# Estimation of road alignment using point cloud data of mobile mapping system

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**Abstract**: Mobile mapping systems have the potential to enhance advanced ITS by estimating the road alignment from the point cloud data acquired by the mapping system. This paper describes methods for extracting a road surface from 3D point cloud data and estimating the alignment based on the pavement markings for the lanes, i.e., the white lines on the road surface. To extract a road surface, the reflection intensity value of laser and RGB color information of the point cloud data were used as the threshold for classifying data points as being either on or off the road surface. The vertical road alignment was estimated by combining the point cloud data comprising the white lines, and the lateral road alignment was estimated based on the perpendicular to the white lines. From a comparison with actual road alignment data, we find that the estimates of road alignment using point cloud data are highly accurate.

*Keywords*: Road Alignment, Mobile Mapping System, Point Cloud Data

## 1. INTRODUCTION

In recent years, the interest in and the need for advanced ITS technologies such as an automated driving system or a driving assistant system has been increasing. There are many approaches to these driving systems that automatically adjust the vehicle speed to maintain a safe following distance from other vehicles and remain within a lane. In general, on-board sensors are used to guide these driving systems, and many passenger cars with sensors are in production. The concept of a sensor-based driving system is to measure the relative distance or the acceleration between the vehicle with the sensors and nearby vehicles. However, in situations of dynamically changing road alignment, it is very important to recognize hazardous situations and obtain road alignment data on a road section ahead of a moving vehicle in advance. However, it is difficult to provide a warning to a driver based on the data for the road section ahead. The other approach to realizing a driving assistant is based on precise positioning data. In recent years, the precise positioning data collected by a Global Navigation Satellite System (GNSS) such as RTK-GPS and VRS-GPS have been available. However, the lack of a detailed road map, including white lines, grades, lane widths and road widths, is a critical problem for using the precise positioning data.

With existing road maps, time is required to obtain detailed information, and the information that can be provided on paper is limited. These paper maps cannot provide detailed three-dimensional information, so representing the height information is difficult, and adapting them to advanced ITSs is difficult.

This study focuses on extracting information from the three-dimensional point cloud data of the surrounding road acquired by a mobile mapping system (MMS). An MMS with laser measurements can quickly and efficiently acquire road surface data and estimate the road alignment. However, although the data can be measured effectively, the time required to process the large amount of information is prohibitive, and the data do not include attribute information.

Several studies have described methods of extracting road information and estimating road alignment. In this field, the International Society of Photography and Remote Sensing (ISPRS) is an important source of research. For example, Boyko (2011) attempted to extract road surface and road center line information. However, there has been no study in which road information was extracted and the road alignment was estimated using only point cloud data.

Yang(2013) developed the semi-automated extraction method to identify the edge of road objective such as boundary of sidewalk and vehicle lane. Yang(2013) proposed the method to identify road side object by using shaped-based segmentation. The conclusion of previous studies has described the possibility of identifying the boundary of road. However it has never described about extracting white line of both sides on road to estimate road alignment.

Given the current state of technical development, this study investigates the extraction of road surface reflection intensity values and color information (hereafter, RGB values) from point cloud data acquired by an MMS. Furthermore, an estimation method is examined to identify the three-dimensional road alignment, which includes height information from the point cloud data of the extracted road surface.

## 2. MOBILE MAPPING SYSTEM AND POINT CLOUD DATA

An MMS is a system with many sensors such as laser scanners, cameras, GNSS antennas, and an odometer, as shown in Figure 1. The MMS measurements provide the point cloud data while the vehicle is traveling on a road. In this study, the Nikon-Trimble MX8 was used as the MMS to collect road data. The data (Figure 2) consist of the reflection intensity, position information (X, Y, Z), and RGB values.

The RGB values are acquired by the camera and included in the point cloud data. The reflection intensity value is expressed as an integer in the range of 0-255, obtained when an object reflects the laser beam and thus giving the intensity of the reflection. Reflection intensity values have characteristics that are less susceptible to the measurement environment. The RGB color model represents any color with integer values in the range of 0-255 for each of the three colors red (R), green (G), and blue (B). Because they are acquired from the camera image, the RGB values are easily affected by changes in the measurement environment.

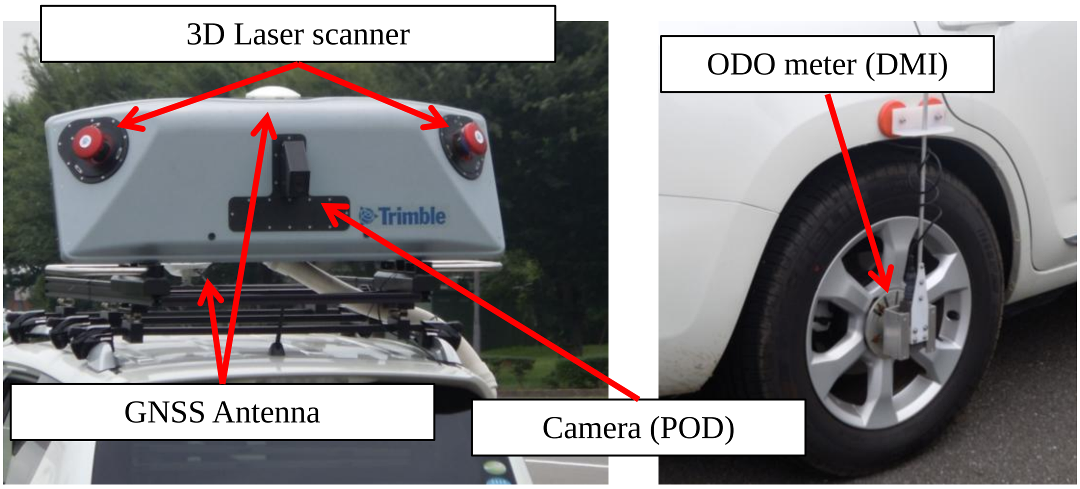


Figure 1. Sensors on Nikon Trimble MX8

Figure 2. Example of road section (left: photograph, right: point cloud data)

## 3. METHODOLOGY

This study investigated whether the point cloud data can be used to estimate the road alignment. Therefore, to extract white lines from the point cloud data, the reflection intensity and the RGB values of several types of road surfaces such as asphalt and concrete were measured, and the white lines were analyzed by calculating the median, the maximum, the minimum and the standard deviation of each value. Each value was calculated from the values of the point cloud data which were selected manually by the author from images displayed on a computer screen. Based on this analysis, the criteria that classify a point as being on the road surface are estimated.

To estimate the road alignment, the extracted white lines were divided into 0.3 m intervals based on the position information, and then the representative point of each was connected to the others white lines.

For the analysis, the mobile mapping system was driven over local roads near the Funabashi Campus of Nihon University, which consist of one lane per direction, shoulders and sidewalks, including curve and direction way. The experiment was conducted on August 2, 2011 and began at noon.

If the method would be available, for example, the hazardous road alignment was easy identified. For the further studies, we have plan to estimate driver's visibility by using point could data. If achieved, the hazardous traffic situation would be estimated by comparison with driver's visibility and vehicle speed.

## 4. EXTRACTION OF WHITE LINES

The minimum, maximum, average, and average plus and minus one standard deviation of the reflection intensity value are shown in Figure 3, and the averages and the standard deviations of the RGB values are shown in Figures 4 and 5.The standard deviation was calculated on the values in which the extracted point cloud data was for each objects. In this study, the lower and upper bounds were set at 25% and 75% of the value, respectively. Therefore, the point cloud data were extracted using the limits of 25% and 75%. This range was chosen based on previous studies, which had produced some incorrect extractions; therefore, in this study, the limits were expanded to 25% and 75%.

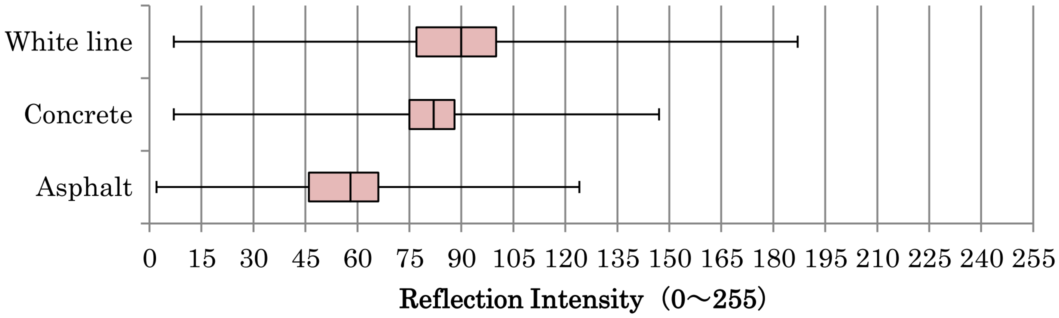


Figure 3. Distribution of Reflection Intensity

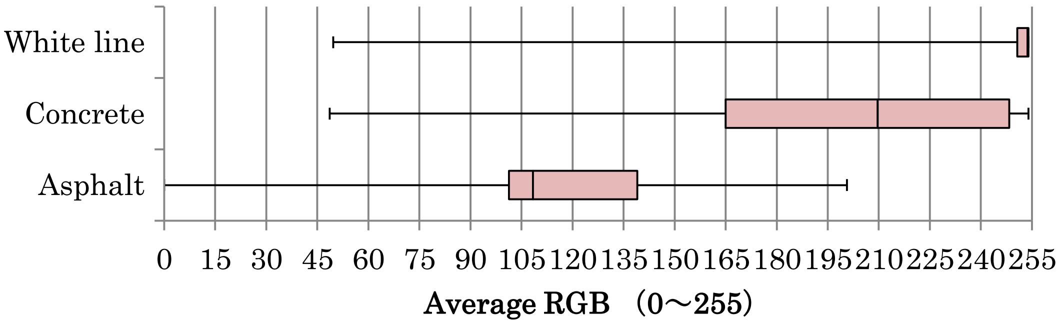


Figure 4. Distribution of average RGB

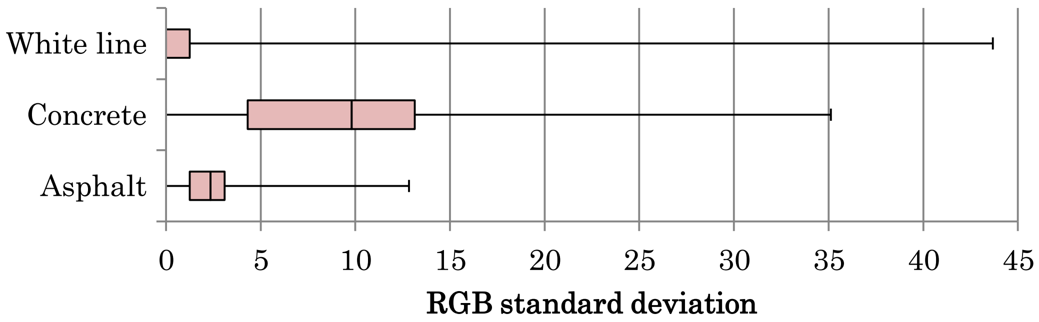


Figure 5. Distribution of Standard Deviation of RGB

The extraction was performed using the criteria in Table 1. Because the reflection intensity is not influenced by measurement conditions, the reflection intensity was used as the first step in the extraction. In the second step, either the RGB values or the RGB standard deviation was used to refine the extraction. In Table 2, the rate of extraction is the percentage of the point cloud data that were extracted from the entire white line, and the rate of removal is the percentage of other point cloud data not including the white line that were removed from the data set. In the second step, the rates of extraction and removal were 20% and 99%, respectively. Even though the rate of extraction seems low, the extraction was successfully completed, as shown in Figure 6.

Combining both, the resulting extraction rate is approximately 21%, and a removal rate of approximately 99% was obtained. With an extraction rate of approximately 21%, the white line can be extracted, as Figure 6 confirms. In this study, we analyzed the RGB values and the reflection intensity of asphalt and concrete, and in extracting the point cloud data of the white lines, we were able to remove many road structures other than FIG. However, extraneous points remain, such as parts of utility poles. These results suggest that the technique is effective in extracting the white lines and can lead to a more efficient processing of the point cloud data.

Table 1. Extraction Criteria

| Road Structure | Extraction range | | |
|---|---|---|---|
| | Reflection intensity value | Average of RGB value | Standard deviation of RGB value |
| White line | 89-100 | 251-255 | 0.0-1.1 |
| Concrete | 75-88 | 165-248 | 4.3-13.1 |
| Asphalt | 46-66 | 101-139 | 1.2-3.1 |

Table 2. Result of Extraction

| Extraction Condition | | Refelection Intensity（89-100） | |
|---|---|---|---|
| | | Average RGB（251-255） | Standard deviation of RGB（0.0-1.1） |
| All data | Before(Number of points) | **70,062** | |
| | After(Number of points) | **8,525** | **8,493** |
| White line | Before(Number of points) *a* | **35,560** | |
| | After(Number of points) *b* | **7,456** | **7,694** |
| | Rate of extraction *b/a*100* | **21.0%** | **21.6%** |
| Other | Before(Number of points) *c* | **665,202** | |
| | After(Number of points) *d* | **1,069** | **1,099** |
| | Rate of remove *(c-d)/c*100* | **99.8%** | **99.8%** |

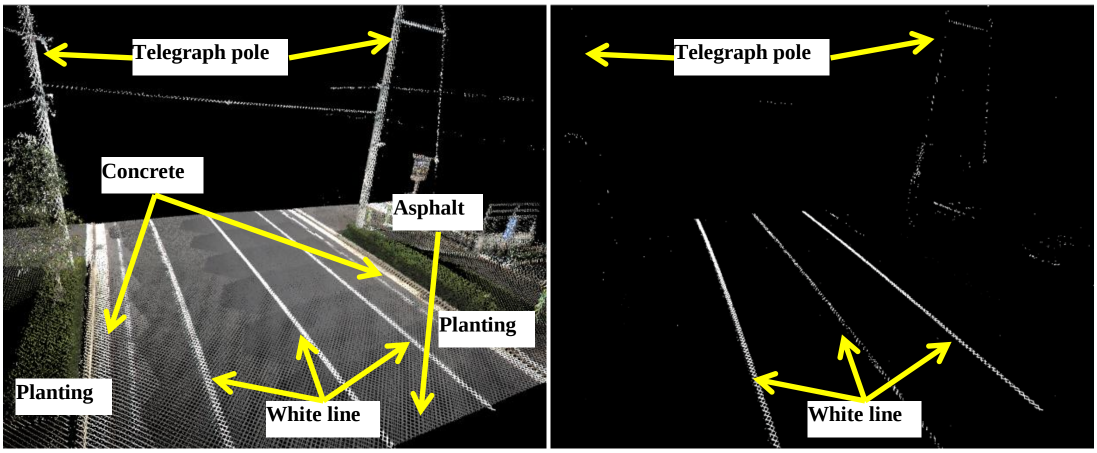


Figure 6. Example of extraction (left: before; right: after)

## 5. ESTIMATION OF ROAD ALIGNMENT

The second part of this study examines the estimation of the road alignment using the point cloud data of the extracted white lines. The point cloud data for the white lines were divided into 0.3 m squares, as shown in Figure 7. The median X coordinate of each block and the Y and Z coordinates were used to estimate the road alignment.

The road width, the vertical grade, and the longitudinal grade were estimated based on the white line point cloud data, as shown in Figure 6. These estimated values can be confirmed from the speed limit that corresponds to the second-class road construction class fourth and the traffic volume. Table 3 gives the standard values for road construction that were used to evaluate the estimates.

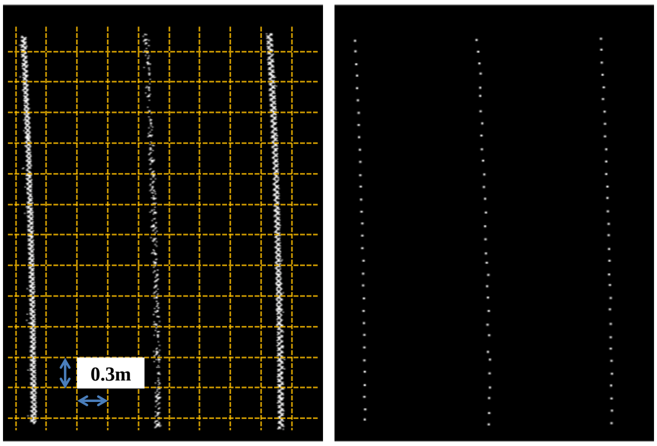


Figure 7. Extraction of white lines

Table 3. Actual values on targeted road section

| | Standard Value |
|---|---|
| Road width | 3.00m |
| Regulation speed | 60km/h |
| Longitudinal grade | 5% |
| Cross grade | 1.5～2.0% |

The road lane width estimate was obtained using the white line position information, from the difference between the left line and the center line or the white line on the right. The value in this case is the distance between the left white line and the center line, the difference was assumed that the XY coordinates of the representative point is the smallest.

The gradient was calculated from equation (1) using the distance and the height difference. The vertical gradient was calculated on the basis of three points, one from the right white line, one from the center line, and one from the white line on the left. In addition, the difference in height between the representative points for each longitudinal gradient was calculated from the difference in height between the distance and the longitudinal slope of the uppermost and lowermost points in Figure 7.

$$\text{Gradient height difference (\%)} = \text{difference of height (m)} / \text{distance (m)} \times 100 \qquad (1)$$

The estimated values of the lane width are shown in Table 4. The minimum width in the table was calculated from several sections of minimum values, and the maximum value was calculated from several sections of maximum values.

The specified value of lane width for the class of roadway targeted in this study was 3.00 m; thus, the resulting errors in the estimates were within 0.1 m. In addition, the value for the left side had a tendency to be greater than the value for the right side.

Table 4 Estimated road width and specified value

| | Left-Center | Center-Right | Specified |
|---|---|---|---|
| Minimum(m) | 2.94 | 2.90 | 3.00 |
| Maximum(m) | 3.04 | 3.00 | |
| Average(m) | 2.99 | 2.95 | |

Table 5 and Figure 8 show the cross gradient. No significant difference was observed in the shape of the graph. However, the cross gradient from left to center decreased from the rear side to the front side. Compared with the specified value, the left - center value on the rear side and the middle are much higher. It is possible that the road is canted because there is a gradual curve at the tip of the rear side ahead.

Table 5. Estimated road width and specified value

| | Left-Center | Center-Right | Specified |
|---|---|---|---|
| Rear | 3.03% | 1.70% | 1.5-2.0% |
| Middle | 2.76% | 1.38% | |
| Front | 1.75% | 0.33% | |

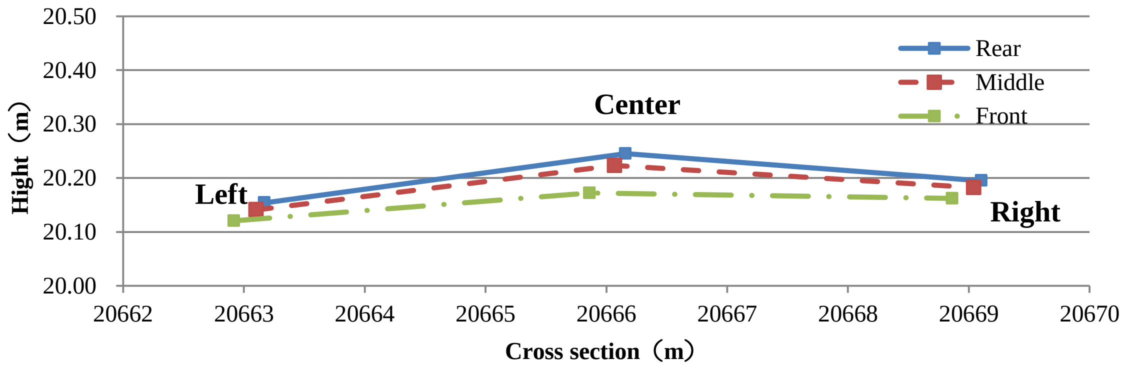


Figure 8. Cross gradient

Table 6 shows the value of the vertical gradient between the rear and front sides, and Figure 9 shows the vertical gradient. It is mentioned in the roadway the effective for a grasp of details such as the gradient or altitude higher than the altitude of the outer line of the center line elevation because there is cross gradient.

Table 6. Estimated vertical gradient and specified value

| | Top-Middle | Middle-Bottom | Top-Bottom | Specified |
|---|---|---|---|---|
| Right | 0.24% | 0.81% | 0.38% | |
| Center | 0.80% | 0.09% | 0.44% | 5% |
| Left | 0.25% | 0.81% | 0.38% | |

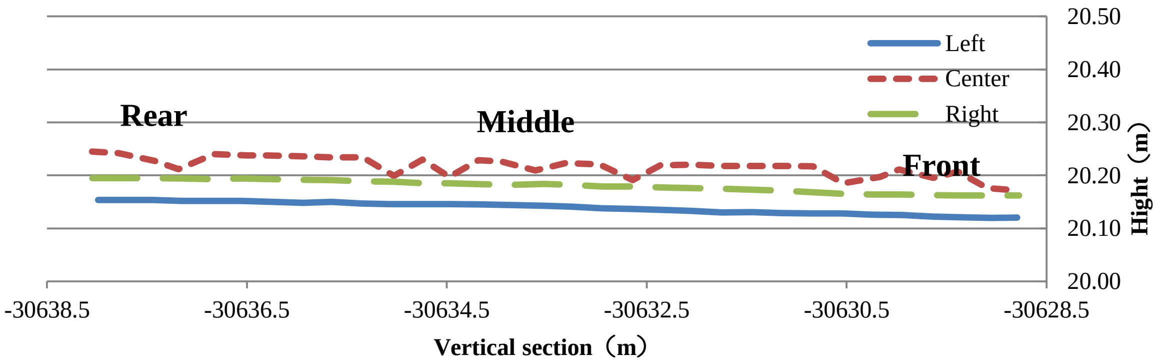


Figure 9. Vertical gradient

## 6. CONCLUSION

In this study, we have demonstrated that it is possible to extract from point cloud data the white lines by analyzing the RGB values and the reflection intensity to specify the extraction conditions. The extraction conditions addressed the problems encountered in previous research which proposed the threshold values estimated by limited data source about road objectives.

In addition, the estimate of the road alignment was examined based on the extracted white line data. It was concluded that the vertical and cross gradient can be estimated from the point cloud data collected by the MMS.

In the future, we will continue to investigate the estimation of the road alignment and cant, such as the curved portion that was not estimated in this study, and compare the estimates with actual CAD data of road alignment.

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