# RECOGNIZING THE ROAD POINTS AND ROAD MARKS FROM MOBILE LIDAR POINT CLOUDS

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**KEY WORDS:** mobile lidar, point cloud, road extraction, road marking, SIFT matching.

**ABSTRACT:** Mobile lidar system is a cost-effective way to acquire spatial data in the urban area effectively. It can be used to generate a detailed street-level road model. As the need for Location Based Service (LBS) is increasing, the demand of understanding the city structure is growing up rapidly as well. For this reason, street-level road model is one of the most important elements to connect the geospatial objects in the urban area. The purpose of this paper is to extract the 3D road points and road marks from mobile lidar system effectively. The major works include road points selection and road marks extraction. In the road points selection, we select the lowest point as potential ground points from all points using elevation threshold. Then, we use the cubic curve fitting and point-to-curve distance to extract road points. It can remove non-ground points like cars and pedestrians. In the road marks extraction, we generate an intensity image by the interpolation of lidar intensity and create the road marking template for matching. Then, we extract location of road marks from the point clouds based on SIFT (Scale-invariant feature transform) matching. The test data acquired by Riegl VMX-250 system is located in Chiu-Chung Road in Taipei city. The accuracy of data is better than 10cm. The pixel size of intensity image is 7.5cm. The experiment results show that this method can extract ground points correctly. However, only limited road mark can be found in the preliminary result. The descriptors of the keypoints have a great effect on performance in matching.

## 1. INTRODUCTION

Mobile lidar system is a cost-effective way to acquire spatial data quickly and accurately in the urban area. It acquires point clouds which provide more useful information around the road environment. Hence, it is possible to reconstruct street-scene and 3D city model more completely. Street-level road model may increase the application of road model, for example, Location Based Service (LBS), urban planning and navigation. For this reason, the extraction of 3D road points and road marks from mobile lidar is one of the important research topics.

In order to extract the road points from point clouds, researchers develop different methods to recognize the road surface. In the data fusion strategy, Boyko and Funkhouser (2011) combine 3D point clouds and 2D road maps to generate a detailed 2D attractor map. The attractor map has two terms, a curb detector and a road boundary constraint. 3D point clouds are used to find the location of a curb, and road maps were used to expect range of the road boundary. Then, they extract the road boundary by the “ribbon snake”. Another way to extract the road points is based on gradient image. It is generated by 3D point clouds and used to extract the curbstones by the height difference. Then, the area covered by the extracted curbstones is used to define the road region (Jaakkola et al., 2008). Denis et al., (2008) extract the road points using the elevation of point clouds. They produce elevation histogram and determine road points by surface growing. As most ground points are accumulated at the highest peak of the histogram, the pavement edges are detected by the elevation gradient. Then, the road length and road width can be estimated. Pu et al., (2011) also use surface growing to determined road points. They assume that the planes composed with road points are large planes at a certain distance below the 3D trajectory of the laser scanner, so they could extract roads points with area and geometric centers of the planes. The paper in Smadja et al., (2010) provide an approach that used the geometric design of road to select the road points. They use the parabola to fit the road surface, then they extract the road points. In the road marks extraction, Yang et al., (2012) set the thresholds of intensity and height to filter the noisy points at first. Then, they calculate the properties by the 4-connected regions extraction to classify the different type of the road marks.

The objective of this research is to extract the road points and road marks from mobile Lidar system. In order to handle large data set, we divide the point clouds into the several road segments along the road direction. Then, we select the lowest point in every segment in initial road points selection. The road points can be extracted using the cubic curve fitting and point-to-curve distance. In the road marks extraction, we produce an intensity image from selected road points. A road mark template is generated in image matching. This study uses SIFT (Scale-invariant feature transform) (Lowe, 2004) matching to recognize the road marks in the intensity image. Finally, we extract the 3D road point in the regions of marks.

## 2. METHODOLOGY

### 2.1 Road points selection

#### 2.1.1 Rough classification by the lowest point

There are two major works in this step. First, we divide point clouds into "road parts" along the road direction. Partitioning point clouds can avoid processing whole point data directly. Moreover, the classification of ground point can be more locally. Second, we find the lowest point in every road parts and set the threshold to divide point clouds into ground point and non-ground. In the equation (1), $p_z$ is the height of lidar points in the road parts, $\mathrm{p_{lowest}}$ is the height of the lowest point. If the height difference $H_d$ between $p_z$ and $\mathrm{p_{lowest}}$ is less than the threshold, the point would be classified into the ground point.

$$|p_z - p_{lowest}| = H_d \qquad if\ H_d \leq threshold \quad p\ is\ the\ ground\ points \qquad (1)$$

#### 2.1.2 Extracting road points by cubic curve fitting

We have to further refine the ground points, because the ground points found with height threshold may contain pavement, pedestrian, bottom of the tree and vehicle. In this study, we use the cubic curve fitting and point-to-curve distance to refine the ground points. Figure 1 shows the road surface profile. First step, we search the lowest point called first point, and find the second point which has minimum distance in height with first point. The range between the first and second point would be the road surface. Then, we consider the points within the boundary as the road surface points, and we use least squares fitting to compute the parameters of the cubic curve. Finally, the road points would be extracted with point-to-curve distance, if the distance is below 5cm.

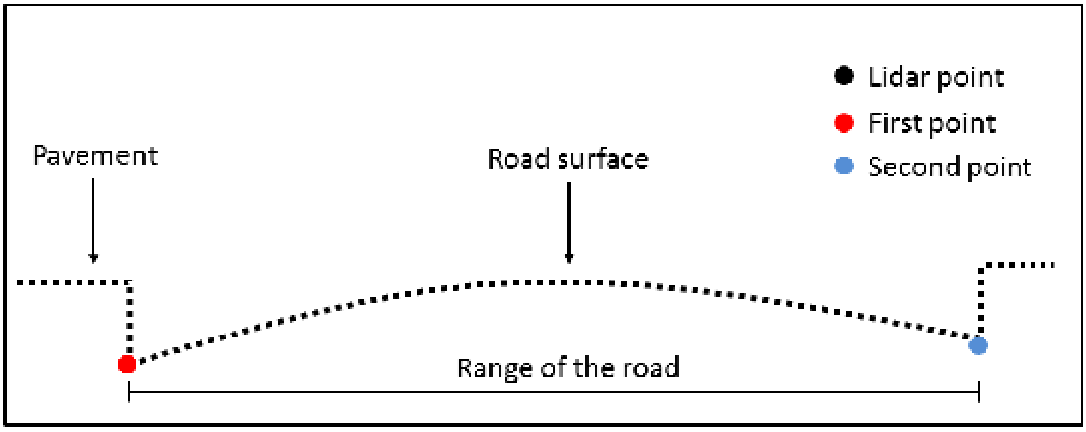



**Figure 1:** The geometry of the road

### 2.2 Road marks extraction

#### 2.2 .1 Generating the intensity image and the database of road marking

We generate an intensity image to create the templates of road marks and find the road marks location. The pixel size of the image in our study is 7.5cm. If there is more than one point in the pixel, we choose higher intensity to be the grey value. Moreover, the gap of the points is interpolated by bilinear interpolation. After that, we transform the image into binary image. The binary image is used to reduce the effect on the noise. Finally, we generate different kind of road marks template for matching.

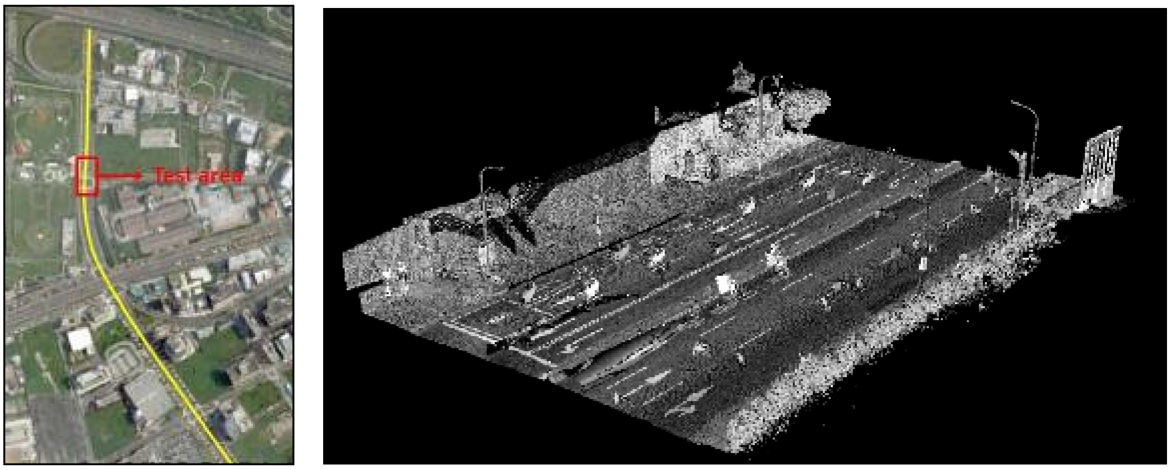
#### 2.2.2 Finding the road marking by SIFT matching

To exactly find the location of the road marks, we use SIFT (Scale-invariant feature transform) matching to recognize the road marks, because of its resistance to image deformations (Lowe, 2004). In SIFT matching, after calculating the descriptors for keypoints, we compute the Euclidean distance of the descriptor between the template and the road marks in intensity image, then use the equation (2) in feature matching. In equation (2), $D_{min}$ is the first minimum Euclidean distance between the template and intensity image, $D_{sec}$ is the second minimum Euclidean distance. If the $R_D$ below the 0.7, the keypoint of the $D_{min}$ would be the tie point.

$$R_D = {}^{D_{min}}/_{D_{sec}} \qquad (2)$$

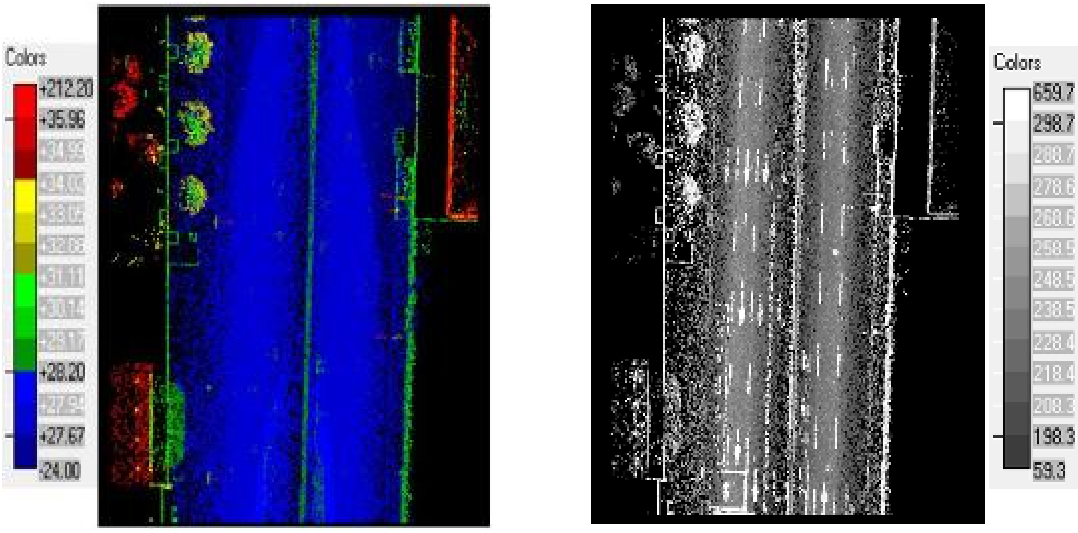
## 3. EXPERIMENTAL DATA

In the study, the input data is mobile mapping system lidar data acquired by Riegl VMX-250. The test area is located in the part of the Chiu-Chung Road in Taipei city, Taiwan, as the figure 2. The accuracy of test data is better than 10cm. The length of the road is about 70 meter. The data has 3760089 lidar points. The objects contain pedestrians, trees, poles, cars and pavements. Figure 3 shows difference mode to display the lidar data.




(a). Location of the test area (b). Lidar point cloud in 3D mode

**Figure 2:** The Lidar point cloud




(a). display lidar data in height (b). display lidar data in intensity

**Figure 3:** Displaying Lidar data in difference mode

## 4. EXPERIMENTAL RESULTS

### 4.1 The result of the road points extraction

In this part, considering that shoulder of the road is higher than the road surface, we predefine the height threshold is 40cm to roughly divide the point clouds into ground and non-ground point. Figure 4 shows the result that point clouds are roughly classified by the lowest point. The small figure in right-up is the top view. In the figure, the white points are the raw data, and the orange points belong to the ground points. We can see that there are lots of thing (e.g., pavement, car and the delimited island) classified into the ground points.

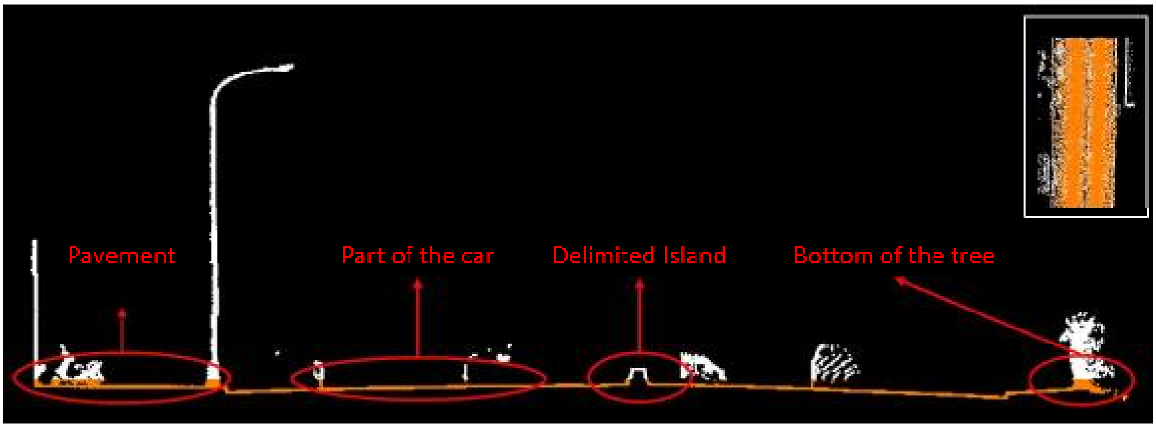



**Figure 4:** The result of rough classification in a profile

Figure 5 is the road points refined by the cubic curve fitting. The white points are the raw data, the orange points belong to the ground point, and blue points are the road points. There are totally 2823738 points in the road points. Table 1 present the number of points and mean transverse slope about right and left side of the road points. The mean transverse slopes of the road are 2.18% and 3.36%. The transverse slope of the road standardize in Taiwan is 3%. The transverse slope value between the road standard and the road points is very close.

**Table 1:** The index of the road points

| | Left side of the road | Right side of the road |
|---|---|---|
| Number of points | 1394793 | 1428945 |
| Mean transverse slope | 2.18% | 3.36% |

With the distribution of the road point in figure 5, we can find out that the road points are more correspondent with the road surface than the Figure 4, and object on the road surface would be separate very well. The boundary of the road is also more correct. However, there are some areas that cubic curve can't be fit well, we can find out this error in figure 6 that display the road point in height. The red circles in the figure show that the road right side seems a little broken.

**Figure 5:** The result of the road point in a profile

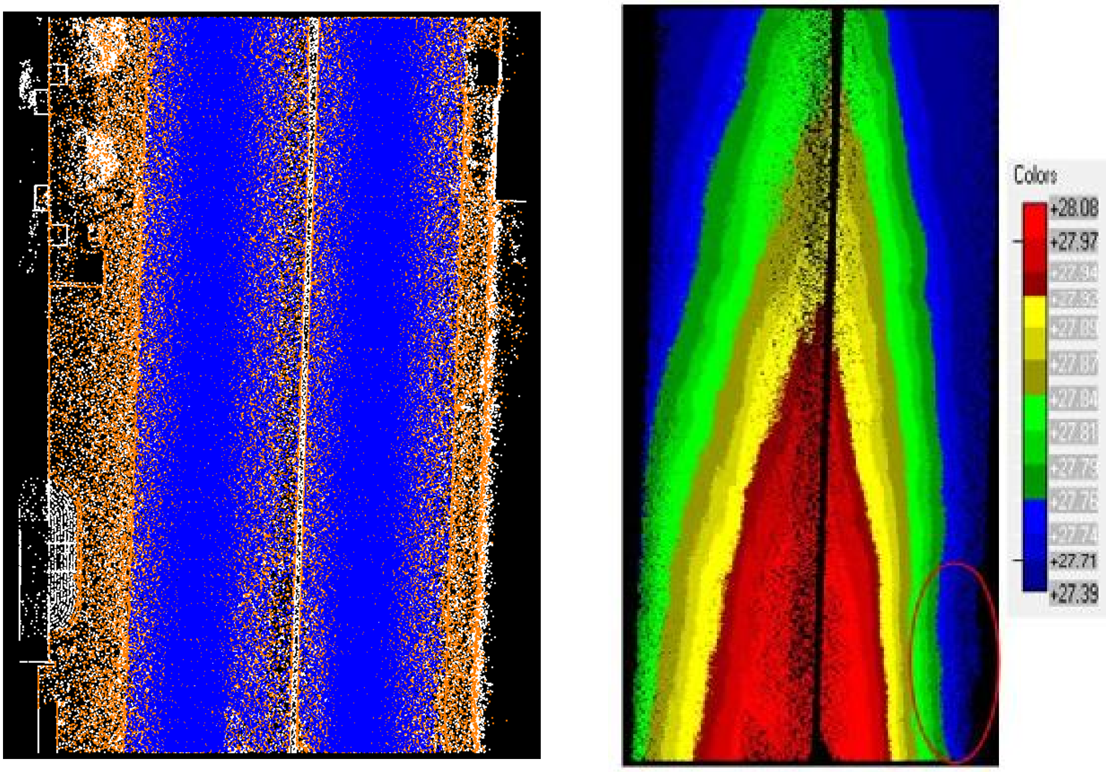



**Figure 6:** The road point compare with raw data and rough classification (left), The result of the road point displayed in height.

Figure 7 depicts more details what happen in the above. Left picture shows indistinct road boundary. We can see that the height difference between the road surface and the shoulder is not obvious. Then, we can't find the correct road range. There is the similar situation that has wrong boundary in right picture. Some points aren't classified into road points. We look back the process of finding road boundary (show as Figure 1). We find out that there are too many points having same height so that we can't find the right road boundary.

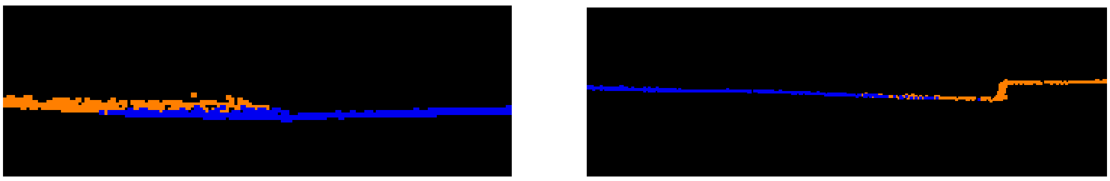


**Figure 7:** Incorrect road points extraction

**4.2 Preliminary results of the road marks extraction**

Figure 8 represents the intensity image, the binary image and the result of the extraction. There are three kinds of road marks in the database. Figure 9 shows the one of the road marks in database. The results of the road marks extraction are shown in Table 2. The experimental results are not very well. Only one kind of road marks could be found more, the rest of road marks just could be found the one which is the original template in the database.

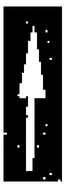


**Figure 8:** Indication of traffic lanes

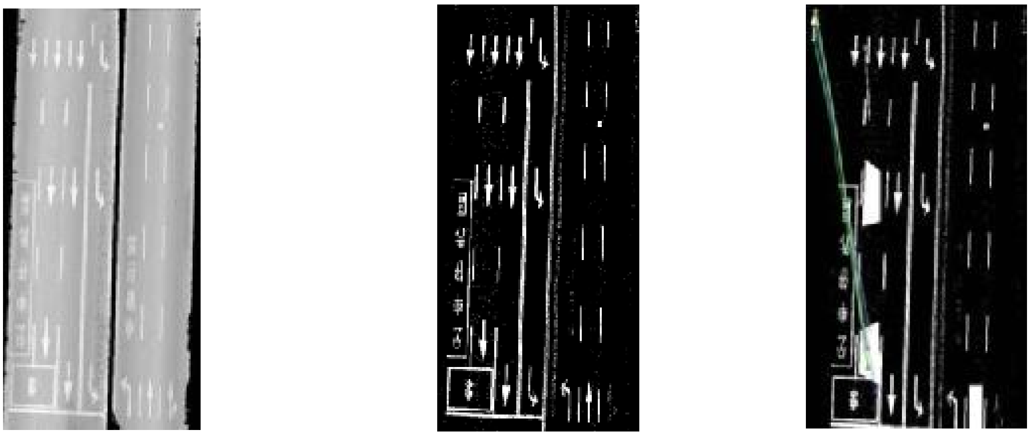


**Figure 9:** intensity image (left), binary image (middle), the result of the extraction (right)

**Table 2:** The results of the road marks extraction

| | Total number of road marking | Number of matching successfully |
|---|---|---|
| Indication of traffic lanes (middle) | 8 | 3 |

## 5. CONCLUSION

In this research, we describe an approach for extracting the 3D road points from mobile Lidar system and to detect the road marks with lidar intensity. We divide point clouds into "road parts" along the road direction in order to avoid processing whole point data and extract the ground point more locally. We use the height threshold and the lowest point to divide ground point and non-ground, and then separate the road points by cubic curve fitting. The result shows that this approach can extract the road well. However, the road boundaries may be affected by the weak geometry of the road. In road marks extraction, the preliminary result of SIFT matching is not very well. We only found a few road marks in the image. The future work will improve the successful rate in SIFT matching.

## ACKNOWLEDGEMENT

This investigation was partially supported by the Ministry of Interior of Taiwan. The authors like to thank the Department of Urban Development of Taipei City Government for providing the test data.

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