REFIT OF PHOTOTHEODOLITE 19/1318 AND ITS APPLICATION TO CLOSE RANGE PHOTOGRAMMERTY

Wang Li,Fan Qiulin,Liao Hongbin
Associate Professor
Institute of Seismology of State Seismological Bureau
China

Commission V

ABSTRACT: The refitting method of the phototheodolite 19/1318 is briefly introduced. The change of lens distortion effect after refitting of camera is discussed. The application of the refitted 19/1318 to close range photogrammetry and some results are suggested.

KEY WORDS: Phototheodolite 19/1318, Refit.

1 INTRODUCTION

The close range photogrammetry has been applied extensively day by day with the advancement of science and production. The various instruments for close range photography are put forward internationally. However,it is difficult that the new instruments are imported largely in a great country like China which belonges in the developping country. A lot of phototheodolite 19/1318 are produced and imported in China in the past. Statistically, there are nearly a hundred or more sets in the productive and scientific departments of China. Could the 19/1318 be used for close range photogrammetry? We have done the test and obtained certain results since 1980.

2 BRIEF INTRODUCTION OF REFIT OF PHOTOTHEODOLITE 19/1318

2.1 Estimation of Increment of Principal Distance

Being of service to the topometry, the principal distance of phototheodolite 19/1318 is fixed and focused at infinity. The hyperfocal distance H is computed from the equation:

$$H=f^2/\varepsilon k \qquad (1)$$

Where ε, the tolerant diameter of the circle of confusion, letting ε=0.1mm; k, the relative aperture of camera, k=25 for 19/1318; f, the focal distance of camera, f=200mm. We obtain H=16m.

The image distance d is not equal to principal distance f because the object distance becomes short in close range photography. In order to keep the imagery condition, the principal distance of camera must be increased.

Using the Δf to indicate the increment from image to prime focal place, the following equation can be written from the geometric optics:

$$1/f = 1/D + 1/(f + \Delta f)$$

then

$$\Delta f = f^2/(D-f) \qquad (2)$$

where D, the distinct camera-to-subject distance. The foreground distance D1=H·D/(H+D) and the background distance D2=H·D/(H-D) can be evaluated with H and D. Then the depth of field is

$$\Delta D = D2-D1 \qquad (3)$$

The relational values among D, Δf and ΔD are calculated as in table 1.

Table 1 Relational Values Among D, Δf and ΔD

No.	Δf(mm)	D(m)	ΔD(m)
A	4.8	8.0	5.3 — 16.0
B	9.8	4.0	3.2 — 5.3
C	16.3	2.5	2.2 — 3.1

2.2 Application of washer

The principal distance of camera is increased by using a washer to insert between the camera magazine and the lens place (Fig.1). The thickness of washer is computed from equation 2. Three washers (A,B,c) with thicknesses listed in table 1 are processed. Applying these washers individually and combinatively, the phototheodolite 19/1318 can relize different close range photographies above one meter.

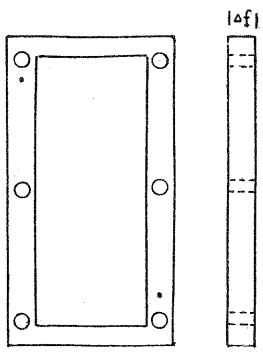

Fig.1 Washer

3 DETERMINATION OF LENS DISTORTION OF PHOTOTHEODOLITE 19/1318 AFTER REFIT

The lens of 19/1318 is projected so that the distortion in focusing at infinity is less than 6μm. Generally, the effect of lens distortion is changed with the change of photographic distance. Thus it is necessary to study the change of distortion effect of 19/1318 after refitting.

The lens distortion cosists of the radial and the tangential one. Ordinarily, the first effect is main. Therefore, the change of main terms in distortion effect of 19/1318 after increment of principal distance is determined according to the collinearity equation:

$$x-x_o+\Delta x=f\frac{a1(X-Xs)+b1(Y-Ys)+c1(Z-Zs)}{a2(X-Xs)+b2(Y-Ys)+c2(Z-Zs)}$$
$$z-z_o+\Delta z=f\frac{a3(X-Xs)+b3(Y-Ys)+c3(Z-Zs)}{a2(X-Xs)+b2(Y-Ys)+c2(Z-Zs)} \qquad (4)$$

in which

$$\Delta x=k1(x-x_o)r^2+k2(x-x_o)r^4+(z-z_o)(1+ds)Sind\beta$$
$$\Delta z=k1(z-z_o)r^2+k2(z-z_o)r^4+(z-z_o)[(1+ds)Cosd\beta-1] \qquad (5)$$

Where Xs, Ys, Zs, f, x_o, z_o, the internal and the external orientation elements; k1, k2, the coefficients of radial distortion; ds, dβ, the parameters of the offine deformation error; X,Y,Z, the known coordinates of control points; x,y, the image coordinates; ai,bi,ci(i=1,2,3), the direction cosine; r, the radial radius of distortion.

The indoor control field in which the survey accuracy of control points reaches up 0.1mm, in the Photogrammetric Department of Wuhan Technical University of Surveying and Mapping is used to photograph and the program of space resection of a single photograph for camera calibration to resolve. The image coordinates are measured on Stecometer and twenty or more marked points on each photograph. the calibration results are listed in table 2.

The distortion correction ($\delta r=k1\cdot r^2+k2\cdot r^4$) of different radial radius (r) for three photographic distances (D) are presented in table 3.

Table 3 Distortion of 19/1318 after refit

r(mm) D(m)	10	20	30	40	50	60	70	80	90
8.0	00	00	00	00	-01	-01	00	03	11
4.0	00	-01	-04	-09	-16	-25	-35	-41	-43
2.5	00	-01	-06	-11	-21	-32	-43	-53	-55

It is shown from table 3 that (1) The closer the photographic distance, the bigger the distortion effect; (2) The biggest distortion effect is 0.01mm when the photographic distance is about 8m, and now, the pair of picture photographed is yet tolerated to operate in analogue mapper. But the distortion effect must be corrected when processing the picture photographed in distance less than about 6m.

4 APPLICATION OF REFITTED PHOTOTHEODOLITE 19/1318 TO CLOSE RANGE PHOTOGRAMMETRY

4.1 Architectural photogrammetry

A lot of ancient architectures in China, such as the temple, the tower and the courtyard and others, are suited to photography by 19/1318. Many ancient architectures and historical relics in Summer Palace of Beijing have been taken. It is found in photography that the middle-sized objects (dimensions 1-10m), like the individual memorial gatsway, and the decorated archway in architectures and the copper lion, the stone horse and the earthen figurines in the sculptures and so on, are especially fitted to photography by refitted 19/1318.

A typical example, the copper lion at door of Summer Palace, is taken by 19/1318 applying the washer no. A. The photographic distance is six meters and the mean photographic scale 1:35. One of photographs of copper lion is shown in Fig. 2 and its elevation mapped on stereometrograph G in Fig. 3. The elevation has been checked in field and accepted up to standard.

It is of pratical significance to point out that if the object as if cylinder is photographed by UMK 10/1318 imported expensively and the same image scale is wanted, the photographic distance shoud be reduced by half. However, the dead area is led to rise because of the shorter photographic distance (refer to Fig.4).

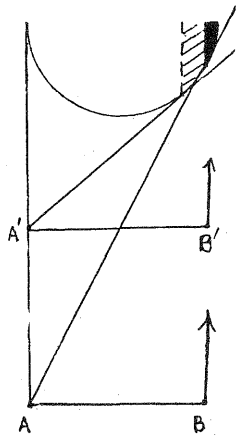

Fig.4 The closer the phtographic distance, the bigger the dead area

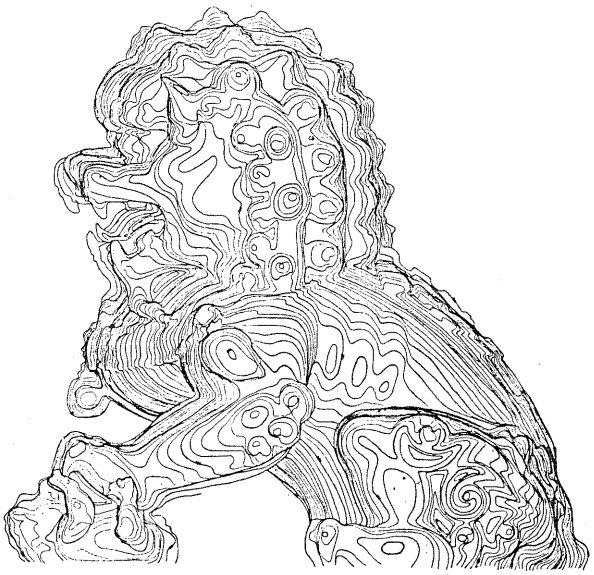

Fig.3 Elevation of the copper lion mapped on the Steresmetrograph G

4.2 Industrial Photogrammetry

The application of refitted phototheodolite 19/1318 which is provided with the medium focal length, to the industrial photogrammetry has the great potentiality, too. Using it, the determination of the design location of engineering model and the test of the hydranlic model etc. are worked. These photographic distance are very short, about 3-5m.

Table 2 Calibrated results of phototheodolite 19/1318 after refit

Mean photo. dis. D(m)	Calibrated internal element f(mm)	x_o(mm)	z_o(mm)	Coefficients of lens distor. K1	K2
8.0	198.69	0.127	-0.062	$-2.492\cdot10^{-7}$	$4.970\cdot10^{-11}$
4.0	203.30	-0.021	0.211	$-1.624\cdot10^{-7}$	$1.269\cdot10^{-11}$
2.5	209.65	0.147	-0.049	$-2.054\cdot10^{-7}$	$1.602\cdot10^{-11}$

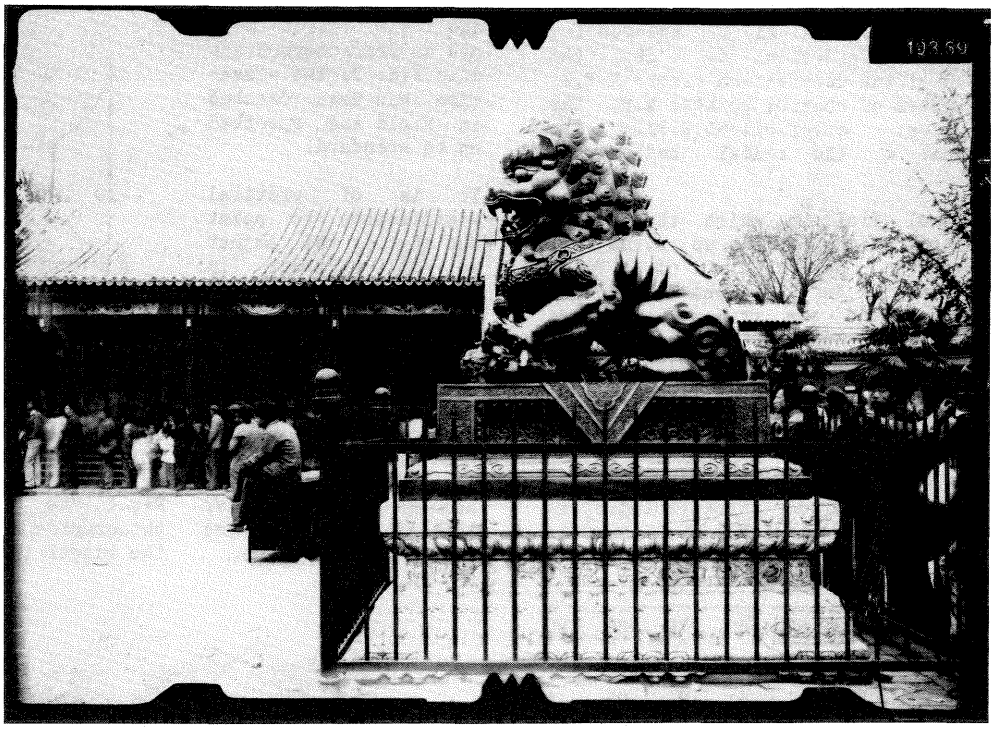

Fig.2 Photograph of the copper lion at door of Summer Palace

In order to meet the requirement for high precise determination of automobile shell, a spiral blade is accurately tested by refitted 19/1318.

The accuracy of survey point in industrial photogrammetry, for instance the automobile shell, is highly required to reach 0.1-0.2mm. For this reason, a high accurate control field in the object space should be established, which is determined by ratio method. Setting and levelling two subtense bars on the object space, the coordinates of control points and two end points of subtense bar are measured by the forward intersection with the approximate base. The ratio factor is resolved from the coordinates of two end points of subtense bar:

$$\lambda = AB/\sqrt{(X'_A-X'_B)^2+(Y'_A-Y'_B)^2} \qquad (6)$$

where AB,the known length of subtense bar; X'_A, Y'_A, X'_B, Y'_B,the aproximate coordinates of two end points. Then the correct coordinates of other points are calculated:

$$X=\lambda X',\ Y=\lambda Y' \qquad (7)$$

The length of second subtense bar can be got from the calculated correct coordinates of end points, equalling 2000.034mm. Comparing it with its known length, 2000.000mm, the difference is obtained, amounting 0.034mm. It is obvious that the accuracy of this measuring method is good to close range control because it is without the error of distance survey and the influence of error of the angle survey on points is not great due to the close range.

The test blade, placing in the center of control field of object space, is photographed by 19/1318 applying washer No. C. the average photographic distance is about 2.5m.

The coordinates of object points are determined by the space resection of photogrammetry from the measured coordinates of ten or more control points, in which the coorrection of lens distortion is considered. Thus the photogrammetric coordinates of sixteen points on blade are obtained. The blade is immediately measured using the machine for three-dimensional measurement (LAMBOA 5606 from Italy), in which the precision of point measurement come up to 6μm, in the die factory of the Second Automobile Manufacturer in China. Taking the immediate measuring coordinates as the pseudo-true value and comparing they with the photogrammetric coordinates, the relative standard error achieves to ±0.118mm. The accuracy is sufficient for requirement of determination of automobile shell.

5 CONCLUSION

Originally, is the phototheodolite 19/1318 mainly adaptable to the topographic survey, and now, is it fully applicable to the close range photogrammetry above one meter after refitted. The refitting method presented in paper is simple to work, easy to process and convenient to operate, and not destroies the former instrumental construction. The satisfactory results was produced through the product application many times. The way of relying upon the old apparatus instead of the new ones could save the import funds. It is recommendable for the developping country like China.