IMU/DGPS-SUPPORTED AUTOMATIC IMAGE MEASURING

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ABSTRACT:

Automatic image measuring is to identify and to measure conjugate points in two or more overlapping photographs automatically. In digital photogrammetry, this process is done by image matching. A straightforward way to make image matching well-posed is to restrict the space of possible solutions and provide good initial parallax. Initial parallax is related to the searching space. The better the initial parallax, the smaller the searching space. So in image matching, the initial parallax should be determined firstly.

Since IMU/DGPS system can get exterior orientation (EO) parameters of the image, using the EO parameters and the corresponding elevation to predict the location of conjugate points can get a better initial parallax. Thus, the limitation of traditional method in deciding initial parallax, such as gaining incorrect initial parallax, large searching space, etc, may be hopefully improved. Then the operator's interference in automatic image measuring will reduce and the efficiency, reliability of image matching will increase.

This paper studies the use of IMU/DGPS data in automatic image measuring. Using IMU/DGPS data to decide the initial parallax can avoid the dependence of image condition. So the parallax decided will be better than that of the gray-correlation's which is depended on image condition. In this paper, two methods are introduced to decide the initial parallax. They are gray-correlation and IMU/DGPS data supported. Experiments are carried out to evaluate the applicability and strongpoint of IMU/DGPS -supported automatic image measuring.

1. INTRODUCTION

Automatic image measuring is to identify and to measure conjugate points in two or more overlapping photographs automatically. In digital photogrammetry, this process is done by image matching. A straightforward way to make image matching well-posed is to restrict the space of possible solutions and provide good initial parallax. The better the initial parallax, the smaller the searching space, the more precise the matching result, the higher the matching efficiency.

In traditional automatic aerial triangulation, the initial parallax is decided by gray-correlation. When there is large rotation angle between stereo pairs and when the image is of isolated island in the sea or dense lakes or desert areas, etc, this method can not decide accurate initial parallax. The incorrect initial value will lead to failure of image matching. When transforming conjugate points between strips, gray-correlation can not always decide the initial parallax because there is a relative smaller overlapping area for searching. Usually, several conjugate points are determined by the operator before image matching. This greatly reduces the automatic level of aerial triangulation.

Integrated orientation systems composed by an Inertial Measurement Unit (IMU) and Differential Global Positioning System (DGPS) allow for direct image georeferencing. These systems allow the determination of all EO parameters directly without using ground control points. Thus IMU/DGPS system can offer a quick and cost-effective way to gain accurate topographic map information.

Since IMU/DGPS system can get EO of the image, using the EO parameters and the corresponding elevation to predict the location of conjugate points can get a better initial position estimation. Thus, the limitation of traditional method in deciding initial parallax, such as gaining incorrect initial position estimation, large searching space, etc, may be hopefully improved. Then the operator's interference in automatic image measuring will reduce and the efficiency, reliability of image matching will increase.

This procedure constitutes an alternative to the conventional approach of automatic image measuring. This paper investigates into the technical feasibility of the approach. We will show with real data what kind of results we can expect from such a procedure.

2. INITIAL PARALLAX CALCULATION

To start automatic image matching and to search correct position of conjugate points, the first thing we should do is initial parallax calculation of stereopairs. The more correctable the initial parallax, the smaller the searching window size and the higher the accuracy of conjugate points matching. In traditional method, initial parallax is obtained by calculating grey cross-correlation of two images. So the traditional initial parallax is limited by image quality.

For an object on a stereopairs, of which pixel coordinates on one image is known, we can obtain its approximate pixel coordinates on the other image with the assistant of IMU/DGPS data. Firstly, position on one image should be transformed from pixel coordinates system to image coordinates system. Secondly, according to collinear-function, we can obtain ground coordinates of the corresponding object by using EO parameters supplied by IMU/DGPS and elevation data of the point (i.e.SRTM3).Then with the ground coordinates and EO parameter of the other image, we can obtain approximate image space coordinates of the conjugate point on the other image. Finally, pixel coordinates of the conjugate point can be obtained through coordinates transformation. Based on the approximate pixel coordinates of the conjugate points, we can calculate the initial parallax and start automatic image measuring.

A ground point P is imaged in the stereopairs made up of image u and image v, and corresponding image points of P are P’ and P”. (I_1,J_1) is pixel coordinates of P’. (X_{S1},Y_{S1},Z_{S1},φ_1,ω_1,κ_1) is approximate exterior orientation parameter of image u supplied by IMU/DGPS, and (X_{S2},Y_{S2},Z_{S2},φ_2,ω_2,κ_2) is approximate EO parameter of image v. At the same time, we can obtain latitude and longitude of projection centre of image u, which is supplied by IMU/DGPS.

Position of P’ should be transformed from pixel coordinates (I_1,J_1) to image coordinates (x_1,y_1). According to equation (1), position of P’ is transformed to image space assistant coordinates (X_{m1}, Y_{m1}, Z_{m1}).

$$\begin{bmatrix} X_m \\ Y_m \\ Z_m \end{bmatrix} = R \begin{bmatrix} x \\ y \\ -f \end{bmatrix} \qquad (1)$$

where f = focal length
x, y, –f = image space coordinates
X_m, Y_m, Z_m = image space assistant coordinates
R = rotation matrix obtained from φ_1, ω_1, κ_1

From latitude and longitude of projection centre of image u and SRTM3 DEM data, we can get initial elevation value Z of ground point P. According to equation (2), scale λ_m can be obtained.

$$\lambda_m = \frac{Z - Z_{S1}}{Z_m} \qquad (2)$$

where Z = initial elevation value Z of ground point P
Z_{S1} = elevation value of project centre of image u
Z_m = image space assistant coordinates

With image assistant coordinates of P’ and ground coordinates of project centre of image u, ground coordinates of P can be obtained.

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \lambda_m \begin{bmatrix} X_m \\ Y_m \end{bmatrix} + \begin{bmatrix} X_{s1} \\ Y_{s1} \end{bmatrix} \qquad (3)$$

where X, Y = ground coordinates of P
X_{S1}, Y_{S1} = ground coordinates of project centre

According to collinear equation (4), we can acquire image space coordinates (x_2 y_2) of P”.

$$\left.\begin{aligned} x - x_0 &= -f\,\frac{a_1(X - X_{S2}) + b_1(Y - Y_{S2}) + c_1(Z - Z_{S2})}{a_3(X - X_{S2}) + b_3(Y - Y_{S2}) + c_3(Z - Z_{S2})} \\ y - y_0 &= -f\,\frac{a_2(X - X_{S2}) + b_2(Y - Y_{s2}) + c_2(Z - Z_{S2})}{a_3(X - X_{S2}) + b_3(Y - Y_{S2}) + c_3(Z - Z_{S2})} \end{aligned}\right\} \qquad (4)$$

where X, Y, Z = ground coordinates of P
X_{S2}, Y_{S2}, Z_{S2} = position of project centre of image v
a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2, c_3 = rotation matrix from object attitude parameter φ_2, ω_2, κ_2 of image v

Through coordinates transformation, initial pixel coordinates of P” can be acquired. With this initial pixel coordinates of P”, we can start automatic image matching and search correct position of P”.

3. IMU /DGPS -SUPPORTED AUTOMATIC IMAGE MEASURING

The purpose of automatic image measuring is to reconstruct relative position of the two images, which makes up a stereopairs, and constructs geometry model of ground objects. In order to improve the accuracy of automatic image measuring, enough well distributed and accurately matched conjugate points should be obtained automatically on the overlapped area of the two images. Thus adopting a good image matching method is also important in automatic image measuring besides correct initial parallax.

This paper adopts feature-based image matching method. Feature-based matching employs as conjugate entities features extracted from the original gray level image. Such features include points, edges, and regions. Based on feature, matching can be carried out with high accuracy and stability even at image area with relative low sign noisy rate.

As we all known, feature points (interest points) are more popular in photogrammetry. So in this paper, the selected matching entities are interest points. In theory, interest points are discontinuous points in image’s gray profile. In aero stereopairs, the comparatively steady interest points always lay at the same or almost the same place near to the object.

To improve the efficiency of automatic image measuring, this paper employs strategy of pyramid image matching. The following figure shows the automatic image measuring strategy.

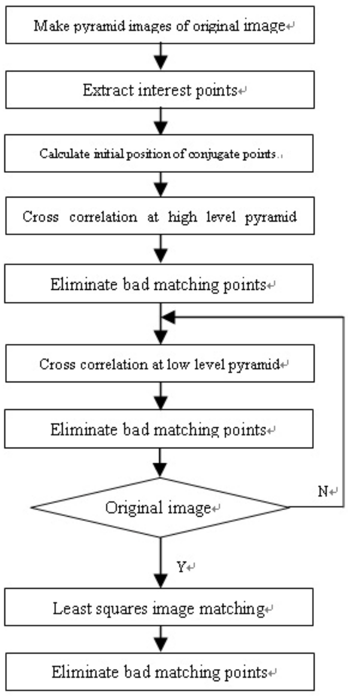

Figure 1 automatic image measuring strategy

Firstly, pyramid image serials of original images should be made. Then interest points are extracted from images. According to the method presented in section 2, we can acquire initial parallax of stereopairs with assistant of IMU/DGPS data. Conjugate points matching starts from the highest level pyramid image. The matching result of higher level should be passed to lower level image matching as initial value and bad matching points elimination must be carried out after conjugate point matching each time. At original image, least squares image matching is performed to further improve the matching accuracy.

4. TEST EXAMPLE

To show the potential of IMU/DGPS supported automatic image measuring, the results of test data are depicted as following. This medium scale (1:5000) image block consists of 1 strip. Altogether 11 images (65% long overlap, LMK-2000 camera) with IMU/DGPS data available are on this strip. In this paper, the IMU/DGPS data is provided by IGI AEROcontrol system and the ground elevation data is provided by SRTM3.

The test area is close to Nanjing, Jiangsu province. In the area, there are many water areas, fields and artificial buildings.

Two methods are used to carry out automatic image measuring: one is IMU/DGPS supported automatic image measuring; the other is traditional automatic image measuring. The following shows the accuracy of the stereopairs' initial position using the two methods.

stereopairs	Traditional method		IMU/DGPS supported	
	x(pixel)	y(pixel)	x(pixel)	y(pixel)
1-2	-95	-609	48	52
2-3	-56	182	-80	-15
3-4	-41	-66	-162	49
4-5	-98	-188	-148	22
5-6	-36	-149	32	13
6-7	-8	-105	88	6
7-8	-73	30	-9	-11
8-9	95	-209	159	27
9-10	21	-9	-27	-31
10-11	3	182	60	-44

Table 1 accuracy comparison of the two methods

For each stereopairs, twelve conjugate points pairs are selected in Photoshop and regarded as true value. Then we respectively use the two methods to calculate conjugate points' initial position and compare the results obtained by the two methods with the true value. Table 1 shows the statistic results.

As is shown in table 1, in most of these stereopairs, the IMU/DGPS supported method has the better results except in the stereopairs 9-10. Especially in stereopairs 1-2, the traditional method has very bad initial position estimation because of image condition (figure 2). Thus the method with IMU/DGPS data has relatively correct initial position estimation.

To show the detail difference of automatic image matching using the two methods, detail matching results of stereopairs 1-2 are presented blow (figure 3 and figure 4). During the automatic image measuring process, 2000 feature points are selected as initial conjugate points in both methods.

Figure 2 shows the original steroeopairs. There are some water areas on the stereopairs. Because of the different photograph condition, some water areas are light on one image but dark on the other image. This leads to different gray condition of the same areas. And thus leads to the bad initial parallax estimation of the traditional method. At the same time, it means that a larger searching window size is needed in the traditional method. Since IMU/DGPS supported method doesn't depend on the image gray condition, this gray difference will not influence its initial parallax estimation.

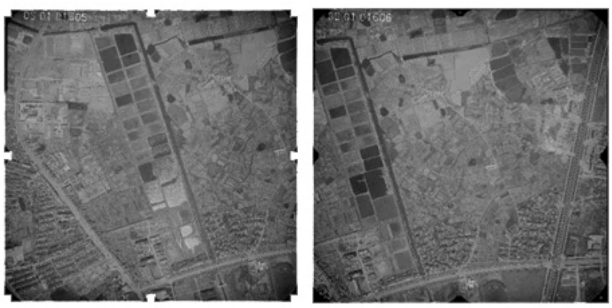

Figure 2 stereopair 1-2

Figure 3 and figure 4 show the matching results of the two methods. Comparing the figure 3 and figure 4, IMU/DGPS supported method obtains more pairs of accurate matching conjugate points, epically in the water areas with different gray condition.

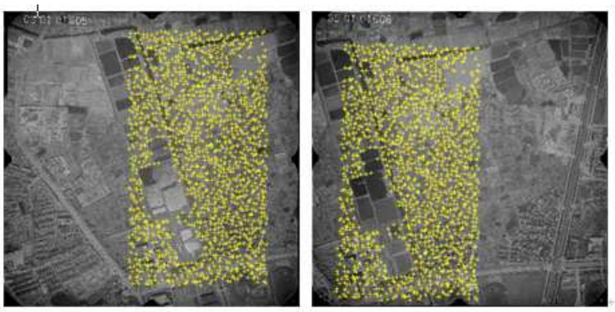

Figure 3 stereopair 1-2 IMU/DGPS supported matching result

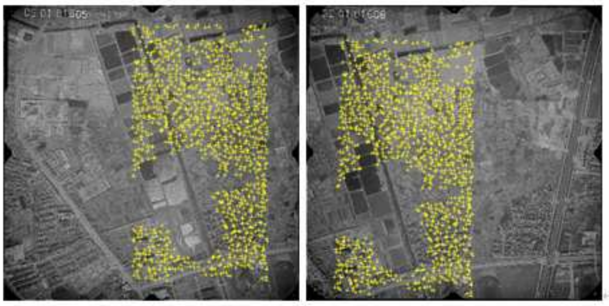

Figure 4 stereopair 1-2 traditional method matching result

In all, using IMU/DGPS supported method with less layers of pyramid image, 1378 pairs of accurate matching conjugate points are obtained with RMS of 9.30µm, and using the traditional method with more layers of pyramid image, 1037 pairs of accurately matching conjugate points are obtained with RMS of 9.48µm. Looking into the matching conjugate points from figure 3 and figure 4, the conjugate points which can be accurately matched with traditional method, can also be accurately matched with IMU/DGPS supported method; and which can't be accurately matched with traditional method, can be accurately matched with IMU/DGPS supported method. This means that because of better initial parallax estimation, IMU/DGPS supported method can carry out image measuring more efficiently.

5. CONCLUSIONS

Comparing to the traditional method in calculating initial parallax of stereopairs, IMU/DGPS supported method can always obtain better initial parallax during automatic image matching. This leads to the decrease of searching window size and interference of the operator. Then the accuracy, reliability and efficiency of automatic image measuring will increase.

To summaries, IMU/DGPS supported method can successfully complete the automatic image matching process whether the traditional method can or not. IMU/DGPS supported automatic image matching can be a good alternative method in automatic image matching.

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