AUTOMATIC REGISTRATION BETWEEN LIDAR AND DIGITAL IMAGES

Deng Fei [a,] * , HuMinjie [b], Guan HaiYan [c]

[a]School of geodesy and geomatics ,Wuhan University. Dengf-wh@163.com;
[b]Shanghai Merchant Ship Design & Research Institute (SDARI), business@sdari.com.cn;
c School of Remote Sensing , Wuhan University

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ABSTRACT:

This paper describes an algorithm framework for registration of airborne based laser scanning data (LIDAR) and optical images by using multiple types of geometric features. The technique utilizes 2D/3D correspondences between points and lines, and it could easily be extended to general features. In generalized point photogrammetry, all lines and curves are consists of points, which could be describe in collinear equation, so it cloud represent all kinds of homogeneous features in an uniform framework. For many overlapping images in a block, the images are registered to the laser data by the hybrid block adjustment based on an integrated optimization procedure. In addition to the theoretical method , the paper presents a experimental analysis the sensitivity and robustness of this approach.

1. INTRODUCTION

In recent years, with the development of relative technology and the constant increasing of market demands, LIDAR technology, as a method of obtaining 3-dimensions space information in real time, was developed very fast. The LIDAR system has broad the source of data effectively, it can get accurate and higher-resolution digital surface model more easily. LIDAR convert the data acquisition method from the traditional mode based on forward intersection into a consistent and automatic mode. This can also make the data processing more intelligentized and automatic. The two kinds of data, laser scanning point cloud and digital optical imagery, have their own advantages and disadvantages, and they could strongly make up each other. Though LIDAR can directly get the 3-dimensions point cloud of object, it can hardly directly get the surface information of the object (such as texture and structure), while the result obtained from the imagery contains affluent semantic information. On the other side, it is difficult to obtain dense 3-dimension points directly by the automatic matching between the overlap images. As a result, it's a new direction in the field of computer vision and photogrammetry, which takes advantage LIDAR and digital image to carry on intelligent feature classification and extraction.

However, prior to such fusion, both systems should be precisely aligned to provide information on an uniform framework. But registration of such different source data sets are time consuming and error prone. Existing solutions suffer from lack of robustness and accuracy due to the fact that the majority of methods utilize only one type of geometric entity , most of them coming from the photogrammetry research community, and their frameworks do not allow simultaneous use of different types of features. The increasing volume of the collected data call for the development of efficient and reliable registration procedures.

There are apparent differences in data processing methods and arithmetic between the traditional optical remote sensing technology and laser scanning data. In order to carry through relevant operation effectively, it needs suitable data structure to organize the laser scanning data. Many solution use direct solutions using three, four or six points matches. More accurate results come from least-square resolution with a larger points set when consideration of data noise. However, such methods are not applicable to LIDAR surfaces since they correspond to laser footprints instead of distinct points that could be identified in the imagery.

2. METHODOLOGY

2.1 General description

The design purpose of our algorithm framework is it could be used to both airborne and terrestrial scenes where may be combine of multiple types of surfaces. From the same scene, two data sets have been obtained, one from laser scanner while the other from image matching. (as in Fig1)

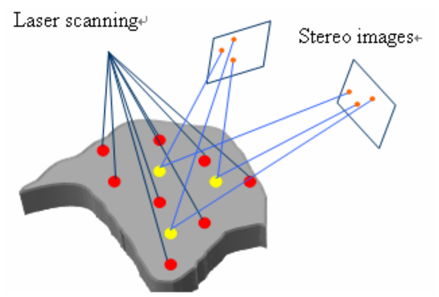

Fig 1: registration between laser scanning and matching points

*Corresponding author

Matching point set **:X**={ x_i , *i=1, 2 ,…, m*}

Laser point set **:Y**={ y_i , *i=1, 2,…, n*)

We assume that the camera was calibrated previously. A relative camera motion could be determined from the matched points. By several coarse selected tie points from laser scanning points and images, a initial 3D similarity transform T_0 could be estimated, which determined the initial two camera positions S_1, S_2 , two rotation matrix R_1, R_2 ,and the matching points coordinate X^0.

From the registration algorithm describe in the following section, we could got a refined transform $T(\lambda, R, t)$,which aligned the transformed matching points $X' = T(X)$ best to the laser scanning point cloud. So, the final camera parameter could be represent as:

$$S_1' = \lambda \cdot RS_1 + t \;\; ; \;\; R_1' = R \cdot R_1 \quad \text{and}$$
$$S_2' = \lambda \cdot RS_2 + t \;\; ; \;\; R_2' = R \cdot R_2$$

In principle, the use of aerial images alone for automatic classification should be difficult to separate the useful information from irrelevant details. We are dealing with a point cloud coming from airborne lasers canning system with a original density of average 6 points per square. A interpolation procedural was deal to map a non-grid (non-integer) position to integer grid in order to create a reference image in which every pixel's value is height or intensity value. Figure.1 are aerial overlap images, point clouds derived by match and laser scanning.

2.2 Features for registration

With the evolution of digital photogrammetry, there has been a tremendous motivates of using of linear features in various photogrammetric activities. The advantages of use line as registration primitive are:
1. Man-made environments are rich in straight lines.
2. Straight lines are easier to detect and the correspondence problem between overlapping images as well as between the image and object space becomes easier.
3. Straight-line parameters can be obtained with sub-pixel accuracy.
The registration method based on features were discussed in detail. The method compresses the information content of image by extracting the prominent feature, which has robust with image gray's change. On the basis of this, the dissertation raises a registration scheme based on 3D and 2D line segment extracted from LIDAR data and aerial images.

At first, we performing a standard version of Canny's edge detector. Though sub-pixel interpolation of the final edge output has been included, and there is patching of single pixel gaps in the edgel chains. Then we get a list of broken lines from the previous detected edges. After Reject edges which are too bent , a least-squares method was used to fitting of straight lines to point sets. At this step we project the endpoints of the edge onto the fitted line, so get the straight line. A Least square line template matching method was used to get the sub-pixel precision of detected line. The above procedure was done in both Lidar elevation image and images taken from digital camera. The Z value of the detected line in Lidar was determined by interpolation on DSM.

2.3 Corresponding feature relations

Point based co-linearity is an essential conception in photogrammetry, while point in photogrammetry means only physical or visible points. From the same object, two data sets have been obtained, one from laser scanner while the other from image matching. Our method also makes use of linear feature as observe primitives and use coplanar condition as error equations to resolve the external orientation parameter of digital image. Here, we are considering rigid body digital cameras which Interior Orientation Parameters (IOP) are known and computed independently.In order to represent all kinds of homogeneous features in an uniform framework, all lines or curves are considered consisting of points, which is expressed as generalized point form. Collinear equation could be used to linear features similar as the matched point features, so all kinds of features existing in photogrammetry can be concentrated on "point"(Figure.2.). According to this philosophy the adjustment form would be more consistent and stable.

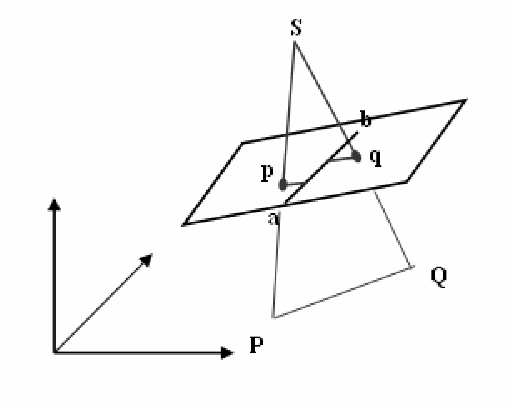

Fig.2. Corresponding linear features represented by collinear equation

This scheme use the line feature gotten from LIDAR data as control information, using initial external orientation elements to project the 3D line segment to image, then using angle and distance as metric to measure and search candidate homogeneous linear features. By using generalized point distance to establish error equation, the external orientation elements could be calculated. The collinear equation could be adopted as :

To robustly handle outliers(wrong matches),proper weights should be assigned to the matched point sets,such that matches with higher errors have less weight.M-estimators are main techniques used in computer vision on robust estimation.They are generalizations of maximum likelihood estimators and least-squares. In particular,the core of M-estimate is a robust loss function which grows subquadratically and is monotonically no-decreasing with variable increasing.

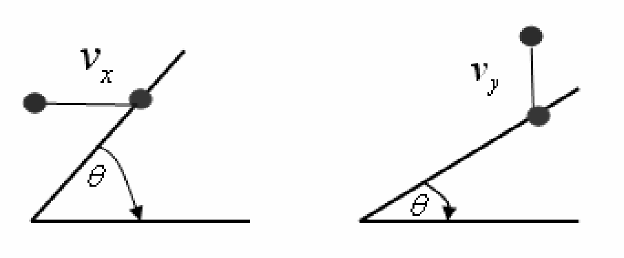

Fig.3. adopted collinear equation to represent multi-geometry features

$$\left.\begin{aligned} x-x_0 &= -f\frac{a_1(X-X_S)+b_1(Y-Y_S)+c_1(Z-Z_S)}{a_3(X-X_S)+b_3(Y-Y_S)+c_3(Z-Z_S)} & |\theta| \geq 45^0 \\ y-y_0 &= -f\frac{a_2(X-X_S)+b_2(Y-Y_S)+c_2(Z-Z_S)}{a_3(X-X_S)+b_3(Y-Y_S)+c_3(Z-Z_S)} & |\theta| \prec 45^0 \end{aligned}\right\} \quad (1)$$

$$\left.\begin{aligned} v_x &= a_{11}\Delta X_S + a_{12}\Delta Y_S + a_{13}\Delta Z_S + a_{14}\Delta\varphi + a_{15}\Delta\omega + a_{16}\Delta\kappa - l_x & |\theta| \geq 45^0 \\ v_y &= a_{21}\Delta X_S + a_{22}\Delta Y_S + a_{23}\Delta Z_S + a_{24}\Delta\varphi + a_{25}\Delta\omega + a_{26}\Delta\kappa - l_y & |\theta| \prec 45^0 \end{aligned}\right\} \quad (2)$$

where：

$$\left.\begin{aligned} l_x &= ((y)-y_a)\times(x_b-x_a)\div(y_b-y_a)+x_a-(x) \\ l_y &= ((x)-x_a)\times(y_b-y_a)\div(x_b-x_a)+y_a-(y) \end{aligned}\right\} \quad (3)$$

(x_a, y_a) and (x_b, y_b) are coordinates of vertex a and b that corresponding to lines in the optical imagery.

If there are not enough line features in the scene can be used as control information, we can use a more general registration method. This method needs to get several overlapping images of the scene (two or more). Via registration the whole points of the overlapping images to the 3-dimension surface generated by laser scanning cloud points, the correct external orientation elements of each image could be calculated. When deal with a stereo image pair, at first it needs match the homogeneous points of two images, and establish the relative position relationship of the two images. The initial external orientation elements could be achieved by Using POS data or several hand-select corresponding points（cursorily and not precisely）, forward intersection was used to get 3-dimension cloud point. While taking advantage of robust iterative closet point arithmetic, a 3d similarity transform could be calculated, then get the best registration between the 2 cloud points, one from laser scanning and the other from stereo matching. Eventually, the orientation elements of both photos could be correctly calculated. As to multi-overlapping images, it should firstly establish free net by whole matched points (the homogeneous points of two or even more images), then align the cloud point generated by multi-overlapping images and LIDAR data. Finally, each image's new orientation elements can be calculated.

3. EXPERIMENTS AND RESULTS

The experiments are address to evaluate the correctness and robustness of our approach. The Comparative analysis of the performance of linear feature RMS projected in aerial imagery. Consider that Lidar data we used has much less resolution (0.7m) than digital image's (0.08m), so the total precision was determined by the DSM. According to this, the precision in the digital image within 5 pixels will be acceptable. Figure 4 shows the LIDAR extracted linear feature projected to imagery before and after registration. Table 1 shows the Orientation Parameters and Table 2 shows RMS.

Fig.4: Project LIDAR linear feature to imagery before and after registration

	X(m)	Y(m)	Z(m)	Phi(deg)	Omega (deg)	Kappa (deg)
Before regist	636130.65	4186532.18	1139.62	2.730	4.071	0.750
After regist	636134.18	4186532.44	1139.23	2.353	3.686	0.337

Tab.1. Orientation Parameters

X (RMS)	Y (RMS)	X(Max RMS)	Y(Max RMS)
4.23	3.16	12.730	9.071

Tab.2. RMS

Registration result are shown by project the laser scanning point cloud to the aerial optical imagery. (Figure 5 and 6)

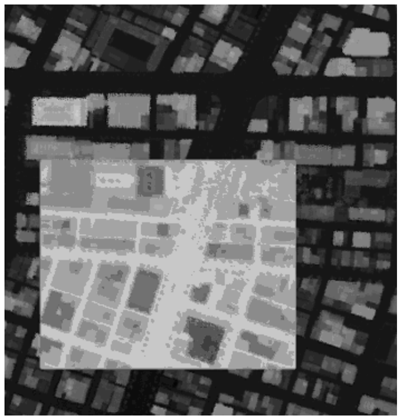

Fig.5: Combine LIDAR and optical color information

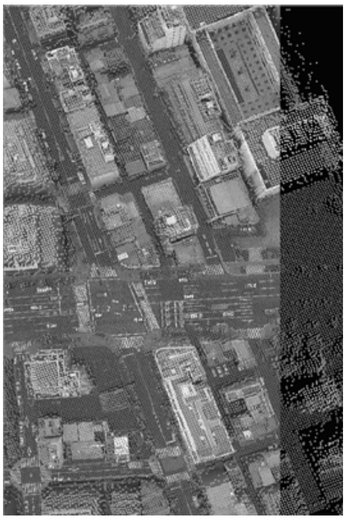

Fig.6: Registration result: project laser point cloud to optical imagery.

4 . CONCLUSIONS

This paper describes an algorithm framework for registration of airborne based laser scanning data (LIDAR) and optical images by using multiple types of geometric features. Collinear equation could be used to linear features similar as the matched point features, so all kinds of features existing in photogrammetry can be concentrated on "point". Experiments shown that this method is effective and stable.

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