PHOTOGRAMMETRIC MODEL ORIENTATION USING LIDAR DATASET

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ABSTRACT:

Today the LIDAR dataset is a powerful alternative to be applied in the optimization of photogrammetric mapping techniques. The complementary nature of LIDAR and photogrammetry allows for the optimal performance of many applications to extract 3D spatial information. For example, photogrammetry image permits accurate borders building extraction. In addition, LIDAR provides a number of accurate 3D points that describe some information about physical building surfaces. These properties show the possibility of combining data from both sensors to arrive at a more robust and complete reconstruction of 3D objects in many applications such as monoplotting, orthophoto generation, surface reconstruction, etc. Photogrammetric procedures need the exterior parameters of images (EOP) for extracting mapping information. Despite of the availability of GPS/INS systems, which greatly assist in direct geo-referencing of the acquired imagery, the majority of commercial available photogrammetric system needs control information to perform photogrammetric mapping techniques. Regarding the accuracy improvement of LIDAR systems in the recent years, LIDAR data is considered a viable supply of photogrammetric control. This paper presents a methodology for using the centroids of building roof as control points in photogrammetric model orientation. The centroid is equivalent to a single control point with 3D coordinates allowing its use in traditional photogrammetric systems. In the experiments performed, the obtained results confirmed the feasibility of the proposed methodology to be applied in geo-referencing of photogrammetric images using LIDAR dataset.

1.   INTRODUCTION

Airborne laser scanning is a powerful automated process used for acquisition of topographic data. The combination of LIDAR and digital image provides complementary properties in many applications. The LIDAR data provides high density of points, but it does not directly capture features like break lines, roof ridges or border of buildings. On the other side, Photogrammetry provides image information about the objects that, in principle, allows capturing of breaklines or linear and spatial objects (Ackermann, 1999). The complementary properties of both datasets have been widely recognized. New developments and new solutions were presented in many researches in the world (see Ackermann, 1999; Axelsson, 1999; Baltsavias, 1999; Vosselman, 1999; Habib and Schenk, 1999; Schenk et al., 2001; McIntosh and Krupnik, 2002; Habib et al., 2005b, Delara et al., 2004).

The precision of any photogrammetric 3D data depends on the quality of interior orientation parameters (IOP), exterior orientation parameters of images (EOPs) and on the methods of generating it. Two alternatives have been used to obtain the position and orientation of images in photogrammetric techniques. The direct geo-referencing way uses GPS/INS systems to determine the exterior parameters of each image in real time during the flight mission. The indirect geo-referencing way uses ground control points or features and photogrammetric methods to estimate the exterior parameters such as phototriangulation or single photo resection (see Mikhail et al., 2001).

The accuracy improvement of LIDAR systems in recent years has allowed the use of LIDAR data as a source of photogrammetric control (Habib et al., 2005b). The majority of photogrammetric procedures have used point primitives to estimate the exterior orientation parameters. To locate a single point in an image that corresponds to one particular laser footprint in the LIDAR dataset is very difficult or impossible (Baltsavias, 1999). Procedures to realize registration of image and LIDAR data that use interpolate both datasets into a regular grid have been used (see Ebner and Ohlhof, 1994). Postolov et al. (1999) show a procedure to realize registration with conjugate points but a particular form of interpolation is necessary to determine these points. Habib et al., (2005a) show the methodologies for the registration of photogrammetric and lidar data using three-dimensional straight-line features.

This paper presents a methodology for the photogrammetric model orientation using centroids of building roofs that are derived from LIDAR datasets. The principal advantage for the use of centroid is related with its easy utilization in traditional photogrammetric system because centroid is equivalent to a single control point.

The following section presents the methodology for extracting the centroid of the building roof using LIDAR datasets and

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photogrammetric imagery. The last two sections cover results obtained in the performed experiments, as well as, conclusions and recommendations for future work are showed.

2. METHODOLOGY FOR EXTRACTING THE CENTROID OF BUILDING ROOF USING LIDAR AND PHOTOGRAMMETRIC DATASETS

A laser scanning dataset can be characterized as sub-random distributed 3D point clouds and it is not capable of any direct pointing to particular objects or object features. The resulting coordinates refer to the footprints of the laser scan as they happen (Ackermann, 1999). The sampling density is not only function of the system but also depends on the flying speed, pulse rate, scan angle, and flying height (see, Wehr, and Lohr, 1999).

Considering what was presented above, the centroid of regular building roof will be calculated using an interpolated regular grid derived from 3D LIDAR points that lie on the building roof.

In this work, building roof is the top of a separate construction. Four points in the image space define the border of roof. See Figure 1. This type of entity is generally represented by orthogonal shape (a square or rectangle) in 2D vector mapping.

Figure 1: building roof

The methodology that were implemented in this work to determine the centroid coordinates of the building roof in the ground and image spaces have four steps.

2.1 Approximate delineation

In this step, the raw laser scanned points, close to the building, are selected. First, three approximate points and their 2D coordinates are obtained using the LIDAR intensity image. Two points define the approximate dimension of the building roof and other one defines the building orientation.

A polygon around the building is calculated and it is used to extract the raw laser scanned points close to the building. Figure 2 shows an example of the raw LIDAR points selected using this methodology.
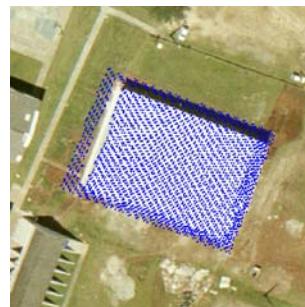

Figure 2: Raw LIDAR points

2.2 Regular grid Interpolation

In this step, the LIDAR points selected in Step 1 are interpolated onto a regular grid overlaid on the building roof and points that lie only on the roof are selected. The regular grid is used to define the borders of the building roof. First, the coordinates of the four points that define the limits of the region to be interpolated will be determined. The X and Y coordinates of each point along each interpolated profile of the regular grid are calculated using simple trigonometric equations, and the Z coordinates are determined using nearest neighbouring interpolation. After that, the points that lie only on the roof are selected by a simple test that uses the heights of the points in the vicinity of the building. An interpolated profile of the regular grid is accepted if more than 60% of its points lie on the roof. This test is necessary in order to avoid the false identification of roof points close to the roof borders due to neighbouring interpolation procedure. Figure 3 shows an example of interpolated LIDAR points on the roof that were selected using this methodology.

Figure 3: Interpolated LIDAR points on the roof

2.3 LIDAR centroid computation

In the third step, the 3D coordinates of the centroid of the rectangular building roof in the LIDAR reference frame are determined. First, using all interpolated profiles selected in the Step 2, the X and Y coordinates of the centroid are determined by the mean of 2D coordinates of all interpolated points on the roof. The centroid Z coordinate is determined by the mean of Z coordinates, using two interpolated profiles closest to the borders of the roof, which have almost equal Z coordinates.

2.4 Image centroid computation

In this final step, the 2D coordinates of the centroid in the image data are calculated. The corners of the building roof define four points, as shown in Figure 1. The 2D coordinates of the centroid in the image frame are determined by calculating

the intersection of two diagonal straight lines that are defined by points A_2, A_4 and A_1, A_3.

More details about LIDAR and image centroid determination are explained in Mitishita et al., 2008.

3. EXPERIMENTS AND RESULTS

To verify the viability of using the centroid of building roofs as control poinst for the photogrammetric model orientation using LIDAR dataset, a typical photogrammetric experiment was carried out. Thirty-six pre-signalized points and twenty-eight centroid points were determined. These points were used to perform the experiment proposed and verify the accuracy of the results.

Figure 4: Type of pre-signalized control points and a typical centroid point determined

3.1 Used Datasets

Table 1 summarizes the properties of the photogrammetric dataset used in this work (scanned analog images captured by a metric analog camera – Wild RC-10). The table also shows expected horizontal and vertical accuracies, considering the pixel size, image coordinate measurement accuracy, image scale, and height-base ratio. The LIDAR dataset was captured using an OPTECH ALTM 2050 laser scanner with an average flying height of 975m and mean point density of 2.24 points/m^2 (~0.7m point spacing). The range and intensity data were recorded. According to the sensor and flight specifications, 0.5m horizontal and 0.15m vertical accuracies are expected.

Camera model	RC10 Wild
Focal length (mm)	153.167
Frame size (W x H)	9" x 9"
Number of images used	3
Number of control points surveyed	36
Number of centroid points determined	28
Avg. flying height (m)	1375
Avg. base (m)	700
Pixel size (mm)	0.024
Expected image measurement accuracy (mm)	± 0.024
Expected photogrammetric procedure accuracy (assuming one pixel measurement error)	
planimetric (m)	0.21
vertical (m)	0.60

Table 1: Specifications of the photogrammetric dataset

3.2 Photogrammetric model orientation

Three photogrammetric images were used in this experiment. The central image covers the campus of the Federal University of Paraná - Brazil and part of a residential suburb. Thirty-six pre-signalized points and twenty-eight centroids of regular building roofs were used as photogrammetric points. Manual monocular measurements were done to define centroids and

pre-signalized points in the images. Twenty-one pre-signalized points and nineteen centroid points appeared in two images and fifteen pre-signalized points and nine centroid points appeared in all images. The thirty-six pre-signalized points have 3D coordinates determined by GPS relative survey and twenty-eight centroid points have 3D LIDAR coordinates determined by the methodology proposed in this work.

First, a mathematical photogrammetric model was reconstructed using the collinearity Equation and image coordinates of measured points (see Mikhail et al., 2001). Afterwards, the similarity model was used to transform photogrammetric model coordinates to LIDAR system. The first model (photos 1 and 2) was obtained using twenty-four pre-signalized points and eighteen centroid points measured and the second model (photos 2 and 3) was obtained using twenty-five pre-signalized points and twenty-one centroid points measured. The results obtained in two photogrammetric models orientations are showed in Table 2.

	Model 1-2	Model 2-3
Maximum y parallax (mm)	0.012	0.016
RMSE in y parallax (mm)	0.002	0.003
RMSE in x coordinate (mm)	0.012	0.014
RMSE in y coordinate (mm)	0.012	0.016
RMSE in z coordinate (mm)	0.035	0.055

Table 2: The statistical analysis of the analytical model established

Using 3D coordinates of centroid points in the photogrammetric model system (x,y,z) and LIDAR system (X,Y,Z), the similarity model parameters were determined using least square adjustment (LSM), (see, Mikhail and Ackermann, 1976). Afterwards, using the similarity model, the pre-signalized points in the photogrammetric model system were transformed to LIDAR system. The LIDAR coordinates of the pre-signalized checkpoints obtained in this mathematical transformation were compared with their surveyed coordinates. The main results obtained in the LSM adjustment and checkpoints analysis are presented in Table 3, and figures 5 and 6.

The planimetric and vertical analysis from the experiment performed prove the feasibility to use centroids of building roofs as control points to perform absolute photogrammetric model orientation. The obtained results from the analytical model established prove the good stability of the image centroid as tie photogrammetric points; see Table 1. The RMSE of the vertical parallax residuals from the analytical model established was close to three microns. The model and LIDAR coordinate residuals resulted from least square adjustment of the similarity equation and their values of the RMSE confirmed the good geometric relation of the centroid of building roof in the model and ground frames, see Table 2.

The figures 5a and 6a show a small tendency for the planimetric discrepancies that were computed in pre-signalized check points analysis. The majority of planimetric discrepancies was distributed in the same quadrant. The inaccurate values of the interior orientation parameters (IOP) are probably the source of this systematic error. However, all the planimetric discrepancies are below the LIDAR horizontal accuracy (0.5m), and the planimetric and vertical accuracies are close to expected planimetric and vertical photogrammetric accuracies that are showed in table 1.

Least square adjustment - main results of the similarity 3D model						
	Model 1-2			Model 2-3		
Number of centroid points used	14			19		
RMSE – model residuals (x,y,z) (mm)	0.006	0.009	0.010	0.008	0.008	0.007
Maximum model residuals (x,y,z) (mm)	0.020	0.029	0.030	0.032	0.030	0.026
RMSE – LIDAR residuals (X,Y,Z) (m)	0.074	0.054	0.079	0.071	0.067	0.066
Maximum LIDAR residuals (X,Y,Z) (m)	0.253	0.184	0.250	0.258	0.256	0.224
Pre-signalized check points analysis						
Number of pre-signalized points used	24			25		
Mean discrepancy (X,Y,Z) (m)	0.132	0.087	-0.081	0.101	0.095	0.098
RMSE – discrepancy (X,Y,Z) (m)	0.068	0.077	0.219	0.099	0.093	0.187
Maximum discrepancy (X,Y,Z) (m)	0.255	0.228	-0.532	-0.223	0.228	0.448

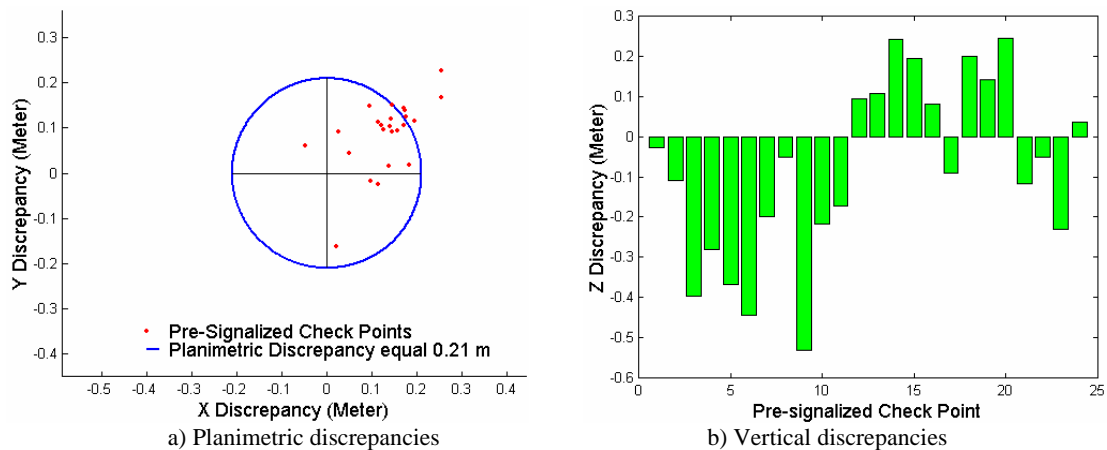Table 3: Results obtained in the LSM adjustment and check point analysis

a) Planimetric discrepancies b) Vertical discrepancies

Figure 5: Discrepancies in pre-signalized check points - **model 1-2**

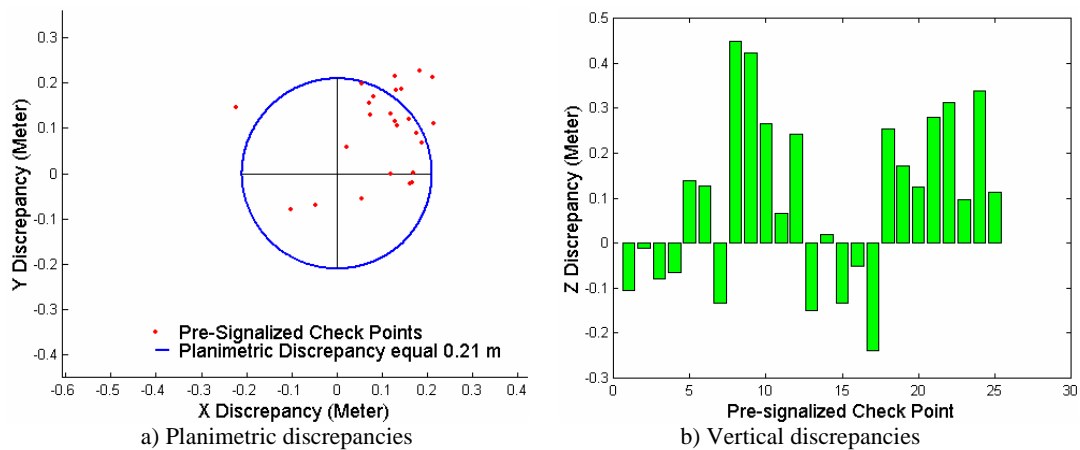a) Planimetric discrepancies b) Vertical discrepancies

Figure 6: Discrepancy in pre-signalized check points - **model 2-3**

The results obtained in this experiment demonstrate the feasibility of using the centroid of building roofs as control points in the photogrammetric model orientation.

4. CONCLUSIONS AND FUTURE WORK

This work showed the methodology to photogrammetric model orientation using centroid of the building roofs derived from LIDAR dataset. Traditional analytical absolute orientation of the photogrammetric model was performed to verify the viability of the proposed methodology. The performed experiment demonstrated the feasibility of the use centroids of building roofs as control points in photogrammetric procedure to be applied in mapping projects. Eighty percent of X and Y discrepancies from the pre-signalized check analysis were less than the expected planimetric accuracy and Z discrepancies from all pre-signalized check points were also below the vertical accuracy expected in this work. Considering the LIDAR horizontal accuracy (0.5m), all X and Y discrepancies were below this value. The planimetric and vertical centroid

coordinate accuracies that were shown in this work were determined relative to the planimetric and vertical discrepancies of the pre-signalized check points. The pre-signalized 3D coordinates were determined using GPS surveying. In this work, the methodology that was applied to determine 3D LIDAR centroid coordinates needs a separate rectangular building to work properly. Future related research would aim at the development of methodologies that will be done to develop automatic procedures to extract the 3D LIDAR and 2D image centroid coordinates of building roofs.

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