ANALYZE OF MATHEMATICAL MODELS FOR DIGITAL CAMERA CALIBRATION

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ABSTRACT:

By development of digital camera technologies and some capabilities of these cameras, development of models to contribute these capabilities for close range photogrammetry needed. With these high resolution images and many images that can be derived from an object we can get more accurate and early 3D map of object. This benefit could be implementing in industrial photogrammetry to control quality of this products by low cost and equipment. First step in close range photogrammetry routine is camera calibration. All recent digital cameras do not have any complete information from distortion of camera lens and unfitness of CCDs. Therefore obtaining some information about digital camera parameters is necessary. After calibration of cameras we can get accurate information from images and combine image observations to obtain 3D-models based on analytical photogrammetry methods. The accurate 3D-model could help manufacturers to control quality of industrial products. In this paper we design a test field for extracting accurate parameters of digital camera. We select a 3D part of building and labelling it with some targets. Precise coordinates of these points derived by accurate device. In some calibration projects sometimes physical parameters of camera derive. But in our project after obtaining physical parameters of camera by additional parameters method we obtain some mathematical parameters by rational functions. Wherever collinearity equation requires suitable initial values then parameter definition by rational function may be very useful in this matter. Presenting a linear model for camera calibration could be easier and comfortable. Therefore we can evolve this method for self calibration. In this case, without obtaining feasible initial value, we can compute both camera parameters and exterior parameters of images.

1. INTRODUCTION

Camera calibration is a very important stage in photogrammetry and it should be applied to each image before to could extract exterior orientation parameters of images. In such amateur camera and professional ones the calibration parameters are unknown. For this matter some calibration methods were applied to set of images derived from object or calibration pattern and then interior parameters determined.

Calibration process could be solved with previous studies about it such as Brown and Ebner parameters. These parameters should be added to collinearity equation or DLT (Direct Linear Transformation) and solved by least square estimation. This nonlinear equation must linearized and for computing, feasible initial value required.

DLT method often used for calibrated coordinates of two images but for calibration of camera we need additional parameters. In most cases additional parameters added to left part of equations. We added some similar parameters to numerator and denominator of DLT equations and make it a rational function with special additional parameters. We add third degree, fifth degree and seventh degree of X, Y and Z to each numerator and denominator. For testing the behaviour of each parameter we apply each parameter separately. In each stage residuals of errors in image points plotted.

2. CASE STUDY

The images derived for test captured with NIKON D80 camera from targets those assembled on the conjugate of walls. In this research the 3D based formula is used. For this reason we should have a set of 3D object points. Assembling of targets in three conjugate faces is for enabling 3D coordinate for calibration points. Coordinates of each point was surveyed with Leica total station with 2 PPM accuracy. Images captured in some location around this field. Coordinate of target points of each image determined. Now we have a set of image measured points and object coordinates of these points. In figure 1 a 3D plot of measured point are displayed.

3. EXPERIMENTAL RESULT

We applied DLT method without any additional parameter in the first step (equation 1). In three images that taken from these points some residuals derived in points. One sample of these images is shown in Figure 2. For the second stage three third order parameters added to numerator and denominator of DLT equation (equation 2) and then residuals plotted. In the stage three five order parameter added to equations and in the fourth stage seven degree parameters added. The RMSE of image points in these four stages listed in Table 1 and one plot of residuals is shown in Figure 3.

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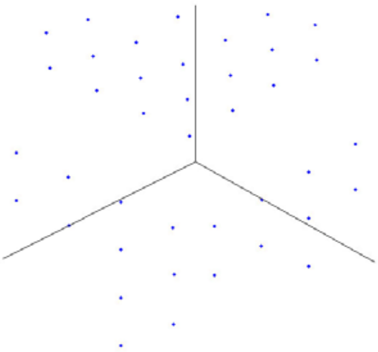

Figure 1. 3D plot of object points

$$x = \frac{a_1X + a_2Y + a_3Z + a_4}{c_1X + c_2Y + c_3Z + 1} \qquad (1)$$
$$y = \frac{b_1X + b_2Y + b_3Z + b_4}{c_1X + c_2Y + c_3Z + 1}$$

$$x = \frac{a_1X + a_2Y + a_3Z + a_4X^2 + a_5Y^2 + a_6Z^2 + a_7}{c_1X + c_2Y + c_3Z + c_4X^2 + c_5Y^2 + c_6Z^2 + 1} \qquad (2)$$
$$y = \frac{b_1X + b_2Y + b_3Z + b_4X^2 + b_5Y^2 + b_6Z^2 + b_7}{c_1X + c_2Y + c_3Z + c_4X^2 + c_5Y^2 + c_6Z^2 + 1}$$

Figure 2. One sample of images

	Image 1	Image 2	Image 3
DLT	1.49	1.63	1.65
First step	0.75	0.90	1.02
Second step	0.71	0.84	0.91
Third step	0.53	0.68	0.82

Table 1. List of residuals derive from four stages

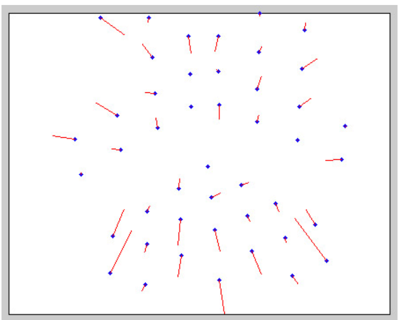

Figure 3. DLT without any added parameters applied to points

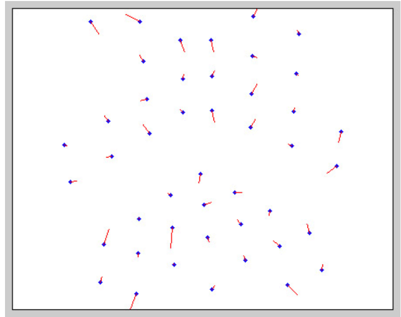

Figure 4. DLT with first 3th order parameter

As we see in table 1 residuals of measured point decrease with added parameters. This decrease in RMSE may be from adding new parameters. But with attention to Figure 3 and Figure 4 we can understand that this parameters decrease the effect of radial lens distortion.

By adding new special parameters to DLT function the problem of camera calibration could be eliminate linearly. These parameters could satisfy lens distortion deformation. The decrease in RMSE is shown in graphic plot in Figure 5.

4. CONCLUSION

In this paper we analyse radial lens distortion with this parameters. It could be examine with other camera parameters such as tangential lens distortion and finding principal point.

The intersection model of rational function could be very useful and simple procedure if the model computing solved. This idea is a good issue in this area.

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REFERENCES

Madani, M., 1999. Real-time sensor-independent positioning by rational functions. *Proceeding of ISPRS Workshop on "Direct versus Indirect Methods of Sensor Orientation"*, 25-26 November, Barcelons, Spain, pp. 64-75.

Tao, C.V., and Y. Hu, 2001. A comprehensive study of the rational function model for photogrammetric processing. *Photogrammetric Engineering & Remote Sensing*, 67(12), pp. 1347-1357.