RECONSTRUCTION OF 3D ZEBRA CROSSINGS FROM MOBILE LASER SCANNING POINT CLOUDS

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ABSTRACT

This paper presents a novel method for reconstruction of three-dimensional (3D) zebra crossings from mobile laser scanning (MLS) point clouds. Firstly, we extract the zebra crossings from the 3D point cloud data in data preprocessing. Secondly, the fitting model is generated by seven parameters to determine one plane commonly and then calculating similarity for fitting the zebra crossings point clouds. Finally, the cuckoo search algorithm is used to adjust the parameters and optimize the results to obtain the optimal model and the geometric information of the zebra crossings can be acquired simultaneously. The proposed algorithm is tested on a set of point-clouds acquired by a RIEGL VMX-450 LiDAR system. The experimental results show the feasibility and stability of our method and the zebra crossings of urban road can be automatically and effectively reconstructed.

Index Terms— Zebra crossings, reconstruction, mobile laser scanning, point clouds

1. INTRODUCTION

Precise measurement capability of the point clouds have an unparalleled role in modern intelligent transportation [1]. High-precision maps and autonomous driving system require models of large-scale road targets. The zebra crossings as a common road target provide instructions to drivers and other road users, which is generally composed of a number of parallel white solid lines. Currently, many researchers focus on the 3D point clouds processing in particulate on the road objects for detection, recognition and reconstruction.

The MLS systems have become a mainstream technology for obtaining surface information of target objects because it is flexible, fast and accurate. The MLS systems have been widely used to collect point clouds of the infrastructure, e.g. trees, light poles, traffic signs and road markings in urban roads. Therefore, the MLS systems provide an effective and reliable data for studying 3D road scenes.

Over the past decades, some studies developed on detecting and extracting objects of urban road environment based on image traffic signal processing [2]. In recent years, researches have begun to be conducted on the detection and extraction of road markings (including zebra crossings) on 3D point clouds. The algorithm in [3] consists of three main steps: road segmentation, rasterization, and zebra crossings detection. [4] extracts road markings directly from 3D point clouds acquired by a mobile light detection and ranging (LiDAR) system. [5] builds a robust method for semi-automated information extraction of pavement marking detected from 3D point clouds. These studies basically detect and extract zebra crossings, but have not got more information about zebra crossings, such as area, slope and so on. These information is widely useful for traffic management and autonomous driving.

In [6], the proposed method can obtain more specific information about the zebra crossings, including start positions, end positions, and distribution directions of zebra crossings, but it can not get the slope information. The contribution of our work in this paper is that we present a novel method for reconstructing 3D zebra crossings from MLS data. Our method first extracts zebra crossing points from raw MLS data, and then uses a newly proposed geometric model fitting approach to reconstruct 3D zebra crossing models from the extracted zebra crossing points. The geometric model fitting approach utilizes a geometric similarity estimator to guide the cuckoo search algorithm to find the model that best fits the extracted zebra crossing points. Most importantly, our method can acquire the geometric information of the zebra crossings, such as length, width and slope of zebra crossings.

The remainder of this paper is organized as follows: Section 2 describes the method in more detail. Section 3 presents experimental results and evaluates the performance of the proposed algorithm. Finally, Section 4 states the concluding remarks.

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2. METHOD

This paper aims at reconstructing the zebra crossings from 3D mobile laser scanning point clouds and obtaining the geometric information of the given data point set. The flowchart is demonstrated in Fig. 1 which includes two main steps: Data preprocessing and Reconstruction of zebra crossings.

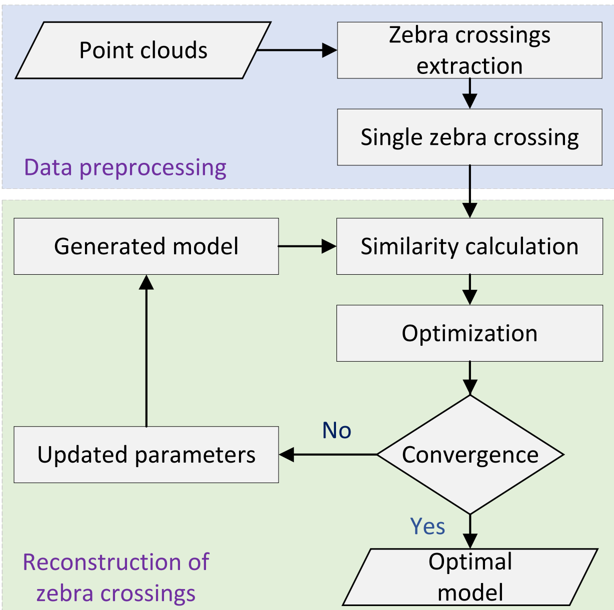


Fig. 1. The flowchart of the proposed method

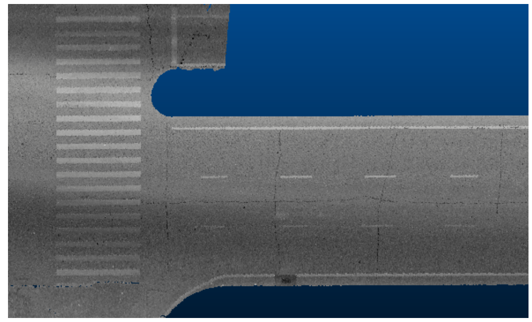
2.1. Data preprocessing

The point clouds of road street scenes contain zebra crossing points and others. The algorithm in [7] is adopted to extract the zebra crossing points. As shown in Fig. 2(a) and Fig. 2(b), we remove the other points and extract the zebra crossing points from the raw data.

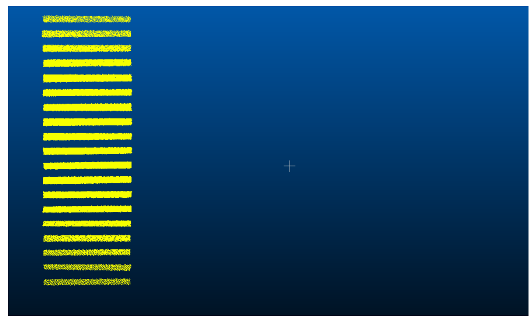
2.2. Reconstruction of zebra crossings

2.2.1. *Model definition*

The zebra crossings is an area that consists of a group of broad white stripes painted on the road. Every zebra crossing can be seen as a plane. Hence, the plane model we designed should be a plane which can rotate freely around one point. As shown in Fig. 3, the plane model we designed not only can rotate freely around the location point $L(x_0, y_0, z_0)$ in the XY plane but also can rotate freely around the L_1 side. We define the x_0, y_0, z_0, L_1, L_2, θ_1, θ_2 as LocationX, LocationY, LocationZ, Length, Width, AngleXY, AngleZ respectively. We explain these parameters in more detail in Table 1.



(a) raw data



(b) the extraction result

Fig. 2. Zebra crossings extraction

Table 1. The definition of parameters

x_0	LocationX	the X-axis coordinate of L point
y_0	LocationY	the Y-axis coordinate of L point
z_0	LocationZ	the Z-axis coordinate of L point
L_1	Length	the Length of L_1 side
L_2	Width	the Length of L_2 side
θ_1	AngleXY	the radian between the projection of L_1 side on XY plane and X axis.
θ_2	AngleZ	the radian between plane model and XY plane.

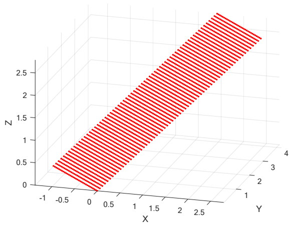
2.2.2. *Similarity calculation*

We use α_i (i=1:7) represents these 7 parameters (3 for location, 2 for area, and 2 for angle) and utilize these 7 parameters to generate the plane model. The goal of fitting zebra crossing is to find a plane model that best fits the given data point set. In order to distinguish which plane model most suitable for the given data, we need to calculate the similarity $s(M, D)$ between the plane model and the given data:

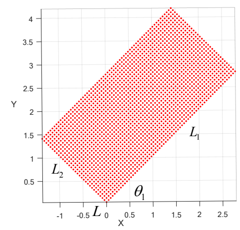
$$s(M, D) = \frac{|M|}{d^2(M, D)} \tag{1}$$

$$|M| = L_1 \times L_2 \tag{2}$$

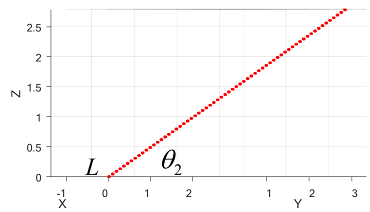
where $|M|$ is the area of the plane model M, $d(M, D)$ is the modified Hausdorff distance from M to data D [8]:



(a) the model



(b) view from top to bottom



(c) view from the side

Fig. 3. The plane model

$$d(M, D) = \frac{1}{|M|} \sum_{\mathbf{p} \epsilon M} \min_{\mathbf{q} \epsilon D} ||\mathbf{p} - \mathbf{q}|| \tag{3}$$

where $||\cdot||$ is the Euclidean distance between two points, and $\mathbf{p}$, $\mathbf{q}$ are the point of M and D, respectively.

2.2.3. *Optimization*

Next, we use the cuckoo search algorithm [9] as described in [10] to solve the maximization problem (see Eq.4). The cuckoo search algorithm is a stochastic optimization algorithm inspired by the breeding behavior of cuckoos. From [10] we recognize that the similarity estimator (Eq.1) is robust to handle outliers even if the data point set contains many outliers. Because the fitting method is based on the error from model to data. The best plane model $M^{'}$ is defined as:

$$M^{'} = arg \ \max s(M, D) \tag{4}$$

In this process, the parameter α_i (i=1:7) will be constantly adjusted to achieve the best results. In other words, the shape of plane model will become more and more similar to the zebra crossing point set we input. The model fitting process is crucial for obtain the geometry information of the given data point set.

3. RESULTS AND DISCUSSION

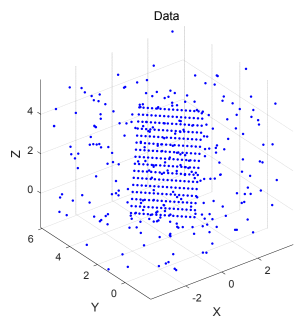
The experiments include two main steps: experiments on simulated data and experiments on real MLS data. The meaning of Length, Width, AngleXY and AngleZ are described in Table 1.

3.1. Experiments on simulated data

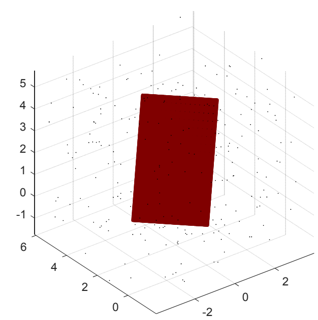
The simulated data used for experiments were shown in the Fig. 4(a), which contains some outliers. Meanwhile, the result is shown in Fig. 4(b). The result indicated that our method is robust. Although the simulated data contains outliers, the simulated data can be fitted well. We can see the value of precision in Table 2. The precision P is defined as:

$$P = (1 - \frac{|D - M|}{D}) \times 100\% \tag{5}$$

where D, M is the mean of Data and Model, respectively.



(a) simulated data



(b) fitting result

Fig. 4. Experiments on simulated data

Table 2. Results of reconstructing simulated data

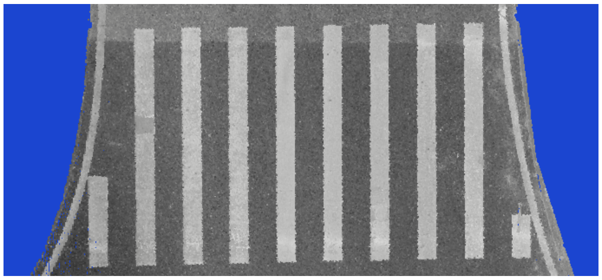
	Length (m)	Width (m)	AngleXY (rad)	AngleZ (rad)
Data	5.0000	3.0000	0.7854	0.9273
Model	5.0400	3.0162	0.7886	0.9292
Precision	99.20%	99.46%	99.59%	99.80%

3.2. Experiments on real MLS data

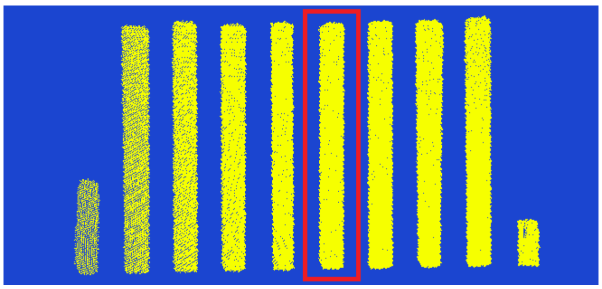
The real MLS data used for experiments were collected by the same RIEGL VMX-450 system as in [7]. As shown in Fig. 5, we first extracted the zebra crossings from the raw data, and then utilized a geometric model fitting approach to reconstruct 3D zebra crossing models, the results clearly indicate that our method is effectively in reconstructing zebra crossings. Especially, our method is better than [6] because our method can obtain the slope of the zebra crossing (i.e. AngleZ). For example, the geometric information of the zebra crossing in the red frame in Fig. 5(b) is shown in Table 3.

Table 3. The geometric information

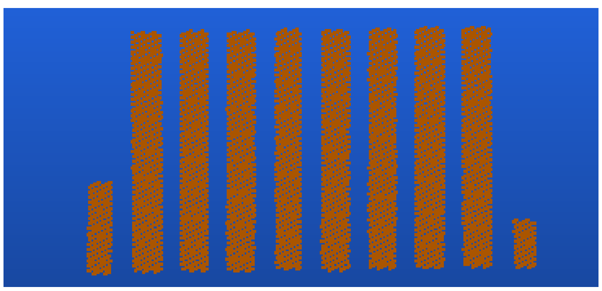
Length(m)	Width(m)	AngleXY(rad)	AngleZ(rad)
5.0000	0.5290	1.1370	0.0439



(a) raw data



(b) extraction of zebra crossings



(c) reconstruction of zebra crossings

Fig. 5. Experiments on real MLS data

4. CONCLUSION

In this paper, we have presented a novel method for reconstructing 3D zebra crossings from MLS point clouds, which is required by many applications such as digital mapping, autonomous driving, and urban planning. The proposed algorithm acquires the geometric information of the zebra crossings using the geometric model fitting method. The experimental results from a set of mobile LiDAR point-clouds demonstrated the efficiency and feasibility of our research. However, only single zebra crossing can be fitted at one time when performing the algorithm, we will improve it during the future work.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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