A Graph Based Registration Method for UAV LiDAR Data and Sequent Images

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ABSTRACT:

Earth observation sensors are moving toward to the way of miniaturization, flexibility, and integration. Simultaneously, the Unmanned Aerial Vehicles (UAV) is becoming a flexible, cheap, and popular platform, which is widely used for emergency response, hazard mapping, and island mapping. However, the limited pay load of the UAV often lead to trade-off between weight and accuracy which will arise the problem of heterogeneous data registration. In this paper, we present a graph based registration method to solve the registration of LiDAR data and sequent images collected by UAV remote sensing platform. Firstly, Multi-view stereo (MVS) point cloud is generated from the image sequence and the building objects are extracted from the MVS and LiDAR point cloud. Secondly, the extracted building objects are taken as graph node to construct graphs and later matched via minimizing graph edit distance (GED). The matched graph node is used to calculate an initial registration between the MVS and LIDAR point cloud. Finally, the initial registration is refined by an iterative nearest point (ICP) algorithm. Experiment is carried out to validate the proposed method and the registration accuracy is evaluated. The results show that the proposed method achieves pixel grade registration accuracy.

1. INTRODUCTION

Unmanned Aerial Vehicles (UAV) is becoming a popular platform to provide flexible and rapid earth observation with integrated miniaturized and light weighted multi-sensors (Nex and Remondino, 2014). UAV based platforms have a range of merits including, low-costs, flexibility, and efficiencies when compared with satellite and airborne earth observation platforms. Thus, UAV based platform is attracting wide attention in hazard mapping, emergency response, and environmental remote sensing and mapping (Jaakkola et al., 2010; Lin et al., 2011; Nagai et al., 2009; Wallace et al., 2012).

Aerial photogrammetry and light detection ranging (LiDAR) systems has unique features. Using both systems to gather the earth observation data for certain applications simultaneously is preferred. Fusing ALS data and imagery captured by satellites or manned vehicles for object classification, change detection et al. has been extensive studied (Awrangjeb et al., 2013; Barnea and Filin, 2013; Gerke and Xiao, 2014; Qin and Gruen, 2014; Rottensteiner and Briese, 2003). The registration between LiDAR data and optical imagery is the first step towards the fusing application. The study of registration between LiDAR data and imagery captured form manned vehicles has been carried out in the last decade (e.g. (Habib et al., 2005; Mastin et al., 2009; Parmehr et al., 2014)).

The existing registration methods for satellites or manned vehicles LiDAR and image data can generally be divided into two categories: area based and feature based (Palenichka and Zaremba, 2010). Area based registration methods retrieve the alignment between image and LiDAR data by maximising / minimising statistical measure (e.g., mutual information) of corresponding regions (Mastin et al., 2009; Parmehr et al., 2014). Feature based methods accomplish the registration task by extracting and matching conducted geometric features from the imagery and LiDAR data (Habib et al., 2005; Liu and Stamos, 2012; Mitishita et al., 2008; Stamos et al., 2007; Zhao et al., 2005).

However, registration of ALS data and imagery captured by UAVs has been paid less attention. Due to the trade-off between accuracy and weight of the sensors on-board the UAV platform, direct geo-referencing or existing registration methods for ALS data and imagery captured by satellites or manned vehicles may result in failure.

This paper thus proposes a robust graph based method to register LiDAR data and imagery captured by UAVs.

Following the short introduction, the key components of the proposed graph based registration method is briefly introduced in Section 2. Before conclusions are drawn at the end of this paper, experimental studies of registering LiDAR data and imagery captured by UAV are presented in Section 3. Finally, a short conclusion and outlook are described in Sections 4.

2. Method and Innovations

The proposed method consists of three key steps: Firstly, 3D dense points were generated from sequent images by the

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multi-view stereo (MVS) method after estimate the exterior orientation parameters (EoPs) of each image in photogrammetric coordinate system utilising structure from motion (SfM) techniques. Secondly, the proposed method extracts building objects from laser scanning points and photogrammetric MVS points to construct two building graph. Thirdly, the two building graphs are matched by minimising the graph edit distance (GED) of the two graph to establish an initial alignment between the imagery and LiDAR point cloud. Using solved initial alignment the EoPs of each image are further refined by registering LiDAR points and the 3D MVS points with an iterative nearest point (ICP) algorithm.

Compared with the previous methods, the proposed method accomplish the registration utilizing the internal pattern of the sense, thus, no direct geo-referencing data is strictly required. Meanwhile, using the graph based registration as initials, overcome the short coming of the 3D-3D ICP registration method for images and LiDAR data originally proposed by Zhao et al. (2005).

3. Experimental studies and analysis

Experiment is undertaken to validate the accuracy and effectiveness of proposed graph-based registration method. The dataset used for the experiment is collected by HeliMapper UAV LiDAR system (Figure 1) at Huangling, Wuhan, China (Figure 2). Within the surveying area, most typical ground features such as building, trees, rivers, and roads can be found. The maximum elevation difference of this area is about 20 meter.

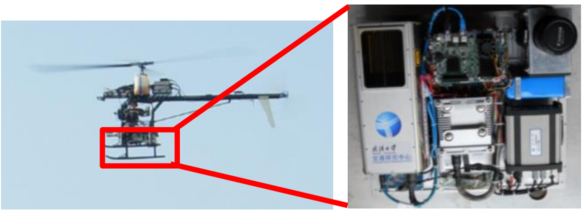
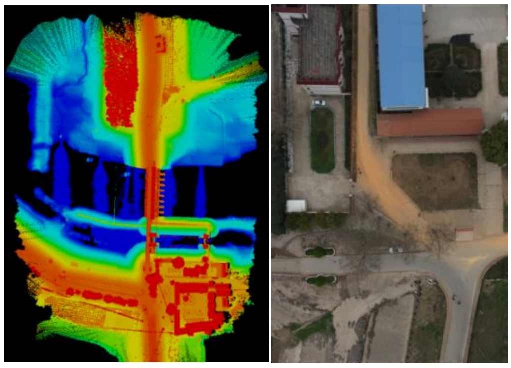


Figure 1. HeliMapper: a rotor wing mini-UAV with a laser scanner, POS, and a digital camera

Figure 2 Surveying location



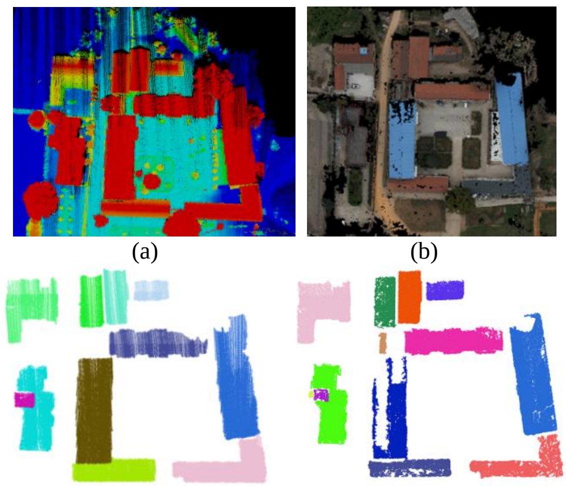
(a)Laser points (b) A sample image

Figure 3. Data collection by the UAV system

Table 1. Dataset description.

Specification	Description
Flight altitude (m)	80
Point density (pts/m2)	25.4
Resolution of image (cm)	2.1
The number of images	78
The number of LiDAR points(pts)	6,506,721
Area (km2)	0.26

The UAV system carrying a laser scanner and a CCD camera flied at about 90 meters above ground. The specific dataset description is listed in table 1. ALS laser points and one sample of the captured sequent image are illustrated by Figure 3. The MVS dense points of the building region is presented in Figure 4-b. As depicted by the figure, some parts of the building point cloud is missing because of the occlusion and match error occurs when there is no or repetitive texture on the roof which will increase the difficulty of matching the graphs. Once the building object point cloud are extracted (Figure 4-c and 4-d), the graphs are generated to summarized the spatial relationship of the buildings (Figure 4-e and 4-f). Figure 5 illustrated the graph match result with a minimum GED value of 0.21. In spite of false detected or incomplete building segments, the GED based matching method still find the correct optimal node matches. The registration result of MVS and ALS point cloud using ICP with the initial transformation solved via graph is described by figure 6



(a) (b)

(c) (d)

(e) (f)

Figure 4. Graph generating form the building point cloud segmented from ALS point cloud (left row) and MVS points cloud (right row)

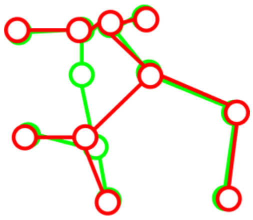


Figure 5. Best matched graphs. GED = 0.21.

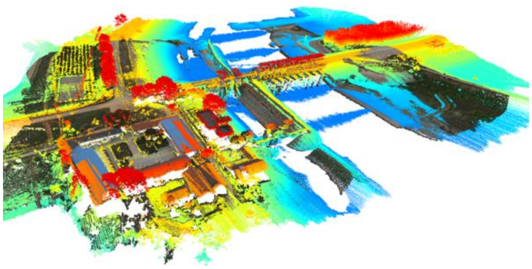


Figure 6. MVS point cloud (rendered with true color) and LiDAR point cloud (rendered with false color)after ICP alignment

To quantify the accuracy of the proposed method, high reflectance artificial targets were mounted in the surveying site before the data collection The final registration accuracy is listed in table 2.

Table 2. Registration errors of test dataset (in pixels).

	Max error	Min error	Average error	RMSE
Registration result	1.923	0.132	0.919	0.627

Figure 7 and figure 8 depicts the colored ALS point cloud and a true orthoimage generated from the registered dataset.

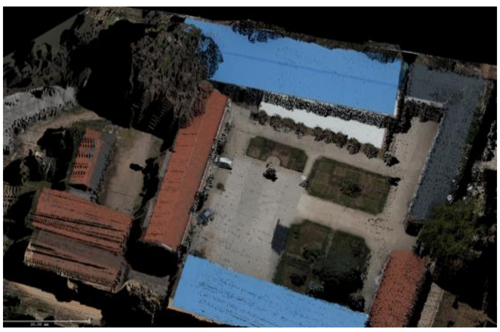
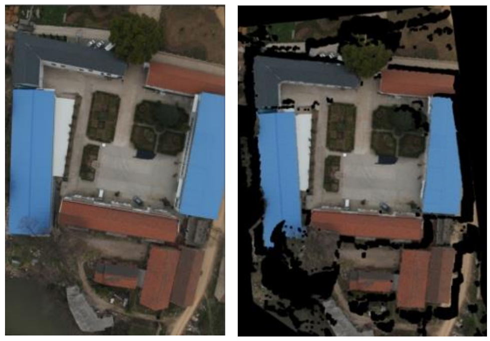


Figure 7. Colored ALS data with the registered images: building detail



(a) (b)

Figure 8. True orthoimage generated with the registered data (b) and its original image

4. Conclusions

We propose a graph based registration method for automatic registering of ALS point cloud and sequent images captured by UAV borne remote sensing platform. We have shown results from initial experiments to illustrate the proposed method by using the dataset collected by a rotor wing UAV: HeliMapper. The registration accuracy reaches pixel level. As next steps, we would like to improve the propose GED cost function by adding node properties difference metric to increase the robustness of the graph matching procedure.

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