SIMULATE APPROACH FOR SEVERAL REMOTE SENSING IMAGES' POSITIONING WITH GPS DATA AND FEW GCPS *

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ABSTRACT:

With satellites' position, the main factors affecting image's positioning accuracy are image's attitudes. Supposing that satellites' position can be determined by GPS, images' positioning without GCP can be implemented upon the characteristic of images overlap. The paper designs an approach for images' positioning with GPS data and no GCP through combined adjustment and proves that the approach is correct with simulated data. Furthermore, the precision of computed attitudes and targets' position is analysed.

1. FOREWORD

The orientation precision of the remote sensing image mainly depends on the exterior orientation parameters of the satellite with no GCP. In general the satellites' position error usually leaded to the horizontal shifting effect, and the precision of the angular parameters are the crucial factors of the targets' positioning. At present some satellites have loaded GPS system which can real-time records the satellite's position. Furthermore the spatial position of the satellite can be measured and controlled more and more accurate because of the improvement of the GPS precision. As a result, how to eliminate the influence of the attitude error is the key question of the targets' positioning.

Supposing there is a film-recovery photographic satellite, and the photographic scale is 1:64000, the range of one scene image on ground is 10km×10km. And the precision of the GPS is good enough, so the data GPS acquired can be regarded as the photographic station, i.e. the line exterior orientation parameters of the satellite. Under this condition, the tie points of two or more images were used to correct the attitude parameters of each image and the technology of image targets' positioning with few or even no GCP was brought forward. And the targets' positioning error on conditions of varying topography and overlap measure was analysed with computer simulation technology.

In this paper, the multi-image combined adjustment principle which based on GPS surveyed satellite position and the tie points was introduced. The error equation of combined adjustment was derived. And the satellite image targets' positioning technology with few or even no GCP was set up. At the same time a series of experiments with simulated data were done to verify the exactness of this method. Further analysis was carried on the influence of targets' positioning error caused by image's measured error.

2. PRINCIPLE

According to the principle of photogrammetry, image's orientation needs six exterior orientation parameters, i.e. 3 spatial coordinate values (X_S, Y_S, Z_S) and 3 attitude values (φ, ω, κ). Firstly, supposing the satellite's position can be measured by GPS very accurately. So we will emphasis on how to measure the 3 attitude values precisely.

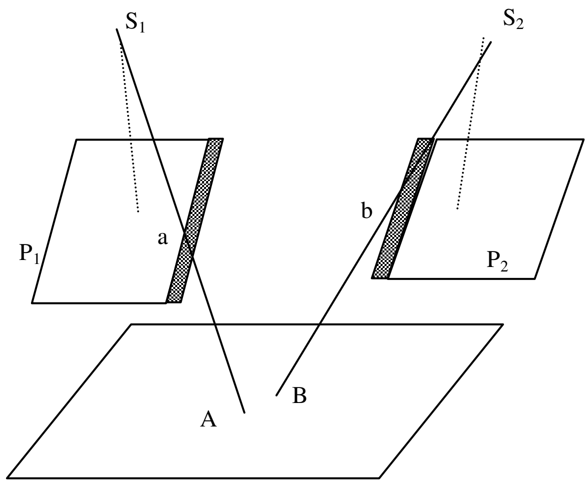

Figure 1. tie point

See figure 1, P_1, P_2 are two adjacent images, the shadow is the area where P_1 overlaps P_2, S_1 and S_2 are photographic stations. S_1a and S_2b intersect at one point P under the ideal situation. Due to the error of the attitude, a and b were projected at A and B separately. The algorithm we put forward is to project a and b at point P correctly through correcting the attitudes of the image while keeping S_1 and S_2 immovability.

According to the principle of photogrammetry, some relative values (or absolute values) of the attitude of one stereopair can be calculated using the relative orientation algorithm. To do relative orientation of single stereopair, the relationship between photo base and tie points can be describe by the following

* Beijing remote sensing information research institute has researched a project named satellite ground application system image processing subsystem. Content of this paper is a part of this project.

equation. The equation was derived from the coplanarity condition equation.

$$\begin{vmatrix} B & 0 & 0 \\ u & v & w \\ u' & v' & w' \end{vmatrix} = B \begin{vmatrix} v & w \\ v' & w' \end{vmatrix} = 0 \qquad (1)$$

Where u , v , w are coordinates of image point a in $S-XYZ$ spatial coordinate system. u' , v' , w' are coordinates of image point a´ in □ $S'-X'Y'Z'$ spatial coordinate system. B is photo base, and the coordinates system is just described by figure 2.

Supposing photo base B is collinear with the X axis of the coordinate system, so the component of photo base B is 0 in the direction of Y and Z. So equation 1 can be denoted as follow.

$$F(\varphi,\kappa,\varphi',\omega',\kappa') = \begin{vmatrix} v & w \\ v' & w' \end{vmatrix} = 0 \qquad (2)$$

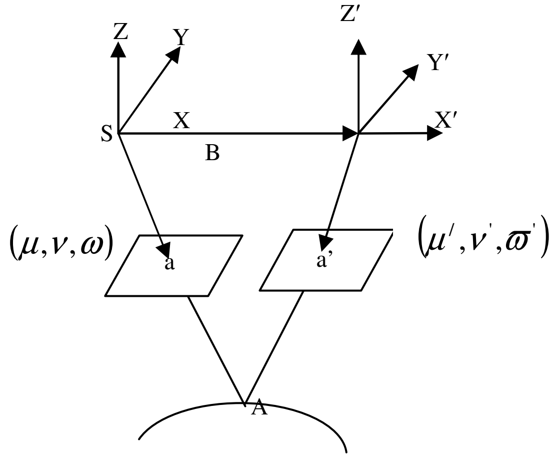

Figure 2. Relative orientation relationship

Linearization of equation 2 is as follow.

$$F(\varphi,\kappa,\varphi',\omega',\kappa') = F_0 + \frac{\partial F}{\partial \varphi}\Delta\varphi + \frac{\partial F}{\partial \varphi'}\Delta\varphi' + \frac{\partial F}{\partial \omega'}\Delta\omega' + \frac{\partial F}{\partial \kappa}\Delta\kappa + \frac{\partial F}{\partial \kappa'}\Delta\kappa' = 0 \qquad (3)$$

Where, φ □ κ are pitch and yaw of left image, φ' □ κ' are pitch and yaw of right image, ω' is the roll angle of right image relative to left image.

Using a number of tie points the absolute values of pitch and yaw can be calculated through this relative orientation algorithm. But the absolute roll angles cannot be computed only using two adjacent images. So the absolute yaw angle can be computed by one of these two ways, one is to import at least one GCP. The other, when there are four or more images which have longitudinal overlap and lateral overlap, the yaw angle of left or right image can be computed by using of these four-image-overlap points. And so as to implement the attitude angles computation without GCP. So after gotten the satellite's position by GPS and the attitude angles using the images overlap characteristic, the targets' can be positioned. The flow is described as follow(see figure 3.).

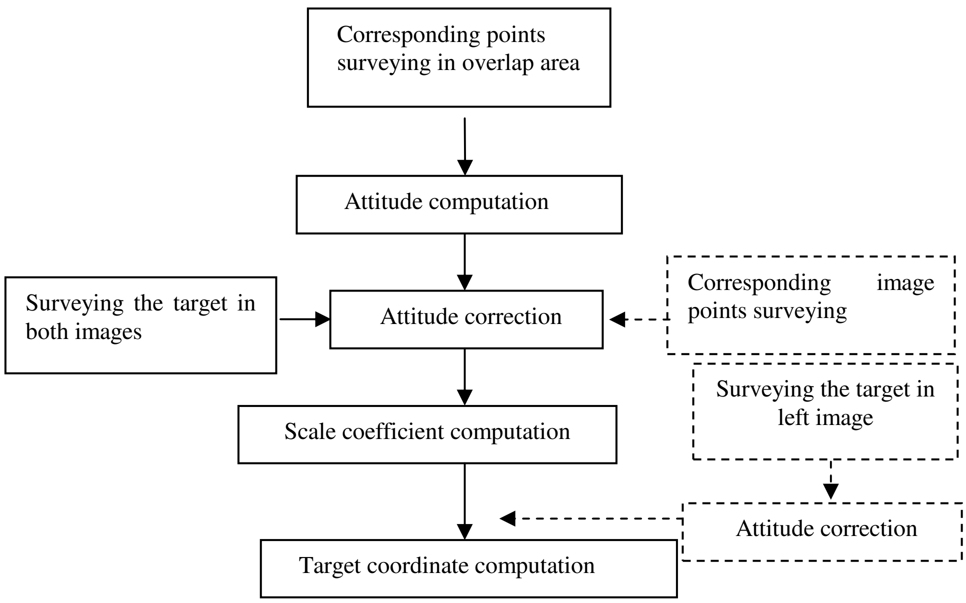

Figure 3. targets' positioning flow

3. SIMULATION EXPERIMENT

Two strips was designed, each strip has two satellite images. The strips have longitudinal and lateral overlap. And the four stimulant images were created (see figure 4, the shadow is the overlap area of the adjacent images), the attitude and the adjacent images' pixel coordinate and geodetic coordinate were known.

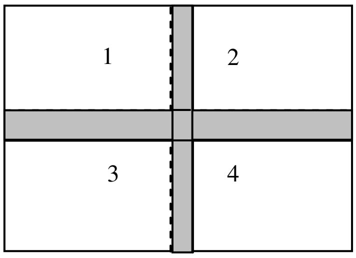

Figure 4. Stimulated area images

Considering the computation precision of the attitude and the targets' ground coordinate are mainly influenced by image points' measured error, the experiment contains two instances. The first is to analyse the influence on the attitude computation precision that image point error caused with varying overlap measure, e.g. the overlap measure is 10□, 20□, 30□ or 60□. The second is to analyse the influence on the targets' poisoning precision that image point error caused when different overlap was given, e.g. the overlap measure is 10□, 20□, 30□ or 60□.

The first instance: the analysis of influence on the attitude computation precision that image point error caused with varying overlap measure.

The experiment was divided into four groups, i.e. longitudinal overlap is 10% & lateral overlap is 10%, longitudinal overlap is 20% & lateral overlap is 20%, longitudinal overlap is 30% & lateral overlap is 30%, and longitudinal overlap is 60% & lateral overlap is 20%. The measured error is variable from 0.00 mm to 0.03 mm. The difference the terrain is 2000 m. the result of this experiment is as follow.

Measured error	Pitch error (second)	Roll error (second)	Yaw error (second)
0.00 mm	0.0022-0.2467	0.0000-0.0016	1.2566-5.6549
0.01 mm	1.7158--4.7654	0.6713-3.4740	12.4537-17.7531
0.02 mm	3.4269-9.5125	1.4262-7.0223	30.1944-36.3754
0.03 mm	5.1427-12.2407	2.2660-10.64427	47.5632-54.6107

Table 1. relationship between the measured error and attitude error
(longitudinal overlap 10% & lateral overlap 10%)

Measured error	Pitch error (second)	Roll error (second)	Yaw error (second)
0.00 mm	0.0022-0.0247	0.0000-0.0016	1.2566-5.6549
0.01 mm	0.2633-1.0049	0.1552-1.1020	2.6934-6.8807
0.02 mm	0.5206-1.9830	0.3072-2.1623	10.2831-12.6474
0.03 mm	0.7100-2.9589	0.4547-3.1792	15.2730-20.2182

Table 2 relationship between the measured error and attitude error
(longitudinal overlap 20% & lateral overlap 20%)

Measured error	Pitch error (second)	Roll error (second)	Yaw error (second)
0.00 mm	0.0022-0.0247	0.0000-0.0016	1.2566-5.6549
0.01 mm	0.2916-0.7645	0.2429-1.7177	0.9321-7.2375
0.02 mm	0.5973-1.5023	0.4820-3.4197	0.8062-17.9389
0.03 mm	0.9073-2.2380	0.7170-5.1059	0.8790-28.3340

Table 3. Relationship between the measured error and attitude error
(longitudinal overlap 30% & lateral overlap 30%)

Measured error	Pitch error (second)	Roll error (second)	Yaw error (second)
0.00 mm	0.0021-0.0246	0.0000-0.0011	1.2566-5.6548
0.01 mm	0.2655-0.9097	0.0118-0.2255	10.6213-15.0465
0.02 mm	0.5148-1.7936	0.0242-0.4479	17.5512-30.9677
0.03 mm	0.7611-2.6761	0.0373-0.6660	24.5598-46.5067

Table 4. Relationship between the measured error and attitude error
(longitudinal overlap 60% & lateral overlap 20%)

Result can be gotten from the experiment:

1. When the measured error of image is 0, the error calculated is computation error. Compared with the forth group experiment (longitudinal overlap 60% & lateral overlap 20%) the pitch error of first group experiment (longitudinal overlap 10% & lateral overlap 10%) is obviously greater.
2. The attitude error is up to the linear increase of measured error.
3. When the longitudinal overlap is 10% and the lateral overlap is 10%(the first group), the attitude error caused by the measured error is relatively great.
4. As for other groups, the pitch error and roll error are small and yaw error is relatively great. The maximum error of pitch and roll is no more than 7 seconds. The maximum yaw error is within 1 minute (in the limit of double maximum square error caused by the measured error which is 0.02 mm).

The second instance: the analysis of influence on the targets' positioning precision that image point error caused with varying overlap measure.

The experiment was also divided into four groups, i.e. the longitudinal overlap is 10% & lateral overlap is 10%, longitudinal overlap is 20% & lateral overlap is 20%, longitudinal overlap is 30% & lateral overlap is 30%, and Longitudinal overlap is 60% & lateral overlap is 20%. The measured error is variable from 0.00 mm to 0.03 mm, and difference of the terrain is 2000m. The result of the experiment is as follow.

Measured error	**X square error (m)**	**Y square error (m)**	**Vertical square error (m)**
0.00 mm	13.24-14.31	12.35-12.93	668.39-731.69
0.01 mm	11.82-17.80	11.75-14.61	628.77-834.99
0.02 mm	10.50-21.45	11.27-16.54	594.23-948.30
0.03 mm	9.30-25.20	10.93-18.64	565.91-1068.25

Table 5. Relationship between measured error and horizontal error when overlap is 10%

Measured error	**X square error (m)**	**Y square error (m)**	**Vertical square error (m)**
0.00 mm	13.73-14.63	12.93-13.29	699.60-752.10
0.01 mm	14.28-14.40	13.13-13.19	718.48-744.96
0.02 mm	14.18-14.84	13.09-13.37	737.93-738.01
0.03 mm	13.96-15.41	12.99-13.63	731.02-758.13

Table 6. Relationship between measured error and horizontal error when overlap is 20%

Measured error	**X square error (m)**	**Y square error (m)**	**Vertical square error (m)**
0.00 mm	13.98-14.67	13.22-13.34	715.58-754.62
0.01 mm	14.30-14.35	13.21-13.51	730.57-742.86
0.02 mm	13.93-14.72	13.10-13.82	731.04-745.94
0.03 mm	13.57-15.11	13.02-14.14	719.45-761.65

Table 7. Relationship between measured error and horizontal error when overlap is 30%

Measured error	**X square error (m)**	**Y square error (m)**	**Vertical square error (m)**
0.00 mm	0.04-0.07	0.05-0.05	1.23-0.095
0.01 mm	0.69-0.83	0.65-0.95	2.10-38.21
0.02 mm	1.39-1.63	1.29-1.88	3.80-76.16
0.03 mm	2.09-2.43	1.93-2.81	5.60-114.11

Table 8. Relationship between measured error and horizontal error when longitudinal overlap is 60% & lateral overlap is 20%

Result can be gotten from the experiment:

1. When the measured error is 0, the targets' positioning error calculated is computation error. In flat area, horizontal precision is relatively high, but the vertical error is greater. In mountain area, the targets' error mainly caused by the terrain relief. In this experiment, the horizontal error is smaller than 15 meters in X direction and in Y direction is smaller than 14 meters. And the altitude error is very great. So this method is good for horizontal positioning but not suitable for the altitude poisoning.
2. Result can be found from the second and third group of experiment (overlap is 20% or 30%) that the horizontal error is basically unanimous, and mainly influenced by the terrain relief. The horizontal precision is great. Error both in X and Y direction are not more than 30 meters (in the limit of double maximum square error caused by the measured error which is 0.02 mm). When the overlap measure is as big as 60%, the horizontal precision reaches in cm grade, and the vertical error is about 1 meters.
3. The targets' positioning error is up to the linear increase of measured error.

4. CONCLUSION

The following conclusion can be summarized through above experiment and analysis.

1. When satellites' position can be determined by GPS accurately, the targets' positioning can be implemented. For the characteristic of the area adjacent images overlay can be used to correct the attitude of the images. The method stated in this paper is correct and feasible, and it offers a scientific approach of targets' positioning with no GCP.
2. In this approach, the precision of the photograph measurement is the main factor influencing the targets' positioning. So the responding points can be found out with automatic match technology, in order to dispel the influence of the measured error as much as possible.
3. The experiment of this method is still on the basis of the simulated data at present. So the next job is to utilize the true satellite remote sensing data and the aerial triangulation principle deepening the research on this model in order to form the practical method of the image orientation with few or even no GCP.