A Novel Approach to Extracting Street Lamps from Vehicle-borne Laser Data

Yujie Hu[1], Xiang Li[1]*, Jun Xie[2]
[1]Key Laboratory of Geographical Information Science,
East China Normal University, Shanghai, China
[2]Department of Geography, Liaoning Normal University, Daliang, China
*Corresponding author, e-mail: xli@geo.ecnu.edu.cn

Abstract—**The role of laser scanning technology in data collection and virtual environment modeling has been long recognized, especially for vehicle-borne laser scanning system (VBLS) which consists of a vehicle equipped with laser range scanners, CCD cameras and positioning devices. Up to now, most researches on vehicle-borne laser data are focused on the extractions of buildings, trees, etc., in correspondence with that on airborne LiDAR data. In this paper, instead, extraction of street lamps becomes our objective and a novel approach is proposed to fulfill it. An experiment is conducted to validate the proposed approach. Comparing with the images collected by the VBLS and real scenario observed from field work, the result indicates that the proposed approach is valid for extracting street lamps in terms of the accuracy of positioning and modeling ground targets.**

Keywords-vehicle-borne laser scanning (VBLS); street lamps extraction; density of projected points (DoPP); distance data; Geographic Information System (GIS)

I. INTRODUCTION

With the development of laser scanning technology, reconstructing virtual environment has become technically feasible. According to the type of mounting platform, laser scanning technology can be divided into airborne laser scanning and ground-based one [1]. Due to the high accuracy and acquisition speed, airborne laser scanning, e.g. airborne LiDAR system, is widely used in constructing DEM (Digital Elevation Model) and DSM (Digital Surface Model) and creating virtual cities [2, 3]. As for ground-based laser scanning technology, a moving style of the platform divides it into stationary system and moving-platform one, e.g. vehicle-borne laser scanning system (VBLS). Normally, aerial scanning can cover a broad area but fail to capture details of urban objects, only with top layer information of ground targets collected. Similarly, there is a drawback of stationary system that planning for location and direction of viewpoints in data acquisition is limited to the scenes measured. Considering these above reasons, a VBLS, consequently, becomes increasingly important in data collection and virtual environment modeling [4, 5].

The vehicle-borne mobile mapping technology has been developed around late 80's [6, 7]. With the development of automobile navigation system and geographical information system (GIS), the development of vehicle-borne mobile mapping system becomes possible. Generally, the VBLS combines laser range scanners, high resolution video cameras, Global Positioning System (GPS) and Inertial Navigation System (INS) instrumentation to capture real scene and to measure its positions and orientation information [8].

In comparison with airborne LiDAR system, the VBLS acquires information on ground. Accordingly, rather than the top layer information of ground targets, distance data between laser scanners and ground targets are collected. Up to now, most researches on vehicle-borne laser data are focused on the extractions of buildings, trees, etc., in correspondence with that on airborne LiDAR data [9-14].

As the distance data are quite large, the processing of these data, consequently, is time-consuming. Thus, some sort of automatic and time-saving processing methods are required accordingly. Typically, a regular processing method can be carried out as follows. First, calculate coordinate information of these data in accordance with GPS records. Second, grade the height attributes of each record calculated in the first step into low- and high-height data according to a threshold. On the basis of these above procedures, the ground surface and ground targets can be distinguished.

In this paper, a VBLS has been employed to collect information on ground. Different from extracting buildings, trees, etc., we, instead, concentrate on the extraction of street lamps which are parts of a road network. Accordingly, a novel approach is proposed to achieve the goal.

The following of the paper is organized as follows. Section 2 presents the proposed approach. Section 3 introduces the configuration of our VBLS. Section 4 describes an experiment and shows the discussions. Section 5 concludes the paper.

II. THE PROPOSED EXTRACTION METHOD

As mentioned in Section 1, the VBLS consists of a vehicle equipped with laser range scanners, CCD cameras and positioning devices. Consequently, its output data involve distance points which describe distance information from laser scanners to ground targets, imaging data and positioning records. In this paper, based on positioning records, distance data are converted into 3D coordinates in order to achieve the goal conveniently.

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On the basis of the output data, the first step of the proposed method is to find the nearest shooting position of each image record. Then, distances between each laser point and each imaging position will be calculated to discard laser points which are definitely beyond a distance threshold from the shooting position. Thus, the range of study area will be undoubtedly narrowed down. Since each image record has initially a corresponding imaging time measured by the VBLS, the nearest imaging position can be extracted from positioning records on the basis of time.

Second, distances between each laser point and each imaging position will be measured. The relative angle of every two continuous imaging positions can be gained as the positioning data are recorded in a projected coordinate system. Therefore, the moving direction can be derived through the relative angle between a current imaging position and the next one. Thus, the left and right regions of the VBLS can be delineated. A program is designed to search and delete all the laser points beyond a distance threshold from each imaging position. As a vehicle is dictated to move on one side of the road (we take the rule of keeping to the right as an example), the threshold, consequently, differs between the left and right regions of the vehicle positions, as shown in Fig. 1. Accordingly, buildings, trees and other ground targets which are far away from the road are deleted. So the data volume is lessened substantially, with a region of mostly the road left.

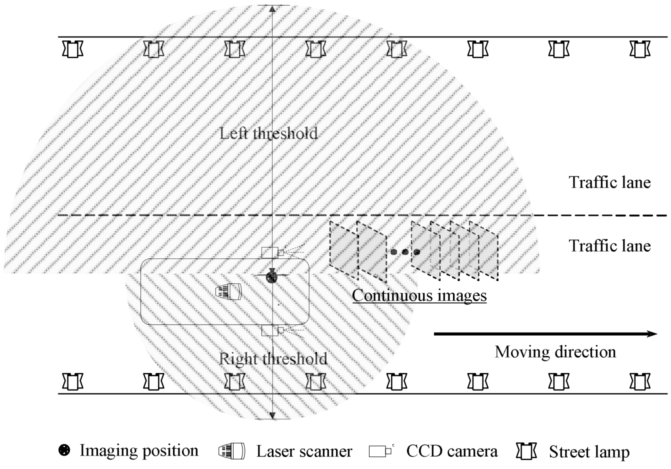

Figure 1. Principle of deleting data based on distance thresholds

Subsequently, a conventional method, namely Density of Projected Points (DoPP), is carried out to fulfill the extraction. With respect to extractions of buildings and trees, the DoPP method is usually employed at the very beginning [15, 16]. Differently, prior to implementing the DoPP method, the proposed method initially searches and deletes all the laser points which are beyond the distance thresholds according to the spatial distribution pattern of street lamps. Thus, the amount of grid cells constructed with this method and its corresponding computational time can be considerably reduced. After gridding process, the maximum height of each grid cell is subsequently calculated, and a height threshold is then set up based on the height data to classify the laser points into two types, i.e. a combination of ground surface and low ground targets, and high ground targets. As trees may not be planted on the road surface in universal urban transportation planning, the laser data, after executing the previous step, are the data of road surface and some ground targets located on both sides of the road, e.g. street lamps, dustbins and traffic signs. Finally, the data whose height values are within the settled height threshold, say, road surface, traffic signs and dustbins, will be deleted. Therefore, the data left are entirely street lamps. Fig. 2 represents the procedures above.

III. CONFIGURATION OF OUR VBLS

The system shown in Fig. 3 represents our VBLS. It consists of two laser scanners, two CCD cameras, a GPS receiver, an inertial navigation system and other sensors, as shown in Fig. 4.

A. The GPS/INS Integration

This module consists of GPS, INS and Odometer, as shown in Fig. 4(a). The GPS measures positions of vehicle via receiving satellite signals. The INS records the velocity and direction variation with high accuracy as the accelerometer biases and gyroscope rotation alter with time. However, on one hand satellite signals may be severely blocked by some ground targets, e.g. bridges, flyovers, tunnels and forests. Consequently, GPS receiver will be out of action when the vehicle is moving at these above places. On the other hand, a drift phenomenon of the velocity and direction collected by the INS will emerge while the vehicle is moving, and the drift extent belongs with moving speed of the vehicle. Nevertheless, the GPS/INS integration can solve these problems by complementing each other as velocity and direction variations are used to interpolate vehicle positions throughout the period when an outage occurs with the GPS receiver, and the GPS records are employed to rectify the drift phenomenon of INS [17]. In our VBLS, the fusion of data from the GPS receiver and INS provides location points of trajectories with an accuracy of less than 0.1m and a frequency of 200Hz.

B. Laser Scanner

Two laser scanners, as shown in Fig. 4(b), having a 180° field of view with a resolution of 1°, a range of 80 meters and an accuracy of ±15 millimeters, are mounted on top of our VBLS. Both scanners face the same side forward, however, one scanner heads upward while the other downward, as shown in Fig. 5.

C. CCD Camera

Similarly, our VBLS comprises two CCD cameras mounted on top of it, as shown in Fig. 4(c). One is focused on left region ahead of the vehicle, while the other, correspondingly, right region. Both them have a resolution of 1392 * 1040 pixels with a shooting rate of 1 frame/sec. Along with shooting images, the corresponding imaging time is recorded by the system simultaneously. Fig. 5 illustrates the configuration and data acquisition manner of our VBLS in top view.

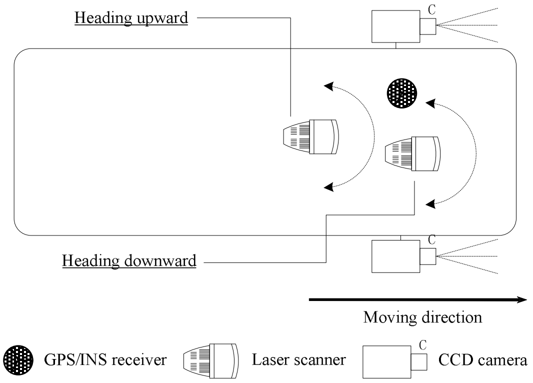

Figure 2. Data acquisition manner of our VBLS

IV. EXPERIMENT

A. Study Area

An experiment is conducted to validate the proposed approach with our VBLS. A series of distance points, imaging data and positioning records are collected in Chongming district in Shanghai.

With this vehicle, we have collected a trajectory of 60KM for 2 hours, with 26854 GPS records received, 1505357 INS records measured, and 13849 images shot by each camera. Based on GPS and INS data, 1486062 records have been generated by data fusion process. Fig. 6 illustrates the trajectories in the road network of Chongming.

The moving speed is less than 30 KM/Hour limited by the traffic conditions and relevant traffic ordinances of Chongming district. While the vehicle moves forward, two laser range scanners do upward and downward profiling, respectively, with totally 54.89 million distance points collected.

B. Data Preparation

All these devices are synchronized with each other, when the vehicle moves along a road. Therefore, GPS/INS records, images and distance points can be matched together. With respect to distance points, a transformation and geo-referencing process is required in order to carry on further executions conveniently. Thus, 54.89 million distance points are converted into geo-referenced data with x, y and z coordinates on the basis of distance points and GPS/INS records. Fig. 7 illustrates the above data preparation procedure.

C. Applications of the Proposed Method

As mentioned in Section 2, imaging data which initially consist of images and corresponding shooting time are updated to a series of data consisting of images and corresponding imaging positions, according to the time of GPS and image records. As the location points of trajectories calculated after integration process has an accuracy of less than 0.1m and a frequency of 200Hz, the error of shooting positions between real and calculated ones will be correspondingly insignificant. If the VBLS is moving, for example, at a speed of 36 KM/Hour, the maximum error between the real imaging position and the calculated one is merely 0.05 meter.

TABLE I. TABLE TYPE STYLES

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Since the amount of entire laser data is significantly large, we have randomly selected a range of laser points, with an amount of 286821, to execute the proposed method. Fig. 8 represents laser points of the selected area.

Next, based on field work, we set two distance thresholds to implement deletion of laser points, with left region 6.5 m and right region 8 m. The laser points beyond the corresponding distance thresholds from each imaging position are then cut out, accounting for 77% of the amount of the selected laser points, as shown in Fig. 9. As for the left ones depicted in Fig. 10, a method named DoPP is sequentially carried out. Considering the actual size of a street lamp, a cell size of 0.2 m*0.2m is then selected to create grids, and Fig. 11 illustrates the procedure. Several attempts considering the universal height of a street lamp and the DEM of our study area are then made, and the critical value of z coordinate is eventually assigned 40.5, which means that in each grid cell, if the maximum value of z coordinate is above the critical value, laser points in this grid cell are accordingly considered to represent street lamps, and otherwise, laser points should be deleted as they may describe the road surface or traffic signs, etc.. As shown in Fig. 12, an extraction result of 2849 records is finally filtered from 68659 records which are within the distance thresholds in the aforesaid deleting process.

In order to validate the proposed method, we first add the extracted laser points in a geo-referenced road network. As shown in Fig. 13, they distribute along both sides of the road. Then, we make comparisons of the extraction result with the images collected by our VBLS and real scenario observed from field work. The result indicates that the proposed approach is valid for extracting street lamps in terms of the accuracy of positioning and modeling ground targets.

V. CONCLUSIONS

In this paper, we have proposed a method to extract street lamps from laser points captured by the vehicle-borne laser scanning system (VBLS) which consists of a vehicle equipped with laser range scanners, CCD cameras and positioning devices. While the vehicle moves forward along the road, positioning data, velocity and direction variation of the VBLS, real scene images and laser points of ground targets around the vehicle are collected. With respect to characteristics of these data, relevant programs, e.g. integrating GPS with INS data, georeferencing distance data collected by laser scanners and calculating imaging positions based on their shooting time, are correspondingly employed. We, then, delete an amount of laser points with distance thresholds which differ between left and right regions of the vehicle positions. With laser points substantially lessened, the computational time consequently becomes less. Next, we employ a DoPP method to achieve the goal. Through conducting an experiment in Chongming district in Shanghai, we draw the conclusion that the proposed method is valid for extracting street lamps in terms of the accuracy of positioning and modeling ground targets. However, the proposed method performs not so well as in this paper while trees, utility poles, etc. have similar spatial distribution and configuration patterns, say, almost the same locations and height values with street lamps along roads. This will be our future step.

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REFERENCES

[1] I. Abuhadrous, S. Ammoun, F. Nashashibi, F. Goulette, and C. Laurgeau, "Digitizing and 3D modeling of urban environments and roads using vehicle-borne laser scanner system," Proc. IEEE/RSJ Int. Conf. Intelligent Robots and Systems, pp. 76-81, 2004.

[2] S.K. Lodha, E.J. Kreps, D.P. Helmbold, and D. Fitzpatrick, "Aerial LiDAR Data Classification Using Support Vector Machines (SVM)," Proc. IEEE Symp. 3D Data Processing, Visualization, and Transmission, IEEE Press, 2006, pp. 567-574, doi: 10.1109/3DPVT.2006.23.

[3] X. Huang, H. LI, X. Wang, and F. Zhang, "Filter algorithms of airborne LiDAR data: review and prospects," Acta Geodaetica et Cartographica Sinica, vol. 38(5), 2009, pp. 466-469.

[4] H. Zhao and R. Shibasaki, "Reconstructing a textured CAD model of an urban environment using vehicle-borne laser range scanners and line cameras," Machine Vision and Applications, vol. 14(1), 2003, pp. 35-41.

[5] H. Zhao and R. Shibasaki, "A vehicle-borne urban 3-D acquisition system using single-row laser range scanners," IEEE Trans. Systems, Man, and Cybernetics, Part B: Cybernetics, vol. 33(4), pp. 658-666, 2003.

[6] M. Dinesh and S. Ryosuke, "Auto-extraction of urban features from vehicle-borne laser data," Symposium on Geospatial Theory, Processing and Applications, Ottawa, 2002.

[7] B. Grinstead, A. Koschan, D. Page, A. Gribok, and M.A. Abidi, "Vehicle-borne scanning for detailed 3D terrain model generation," SAE 2005 Transactions Journal of Commercial Vehicles, 2005, pp. 196-204.

[8] T. Ou, X. Geng, and B. Yang, "Application of vehicle-borne data acquisition system to power line detection," Journal of Geodesy and Geodynamics, vol. 29(2), 2009, pp. 149-151.

[9] X. Lu and L. Huang, "Grid method on building information extraction using laser scanning data," Geomatics and Information Science of Wuhan University, vol. 32(10), 2007, pp. 852-855.

[10] B. Li, Z. Fang, and J. Ren, "Extraction of building's feature from laser scanning data," Geomatics and Information Science of Wuhan University, vol. 28(1), 2003, pp. 65-70.

[11] D. Manandhar and R. Shibasaki, "Vehicle-borne laser mapping system (VLMS) for 3-D GIS," Proc. IEEE Symp. Geoscience and Remote Sensing, IEEE Press, 2001, pp. 2073-2075, doi: 10.1109/IGARSS.2001.977907.

[12] C. Früh and A. Zakhor, "An automated method for large-scale, ground-based city model acquisition," International Journal of Computer Vision, vol. 60(1), 2004, pp. 5-24.

[13] H. Zhao and R. Shibasaki, "Reconstructing urban 3D model using vehicle-borne laser range scanners," Proc. IEEE Conf. 3-D Digital Imaging and Modeling, pp. 349-356, 2001.

[14] C. Früh and A. Zakhor, "Constructing 3D city models by merging aerial and ground views," Computer Graphics and Applications, vol. 23(6), 2003, pp. 52-61.

[15] B. Yang, Z. Wei, Q. Li, and Q. Mao, "A classification-oriented method of feature image generation for vehicle-borne laser scanning point clouds," Acta Geodaetica et Cartographica Sinica, vol. 39(5), 2010, pp. 540-545.

[16] W. Shi, B. Li, and Q. Li, "A method for segmentation of range image captured by vehicle-borne laserscanning based on the density of projected points," Acta Geodaetica et Cartographica Sinica, vol. 34(2), 2005, pp. 95-100.

[17] H. Zhao and R. Shibasaki, "Updating a digital geographic database using vehicle-borne laser scanners and line cameras," Photogrammetric Engineering & Remote Sensing, vol. 71(4), 2005, pp. 415-424.