THE RESEARCH AND DESIGN OF THE BASE-HEIGHT RATIO FOR THE THREE LINEAR ARRAY CAMERA OF SATELLITE PHOTOGRAMMETRY

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ABSTRACT:

In the satellite photogrammetry, the base-height ratio greatly impacts the elevation accuracy of the targets for the plotting map, and the greater base-height ratio, the higher elevation precision. The paper firstly analyzes the difference of the projection intersection angles between three linear array satellite and air photogrammetry. Then, the mathematic models calculating the intersection angle and the base-height ratio are detailedly deduced in the three linear array satellite photogrammetry. In order to ensure the elevation precision, the relation of the base-height ratio and the intersection angle is attentively researched in the case of considering the flight altitude. Lastly, the range of the intersection angle of the three linear array CCD camera for the satellite photogrametry is provided to the design system.

1. INTRODUCTION

In 1980s, the three linear array CCD camera began to be used to spatial photogrammetry. From the point of view of the photogrammetric mapping, scholars of America firstly put forward Stereosat and Mapsat system, which has ever been implemented because the stability of the flight vehicles attitude must be less than 10^{-6} degree per second (Wang Ren-xiang et al, 2004). At the same time, scholars of Germany brought forward DSP system. The elements of exterior orientation could be solved using photogrammetric aerial triangulation method with the geometrical relation of the three linear array CCD imagimg and less ground control points in the system, which could greatly fall the need of the stability of the sensor attitude and meet photogrammetric mapping. From 1983, MOMS-01, MOMS-02 and MOMS-2P cameras had gradually been used to experiment, the datum acquired by MOMS-02 camera, which was equipped in America space shuttle, had been used to make DEM with 5m elevation precision and were proved to be satisfied for the photogrammetric mapping (Ebner H, Koryus W et al, 1999).

Three linear array CCD camera is comprised of forward view, upright view and backward view, which can take images sloping forward, upright and sloping backward along the satellite orbit direction. Any two images of the three images may form a stereoscopic pair that overlaps along the flight direction. Elevation precision is one of the keys in photogrammetry mapping, so international society for photogrammetry regards formula (1) as the standard to evaluate the mapping efficiency.

$$CI = 3.3 \times \sigma h \tag{1}$$

Where, CI is contour interval; σh is the error of the elevation point; the coefficient 3.3 denotes that the errors of the elevation points over 90% are less than a contour interval.

In the satellite photography, the greater base-height ratio is, the higher elevation precision. Elevation accuracy is the highest when the base-height ratio is equal to 1, which means the picture format is extraordinary bigger for the plane array camera. However, the three linear array camera can make the base-height ratio approach to 1 by adjusting the intersection angles among the forward view, upright view and backward view. Therefore, the three linear array camera is superior in the aspect of the satellite photogrammetry base-height ratio. The intersection angles is designed in reason for the three linear array CCD imaging system so as to assure the photogrammetric elevation accuracy of the target points (Wang Ren-xiang et al, 2003).

2. THE PROJECTION INTERSECTION ANGLES OF SATELLITE PHOTOGRAMMETRY

In the aerial photography, the influence of curvature of earth isn't considered because the photogrammetric height is lower, and the diminutive area is covered in a photogrammetric base line length (see Figure 1) (Wang Zhi-zhuo,1979). Nevertheless, the height is generally 300-800km in the three linear array satellite photography, so the coverage extent is greater, which makes the angle between the projection intersection angle α' and the inner intersection angle α of the CCD camera in the different condition of the forward view and backward

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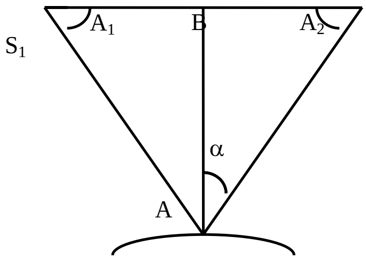

Figure 1 Coverage of the aerial photography

view inequality in the space intersection because of the curvature of earth (see Figure 2). So far, the formulas calculating the intersection angle and base-height ratio in photogrammetry are always deduced on the basis of the figure 1, which couldn't accord with the actual imaging relation in the satellite photography conditions (Wang Ren-xiang et al, 2005).

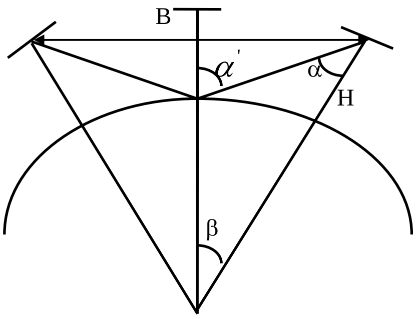

Figure 2 The intersection angles of the satellite photography

3. THE MODELS OF THE INTERSECTION ANGLE AND BASE-HEIGHT RATIO

In order to calculate the intersection angle α and the base-height ratio B/H, the height and earth radius values is respectively described by H and R (see Figure 3).

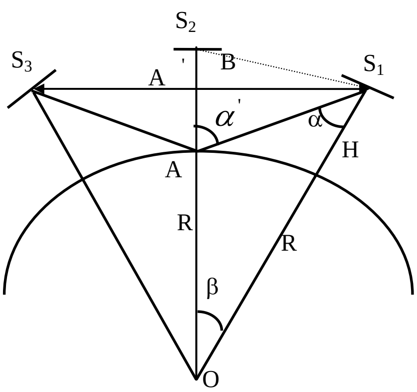

Figure 3 The space intersection principle in the satellite photography

$$\frac{S_2 A'}{B} = \frac{1}{2} tg \frac{\beta}{2} \tag{5}$$

Where, B is the photographic baseline. The projection intersection angle α′ and the base-height ratio B/H may be deduced.

3.1 The projection intersection angle α′

In triangle S_1 AO, the angle relation is:

$$\alpha' = \alpha + \beta \tag{2}$$

And,

$$\frac{\sin\alpha}{R} = \frac{\sin \angle S_1 AO}{R+H} \tag{3}$$

Formula (3) can be written

$$\angle S_1 AO = \arcsin \frac{(R+H)\sin\alpha}{R}$$

Because the angle $\angle S_1 AO$ is greater than 90°, the range of the arcsin function is $[-\frac{\pi}{2}, \frac{\pi}{2}]$. The formula above may be expressed as:

$$\angle S_1 AO = 180° - \arcsin \frac{(R+H)\sin\alpha}{R}$$

The angle β in the formula (2) can be calculated

$$\beta = 180° - \angle S_1 AO - \alpha = \arcsin \frac{(R+H)\sin\alpha}{R} - \alpha \tag{4}$$

The projection intersection angle will be obtained by formulas (2) and (4).

3.2 Base-height ratio B/H

In triangle S_1 S_2 O,

$$\angle S_1 S_2 O = (180° - \beta)/2 = 90° - \frac{\beta}{2}$$

And, in triangle S_1 S_2 A',

$$\angle A' S_1 S_2 = 90° - \angle S_1 S_2 O = \frac{\beta}{2}$$

$$S_2 A' = \frac{B}{2} \times tg \angle A' S_1 S_2 = \frac{B}{2} \times tg \frac{\beta}{2}$$

Therefore,
In triangle S_1 AA′,

$$ctg\alpha' = \frac{(H - S_2 A')}{B/2} \tag{6}$$

In term of the formulas (5) and (6), the base-height ratio can deduced:

$$\frac{B}{H} = 2 \times \frac{1}{tg\frac{\beta}{2} + ctg(\alpha + \beta)} \tag{7}$$

Where, β is calculated by formulas (4).

4. THE BASE-HEIGHT RATIO COMPARISON

When the flight altitude H is respectively 10km, 300km, 400km and 700km, and the intersection angle α is respectively 24°, 21° and 21.4°, the values of the base-height ratio are listed in table 1(R=6378km).

B/H \ H, α	10km	300km	400km	700km
24°	0.890457	0.936729	0.952260	0.999183
21°	0.767728	0.806644	0.819682	0.858994
21.4°	0.783791	0.823644	0.836998	0.877274

Table 1 The base-height ratio in the case of the different flight altitude and intersection angle

Table 1 shows the values of the base-height ratio are different between the aerial photography and the satellite photography, and the factor which the intersection angle affects B/H must be considered in the satellite photography.

In order to get the better elevation precision, the B/H is usually designed to approach 1. Suppose B/H=1, the intersection angle α can be derived from formula (7). That is,

$$ctg(\alpha + \beta) = 2 - tg\frac{\beta}{2} \tag{8}$$

Consider equation (8),

$$\alpha = arcctg(2 - tg\frac{\beta}{2}) - \beta \tag{9}$$

In triangle $S_1 A\ O$ (see Figure 3),

$$ctg\beta = \frac{R + H - A' S_2}{B/2}$$

Namely,

$$ctg\beta = 2 \times (\frac{H}{B} + \frac{R}{B} - \frac{A' S_2}{B})$$

Consider formula above with B/H=1,

$$ctg\beta = 2 \times (1 + \frac{R}{H} - \frac{A'S_2}{B}) \tag{10}$$

In triangle $S_1 S_2 A'$,

$$tg\frac{\beta}{2} = \frac{A'S_2}{B/2} = 2 \times \frac{A'S_2}{B}$$

The formula below can obtained from (10),

$$ctg\beta + tg\frac{\beta}{2} = 2 + 2 \times \frac{R}{H}$$

The half-angle formula is:

$$tg\frac{\beta}{2} = \frac{1 - \cos\beta}{\sin\beta} = \frac{1}{\sin\beta} - ctg\beta$$

β may be given by:

$$\beta = \arcsin[\frac{1}{2 \times (1 + R/H)}] \tag{11}$$

The intersection angle can be calculated by formulas (9) and (11). In the case of the different flight altitude, the intersection angles α is listed below table 2 when B/H=1.

H	300km	400km	700km
α	25.407269°	25.04427°	24.017002°

Table 2 The different intersection angles α when B/H=1

Table 2 is the foundation to design the space intersection angles among the forward view, upright view and backward view.

5. CONCLUSIONS

In the three linear array satellite photography, elevation accuracy decides whether the datum can meet the mapping index or not, so the elevation precision, which the base-height ratio directly relates to, is often considered principally(A. Gruen, L. Zhang, 2002). In order to obtain the high elevation precision, it is greatly important that the model calculating the base-height ratio is correctly deduced. Therefore, the idea of the paper can been not only regarded as the direction of the system designing of the spaceborne three linear array CCD camera (Wang Ren-xiang et al, 2007), but also used to the different camera system for the intersection stereo photogrammetry in the satellite photogrammetry.

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