraction of floor plan utilizing a slope filter developed by Susaki[4)]. The method is introduced as follows. First, divide the area into grids of 0.3 m × 0.3 m. Since there are still some noises close to the road plane, such as points from the vehicles, which will affect the result of slope filter, noise should be eliminated before processing. The idea is to apply RANSAC filter in each small grid so that only the road point will be kept as shown in **Fig.6**. Because the grids size is very small, road can be considered as a perfect plane, and the threshold of inlier is set as 0.05 m.

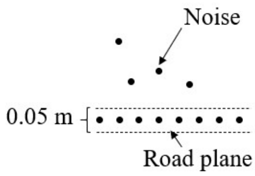

Fig.6 Noise elimination in each grid

Then, the extracted height value (z axis value) are averaged to represent the grid. After that, an initial seed point is chosen as **Fig.7**, and compared the height value with the four grids surrounded so that the side walk and constructions can be sepertated from the road grid. The threshold is set as 0.05 m, if the height difference is greater than threshold, it will be eliminated, other wise it will be considered as a new seed point and the procedure will be repeated until all the grids are traversed. The result is shown as **Fig.8**.

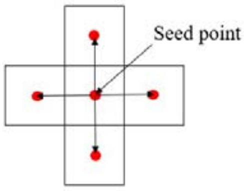

Fig.7 Height comparison from seed point

Although the basic shape of crossroads area is extracted, some problems remains. In some area, the sidewalk has a mild slope that connected to the road, which cause a misrecognition. One more step is

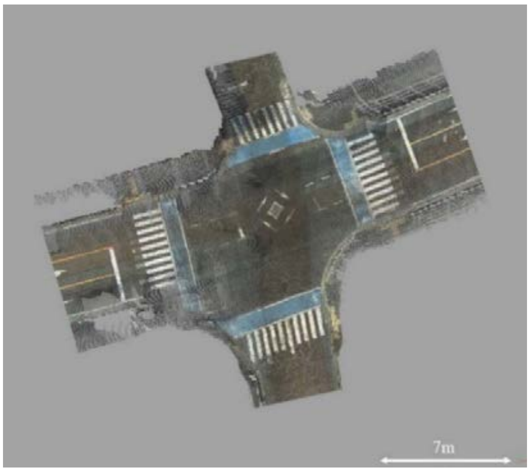

Fig.8 Top view of crossroads area

needed to separate such two parts. The final step is to separate the extracted area into four parts diagonally and apply RANSAC filter again in each part with a very small threshold of 0.05 m. Then the sidewalk and the road can be separated completely. The final result is shown in **Fig.9**. The white area refers to the floor plan of extracted crossroads area. The red line is the boundary of road and side walk drawn manully.

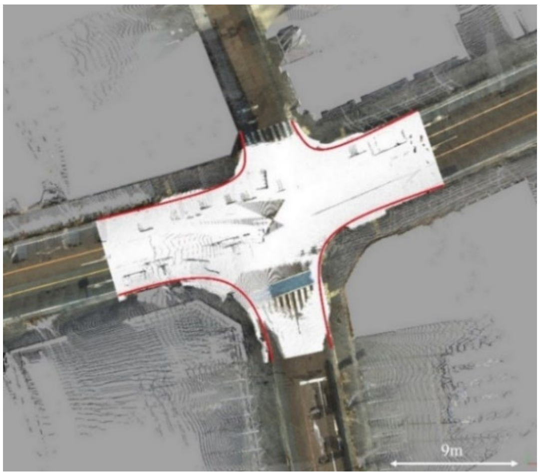

Fig.9 Final result of extracted crossraods area

(5) Result validation

Result validation is based on the comparison between extracted road width in four direction and the real value. The width value can be calculated from the floor plan utilizing the extracted boundary line in the previous section as shown in **Fig.10**. The data for verification is obtained from the field trip. A Riegl VZ-400 3D terrestrial laser scanner was used to create the point cloud of the crossroads area. For each road, 5 pairs of points were selected to measure the real width and then averaged as the validation value. The validation results are showed in **Table 2**.

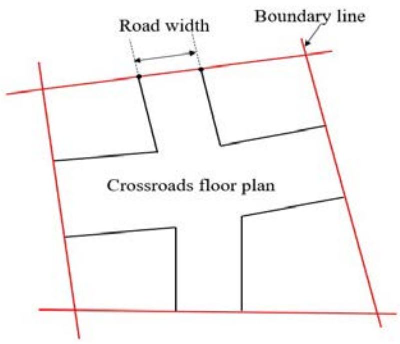

Fig.10 Extraction of road width

Table 2 Road width validation

Direction	Extracted result (m)	Measured value (m)
North	7.95	8.02
East	11.14	11.16
South	9.15	9.06
West	11.94	11.15

4. DISCUSSION AND CONCLUSION

In this study, an automatic process to extract the crossroads area and calculate the road width from the original Mobile Mapping System (MMS) data was developed. As a result, the extracted floor plan of crossroads area was quite close to reality and the width of the road is also close to the measured value. Some parts of the sidewalk is also recognized as the road area, this is because some slope are so mild that they are difficult to be separated with the road area utilizing slope filter. For future work, a more generalized process that can extract multiple crossroads area will be developed and the process will be validated on other areas in Tokushima.

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