HD-Map assisted lane marking worn out detection from MMS data

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KEY WORDS: Mobile mapping system(MMS), lane marking, High-definition map, kappa.

ABSTRACT:This study focus on developing an efficient and quantifiable method for lane marking worn out detection. In this study, the proposed method for lane marking worn out detection is as follows: 1. Extract ground points from the data collected by MMS by using Clothes Simulation Filter(CSF). 2. Generate DEM from the ground points. 3. Based on the lane markings position provided by the High-definition map, extract image segments that contain lane markings. 4. Project image pixels of lane markings onto the DEM and calculate the coverage area. 5. Calculate lane markings worn-out ratio and divide into 10 levels. Worn-out ratio computation is based on the area information of lane markings provided by the High-definition map.

1. INTRODUCTION

Lane marking is an important element for traffic guidance, which restricts the driving direction of vehicles and time limit for parking. However, lane marking could be worn out over time, resulting in poor recognizability. The repairment of lane marking is usually time-consuming and labor-intensive. On the other hand, individual evaluation on the degree of worn out is often subjective. Thus, it is important to develop an efficient and quantifiable method for lane marking worn out detection. In order to provide the information to the government for road maintenance. This study is based on the High-definition map to provide lane marking position information, for calculating the area lane marking. And use this research method to evaluation on the degree of worn out of lane markings.

2. EXPERIMENT DATA

In this study, the general roads around National Cheng Kung University in the East District of Tainan City were used as the experimental area. Since the general roads in the city didn't have the High-definition map point cloud data, the experimental field used (RIEGL VZ-400) point cloud data to replace the High-definition map point cloud data. And the High-definition map vector layer data are replaced by the human-edited three-dimensional marking vector file to provide the known road marking position information of each road section. The experiment vehicle system is equipped with two Velodyne VLP-16 lidars to collect point cloud data. These Velodyne VLP-16 lidars are set up on the front side of the vehicle, one on the left and the other on the right. Installed one Flir Blackfly BFS-U3-5IS5PC-C camera on the rear side of the vehicle to collect image data. The GNSS/IMU system is used to obtain the position and attitude of the vehicle system. The relevant experimental site addresses and experimental equipment are shown in figure 1 and figure 2.

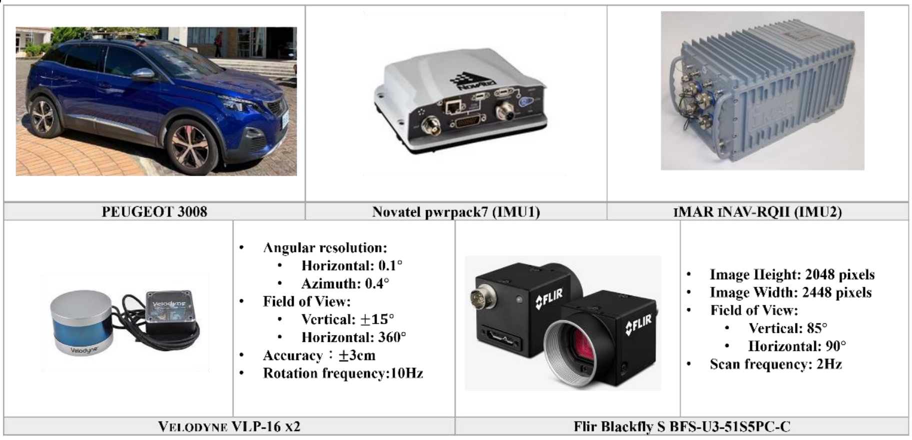


figure 1 Experiment instrument of this study

figure 2 Experiment site of experiment

3. METHODOLOGY

3.1 Point cloud data processing

This research experiment combines the point cloud of the vehicle lidar system and the camera image to evaluate the worn-out level of lane marking based on the color of the image. The flow chart of the study is shown in figure 3. This experimental study uses High-definition map point cloud data as the control point and INS/GNSS raw data to perform NDT matching on the vehicle lidar point cloud data and IMU/GNSS data. The vehicle lidar point cloud and the sampled IMU/GNSS data are designed to reduce the elevation change of the vehicle lidar point cloud data. The results of using the High-definition map point cloud data as the control point for NDT matching are shown in figure 4, after the vehicle-mounted lidar point cloud data is matched and spliced by NDT, it is used to provide road three-dimensional object space information to establish a digital terrain model (Digital Elevation Model, DEM). The steps are as follows. According to the vehicle trajectory, it is divided into sections every 2.5 meters, and the vertical direction of the vehicle is extended by 3.5 meters. The point cloud data is divided into blocks to reduce the data processing time, and the Cloth Simulation Filter algorithm is used to obtain approximate road surface point cloud data. Based on the road surface point cloud data produce a DEM with a resolution of 0.01cm to interpolate the average elevation of the point cloud within the search radius (20cm).

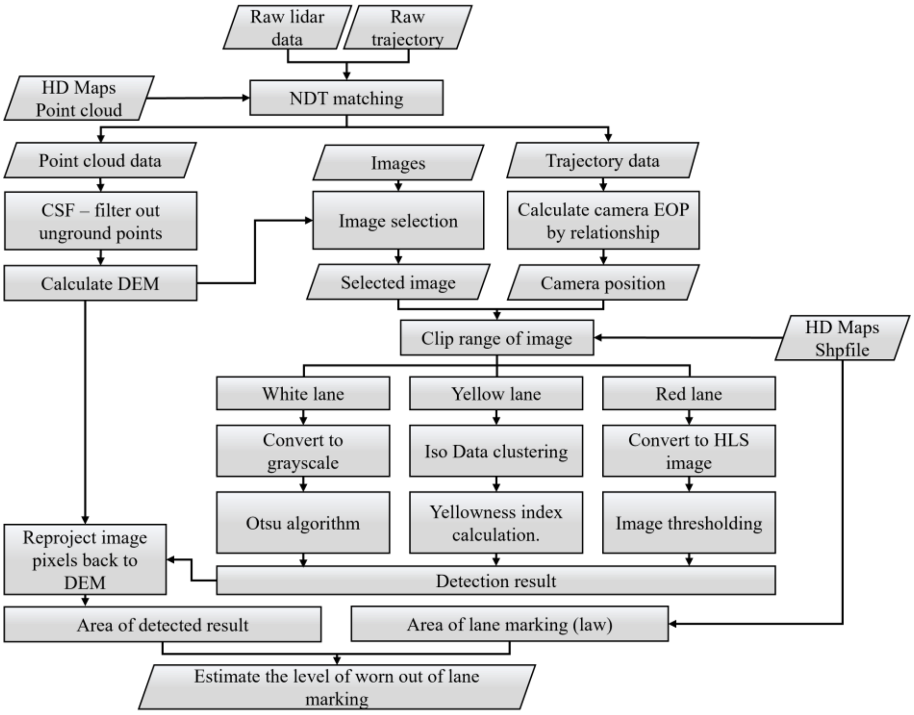
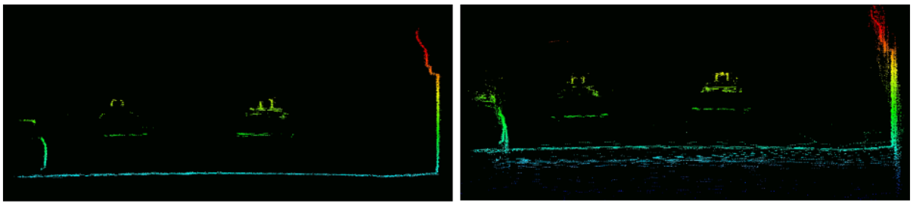


figure 3 Flow chart of methodology



(a) (b)

figure 4 (a) Adopting the High-definition map point cloud as the control points, the max elevation variation is 0.04~0.1cm. (b) Registration point clouds based on raw INS/GNSS data, the max elevation variation is 1m~2m

3.2 Image data preprocessing

After the point cloud data processing is completed, the position and attitude of the vehicle camera are calculated from the sampled IMU/GNSS data of the NDT matching result. Calculate the three-dimensional distance between the center coordinates (X, Y, Z) of the DEM and the onboard camera, and use the image captured by the camera at a distance of 10 to 20 meters from the DEM. The purpose is to avoid that the entire reticle range cannot be covered in the image or the number of pixels occupied by the reticle is too small to be recognized. Use the intersection line segment of the High-definition map vector layer and the DEM for buffering. Since the 3D coordinate accuracy of the High-definition map vector layer is 30 cm, considering that the maximum reticle width is 15 cm, buffering the intersection line segment of the High-definition map vector layer 37.5 cm as a possible range of lane marking as shown in figure 5. And project this range onto suitable images for detection and processing.

figure 5 The projection of buffer range from the High-definition map n image

3.3 Detection of lane marking

Since the code of each type of marking is recorded in the High-definition map vector data, it can be known which color of road marking the intersection line belongs to according to the code. Different detection methods are used for each color marking. The following is the detection method of each color marking. In the measurement method, the white lane marking will convert the color image into a grayscale image. Performing the Otsu algorithm based on the grayscale image. As shown in figure 6, the Otsu algorithm calculates the variation between two groups, and set up the threshold with the maximum variation between the groups as the final threshold value for the image binarization; the yellow lane marking adopts ISODATA unsupervised classification classifies ROI images, and its ISODATA unsupervised classification can obtain the RGB value of each cluster center and the standard deviation value of the cluster, calculate the Yellowness of each cluster center, and use the RGB value of the cluster center as the threshold. Because the yellow lane markings has a high exposure level in this experimental image, the RGB value is relatively high. Therefore, the classification with RGB values higher than the threshold is selected as the detection result of the yellow lane marking to solve the problem of exposure. The problem of excess, ISODATA and calculation of Yellowness are shown in figure 7; the detection method of the red line is to convert the original RGB image into an HSL image first, and the red color of hue defined in the HSL color space is 0, This experiment is based on the distribution of HSL values according to the red marking line in the experimental sample area, taking the hue of ±10 degrees from 0 degrees, because the HSL hue is 0~360 degrees, the range of ±10 degrees is 350 degrees~0 degrees and 0 degrees~10 degrees, the rest of the lightness, saturation use the threshold of 26 to 230, this threshold is based on the image captured by the camera in this experiment, in which the lightness and saturation of the red line have no obvious difference In the case of distribution, use 26 to 230 as the threshold value of the red line and perform image binarization.

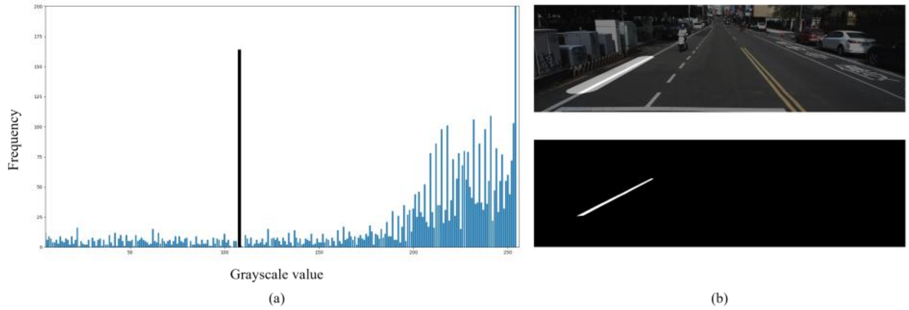


figure 6 (a) Otsu algorithm: Calculate the threshold by minimizing intra-class intensity variance, or equivalently, by maximizing the inter-class variance. (b) The binary image result from Otsu algorithm

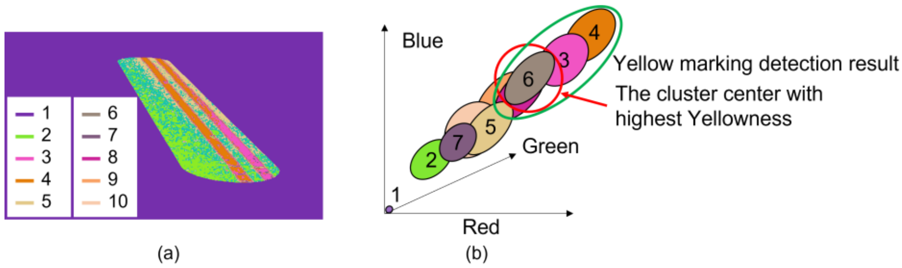


figure 7 (a) ISODATA clustering result of the possible range of lane marking. (b) Calculate the Yellowness of each cluster center and the result of yellow lane marking detection.

3.4 Evaluation level of worn out of lane marking

After completing the detection of various types of lane markings, calculate the DEM raster position corresponding to the image detection result based on the relationship between the camera and mobile lidar system. Calculate the detection result area based on the DEM raster, and compare it with the High-definition maps vector layer data buffer area result. The High-definition map vector layer data records the width of different types of lane markings, based on the width information to calculate the area that the lane marking should have. Calculate and rounding the evaluation of worn out level of the lane marking based on equation (1)

$$\text{The worn out level of lane marking}(\%) = \left[1 - \left(\frac{\textit{area of detection result}}{\text{High defintion buffering area}}\right)\right] \times 100\% \ (1)$$

4. RESULT

The experimental results are shown in figure 8. The wear degree is calculated with a 10% interval, and the white, yellow and red lane markings can all be used to evaluate the level of worn out of lane marking. The wear rate accuracy of each color marking can refer to in table 1. The ground lidar point cloud data is used as the reference value of the true value of the marking wear rate. The ground lidar point cloud is gridded into an image of the point cloud reflection intensity value, and the marks are manually distinguished. Obtain the area occupied by the marking line and the asphalt pavement, calculate the actual marking area included in the extended range of the marking line, and obtain the ground truth level of worn out of the marking line. The reflection intensity of cloud reflection is different for different materials. The distribution of reflection intensity of road markings is higher than that of asphalt pavement. However, the lidar system in this experiment is a circular 360-degree scan, and each scan is affected by factors such as vehicle speed and vehicle vibration. , resulting in an uneven density of the point cloud, the marking line can be roughly identified in the point cloud but the area cannot be accurately calculated, and due to the uneven density of the point cloud, the area calculation will also be affected, but the static scanning of ground light can be avoided. The problem of uneven density can clearly distinguish the difference between the marking line and the asphalt pavement in the ground LiDAR point cloud data. Therefore, the reference source of the marking line wear degree is the ground LiDAR data.
Divide 0~100 into 11 wear degrees and calculate the kappa value between the detection and reference value of each degree. When the kappa value is closer to 1, it means that it is more consistent with the reference value, otherwise it means that the consistency of the result is Random distribution, the calculation of its kappa value can be seen in

formula (2).

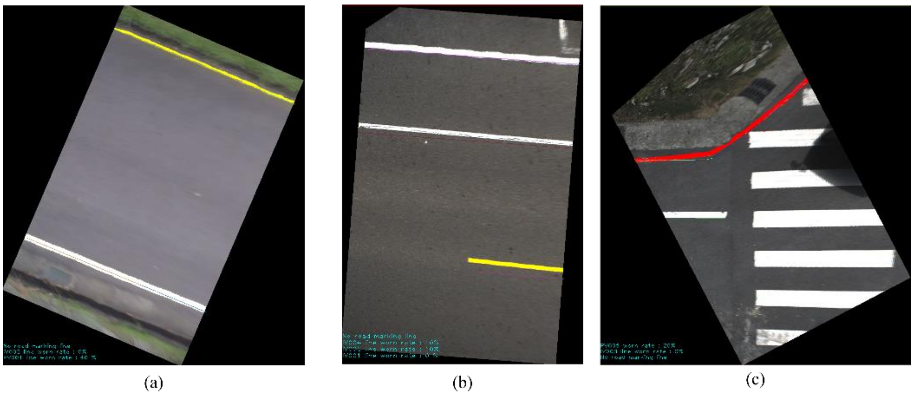


figure 8 (a) yellow lane marking(40%) and white lane marking(0%) ; (b) white lane marking(10%, 10%) yellow lane marking(0%) ; (c) red lane marking(20%)

$$kappa = {P_o - P_e}/{1 - P_e} \quad (2)$$

Type of lane markings	Kappa value
White	0.64234
Yellow	0.45865
Red	0.52071

Table 1 kappa value of type of lane markings

5. CONCLUSION AND ANALYSIS

The method currently used in this study uses images as the main source to identify whether the marking line is worn or not. Judging from the accuracy of the wear degree of each color marking line, the kappa value of each color marking line wear degree is 0.4~0.6, and the influencing factors may include the following: other vehicle blocking and shadows influence, will affect the judgment of wear and tear, and the accuracy of lidar point cloud and camera calibration. This experimental method can still evaluate the degree of wear and tear of each road marking, and relies on the positioning system to provide road location information, information related to road repair, and the degree of wear of road markings on each road, regardless of various color markings. Judging from the judgment, there is still progress in the automation of evaluating the degree of wear and tear of road markings in Taiwan. As for the restrictive conditions, it is hoped that in the future, AI, image processing and other methods can be used to correct or remove shadows or vehicle occlusion effects.

6. REFERENCE

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