THE POSSIBILITY OF EXTENSIVE APPLICATION OF NON-METRIC CAMERA MADE IN CHINA

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Comission I

ABSTRACT: The lens distortion of non-metric camera "Seagull" made in China is calibrated. It is found that the change of distortion coefficient (K1) in the process of photography of whole film roll is small. The photogrammetric accuracy of non-metric camera can be also improved by using the average distortion coefficient for correction.

KEY WORDS: Non-metric camera, Film deformation, lens distortion, Average lens distortion coefficient.

1 INTRODUCTION

It is the conventional photogrammetry of non-metric camera that a few controls (often seven or more) in the object space are determined, then the camera parameters (including the lens distortion coefficient) along with the coordinates of unknown points are resolved using some analytical methods (for instance DLT). The photogrammetric accuracy of non-metric camera can be greatly improved by this way. However,it has a shortage that enough controls must be measured or the moving control framework supplied in each pair of picture . This has virtually limited the extended application of non-metric camera.

As far as some photogrammetries with middle and low accuracy are concerned, could the non-metric camera be used like the metric camera with less or without controls? For this purpose,a series of tests of non-metric camera made in China are done.

2 CALIBRATION OF NON-METRIC CAMERA

Comparing with the metric camera, the non-metric camera has the main disadvantages, such as lack of the collimation mark and flattening device, The unstable internal orientation and the big lens distortion etc.. Some defects can be overcome, for example,the collimation mark can be cut artificially. The unflatness effect of film in non-metric camera is big, but contrasting with the effect of lens distortion,it is smaller. Therefore, we chiefly calibrated and determined the film deformation and the lens distortion.

2.1 Deformation of Non-metric Film Made in China

The black and white panchromatic film 135 and 120 made in Shanghai Film Manufacturer are analysed. For the sake of determining the film deformation, the frame span in middle part of photograph is measured by paralleling the picture side with the comparator axis because out of the collimation mark in non-metric camera. Comparing frame spans each other, the change of film in the process of photography is understood. The change curves of film in 135 and 120 are separately shown in Fig.1 and 2. It can be seen from figures that:

(1) The change along x (roll direction) is greater than that along y for both films. The change along x and y in 135 film are 0.07mm and 0.03mm, and in 120 film 0.05mm and 0.04mm respectively. The changes exceed the error of picture measurement. Thus the film deformation has to be corrected while the non-metric film is used for photogrammetry.

(2) It is generally considered that the bigger the area of film, the larger the deformation. However, the deformation of film 135 is a littlè larger than that of film 120 from our test results. We infer it is possible that the pulling-force supported in film 135 in use is greater than that in 120 because the former is twice as long as the latter. Also it can be seen from the curve of Fig.1 that the deformation in both ends is smaller than that in middle part for 135, which indicates that the pulling-force supported in middle part of 135 film roll is bigger than that in both ends.

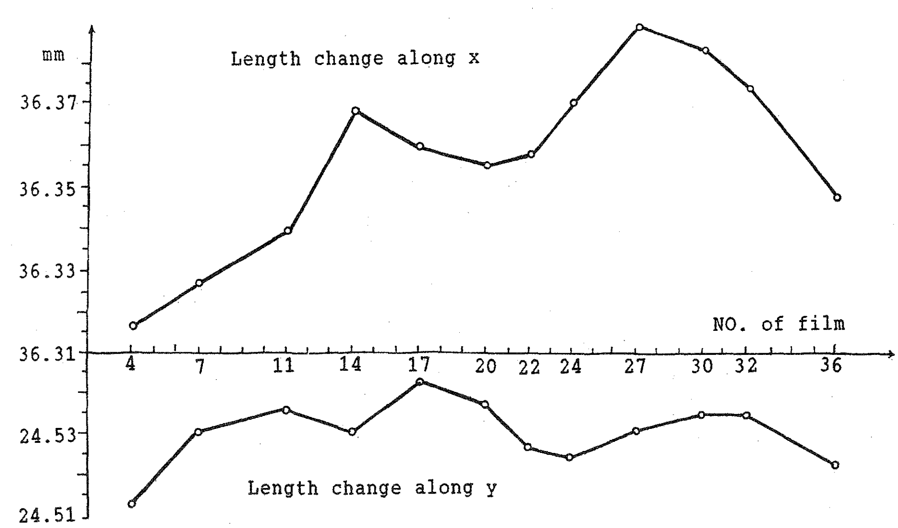

Fig.1 Change of film 135

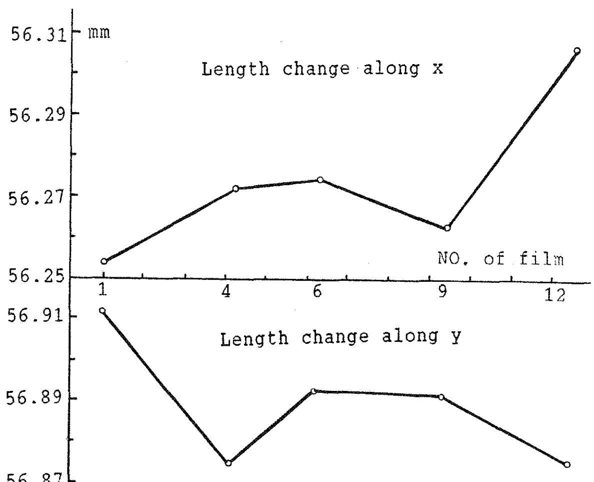

Fig.2 Change of film 120

2.2 Determination of Internal Orientation (Including the Lens Distortion) of Non-Metric Camera

The determination is aimed at a research for the change of the internal orientation (including the lens distortion) of non-metric camera in all course of photography. For this purpose, the same external geometric condition should be kept in photography. Thus, the camera is fixed as far as possible; The 3-D control field is repeatedly photographed; the points with same number and location in each photograph are used (19 points every picture) and image coordinates measured by same operator. The season for adopting these steps is due to the fact that the influences of changes of internal and external orientation for camera are correlated each other. The application of same photographic condition could be deemed that the effect of change of external orientation is basically same for each film. Equally, the selection of similar number and location of control points and the observation by same operator could be thought that the effects of the distribution of control points and the identification and measurement errors of picture points are primarily similar for each film too. Thus it is good for us to compare the relative variation of parameters (including the lens distortion coefficients) of non-metric camera computed by each film and appraise their stability in the process of photography of all film roll. The film are measured on the large tool microscope which can read by estimate the coordinate up to 0.1μm. Then the solution is done with following procedure

(1) correction of film deformation

$$x=x'(dx'/dx), \quad y=y'(dy'/dy)$$

Where x', y', measured image coordinates; x, y, corrected image coordinates; dx, dy, frame spans measured in film along the lines of x and y; dx', dy', corresponding practical frame spans of camera.

(2) The internal and the external orientation of camera are calculated by the space resection with a single photograph:

$$x-x_o+\Delta x= f\frac{a1(X-Xs)+b1(Y-Ys)+c1(Z-Zs)}{a2(X-Xs)+b2(Y-Ys)+c2(Z-Zs)}$$

$$y-y_o+\Delta y= f\frac{a3(X-Xs)+b3(Y-Ys)+c3(Z-Zs)}{a2(X-Xs)+b2(Y-Ys)+c2(Z-Zs)}$$

where $\Delta x=k1(x-x_o)r^2$, $\Delta y=k1(y-y_o)r^2$, $r^2=(x-x_o)^2+(y-y_o)^2$. Every symbol in equation is known to all.

The photographs are measured and calculated about three intervals. The computational results are listed in table 1 and 2 separately

Table 2 Principal distance and lens distortion of "seagull"4D

NO. of film	1	4	6	9	12
f(mm)	75.820	75.883	75.831	75.879	75.850
$k1\cdot10^{-6}$	4.730	5.480	5.938	6.113	5.835
residual(mm)	0.016	0.014	0.014	0.014	0.013

Note * The residual of point means the standard error estimated by the coordinate residuals of image points in space resection computation according to equation $m=\pm\sqrt{m_x^2+m_y^2}$

** The coordinates of principal point is not listed in table because there aren't collimation marks in camera and a known point is used to be origin in computation.

2.3 Discussions

2.3.1 The effect of lens distortion in non-metric camera: Based on the results calibrated above, The effect of lens distortion of two non-metric camera made in China is shown in table 3, in which the data of a Japanese camera is also given for comparison.

Table 3 The Mean Calibrated Data and The Biggest Influence of lens Distortion of Three Camera

Model of camera	formal (mm·mm)	Princ. dis. (mm)	Pho. dis. (m)	Distor. coef. (k1)	biggest δr influence (mm)
MAMIYA C330 (Japan)	36·24	55	6	$1.2\cdot10^{-5}$ *	0.095
Seagull DF-1 (China)	36·24	58	6	$3.7\cdot10^{-5}$	0.294
Seagull 4D (China)	55·55	75	6	$5.6\cdot10^{-6}$	0.208

*The data is supplied by photogrammetric Department of Wuhan Technical University Of Surveying And Mapping

Table 1 Principal distance and lens distortion of "seagull" DF-1

NO. of film	4	7	11	14	17	20	22	24	27	30	32	36
f(mm)	58.765	.786	.843	.853	.802	.801	.811	.840	.802	.840	.795	.832
$K1\cdot10^{-5}$	3.510	.858	.728	.653	.710	.675	.845	.774	.557	.669	.668	.791
residual(mm)	0.007	.007	.008	.006	.008	.007	.008	.008	.005	.007	.008	.009

It is shown from table 3 that the influence of lens distortion for three cameras are considerable.The camera "seagull" DF-1 135, consisting of six pieces of four groups of lenses, belongs to a good quality of amateur camera in China, but its distortion influence is 3 times bigger than that of MAMIYA of Japan and bigger than that of "seagull" 4D 120 too. If these cameras are immediately applied to photogrammetry such as stereophotogrammetry, the accuracy of determined object point is low from the computational results using the estimation formula of stereophotogrammetric accuracy $\Delta Y=Y^2.m_p/Bf$ and letting Y=10m, B=1.2m and $m_p = \delta r$(table 4). Consequantly, the lens distortion must be calibrated and corrected in photogrammetry in order to expand the practical value of non-metric camera.

Table 4 Stereophotogrammetric Accuracy Using the Non-metric Camera Immediately

Model of camera	ΔY (mm)	Y (m)	Relative accuracy
MAMIYA C330	144	10	1/69
Seagull DF-1	422	10	1/24
Seagull 4D	231	10	1/43

2.3.2 Analysis of the average principal distance and lens distortion of non-metric camera: The average principal distance ($\bar{f}$) and lens distortion coefficient ($\bar{k}1$) for two kinds of camera can be obtained from table 1 and 2, the standard errors (m_f and m_{K_1}) are estimated from the difference between average and each computational value, and the biggest displacement ($\delta r_m = m_{K_1}(x-x_o)r^2$) due to the standard errors of distortion coefficient are derived. The results are in table 5.

Table 5 Results After Correcting by Mean Distortion Coefficient

Model of camera	$\bar{f}$ (mm)	$\bar{K}1$ ($\cdot 10^{-5}$)	m_f (mm)	m(k1) ($\cdot 10^{-6}$)	δr_m (mm)
"Seagull"DF-1	58.814	3.703	0.027	1.05	0.008
"Seagull" 4D	75.853	.5619	0.028	.548	0.019

The under knowledges could be found from above tables:

(1) The changes of principal distance for two cameras are near. The standard error of changes are 0.027mm and 0.028mm respectively. The coordinate error on photograph due to the change of principal distance is δx=0.007mm for camera 135, and δx=0.008mm for 120, estimated by formula $\delta x=(x/f)\cdot mf$.

(2) The changes of distortion coefficient (k1) of film 135 in the process of photography for all film roll are small. Comparing with the mean distortion coefficient ($\bar{k}1$), the standard error of distortion coefficient changes (mk1) is decreased by about 34 times. The biggest effect (δrm) of remainder distortion after correcting all film roll by mean distortion coefficient is only 0.008mm. While the camera after correction of distortion is applied to stereophotogrammetry, the error of determined points ΔY equals 11.4mm and the relative accuracy can attain to 1/880 in photographic distance 10m and base 1.2m.

(3) The changes of distortion coefficient for all film roll in camera 120 are greater than that in 135. Comparing with the mean distortion coefficient, standard error of these changes is decreased by about 9 times. The biggest effect of remainder distortion after correcting all film roll by mean distortion coefficient is 0.019mm. In same case, the error of determind points ΔY equals 21.1mm and the relative accuracy achieves to 1/470 while the camera after correction of distortion is used for stereophotogrammetry.

(4) Generally speaking, it would seem that the effect of the remainder distortion in camera with greater lens distortion after correction is higher than that in camera with smaller lens distortion. But from our results,it is the contrary situation that the accuracy of camera 135 after correction is better than 120. The average residual of image points obtained by residual of resection (table 1 and 2) is 0.007mm for camera 135 and 0.014mm for 120. The accuracy of the latter is lower than that of the former by half. We suppose the reason may be that the film 120 contains the bigger unequal deformation. The film deformation is caused by the expansion and contraction and unflatness influences. The area of film 120 is larger than that of 135 as stated above. Because there is not the flattening device in non-metric camera, the area suspended in air of film 120 in photography is greater than that of 135 by three times (John,1988),and the large areal unequality could cause the large unequal deformation. Previously, the equal deformation of film is only analyzed with the change of frame span in middle part of photograph and the simple ratio correction is only added in computation. It appears that for camera 120, the unequal deformation of film has to be considered further, and corrected by the affine transformation using four or even eight collimation marks.

3 CONCLUSION

The accuracy of non-metric camera made in China can be improved considerably by means of the prior calibration to determine and correct the average lens distortion and the film deformation. Thus by this method, the non-metric camera could be immediately applied to some photogrammetries with middle and low accuracy, like the metric camera with lens or without control points. Comparing with calibration in operation, the way of the prior calibration and correction could even more contribute to the popular application of non-metric camera.

The lightweight stereocamera developed by our way has the characters of the uncomplicated structure, the convenient utilization and the more stable relative orientation (Wang,1988). It can be used in measurements of the geology, the traffic accident, the criminal scene, the simple and rapid architecture and the small areal topography as well as the seismology, having the wide prospect of application to the close range photogrammetry.

Reference

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