

A RAPID AND LOW COST PHOTOGRAMMETRIC SYSTEM

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ABSTRACT:

The objective of this paper is to introduce a low cost digital close range photogrammetric system developed in our department. With this system an amateur camera is employed for stereo coverage of industrial objects. The acquired images are scanned by a desktop scanner. The digitized images are then fed into a desktop computer for photogrammetric processing developed in Matlab6.5 environment. Processing includes the solution of approximate interior orientation of the camera followed by the Moniwa self calibration space resection/intersection strategy. Imperfections due to the camera and the scanner instable geometry are catered for by the self calibration parameters. The reliability and stability of the solution of the space/resection intersection equations are secured by a priori constructed control network whose coordinates are determined by a geodetic surveying method. First experiments carried out by our photogrammetric system for measuring nearly 100 points on a piece of reinforced concrete for a civil engineering project indicates accuracy figure within 0.2 mm (rmse) for the check points.

1. INTRODUCTON

In the last two decades, industrial application of close range photogrammetry has gained considerable attention due to its cost effectiveness, simplicity of the data processing and the ease and speed of its data acquisition. As regards the economical aspects, the utilization of amateur cameras in close range applications can still further reduce the project cost provided that the required accuracy is compromised. A simple inexpensive camera may be installed in a predefined network of imaging stations for the stereo coverage of the object. The low accuracy of the amateur camera due to the large amount of lens distortions, film shrinkage, platen non-flatness, etc., can be somehow compensated by a suitable mathematical model. These models have been investigated in the field of photogrammetry and their merits and demerit have already been reported (see for example: Slama, 1980; Fraser, 1984; Fryer, 1994; Mason, 1995a,b). The main intention of this paper is to introduce the working principle of our software system "*Parmehr*" designed to serve as a low cost close range photogrammetric software package to be used for the 3D metric information extraction of small objects. The system makes use of an amateur low-cost camera in an off-line solution for the industrial photogrammetric applications. The following sections describe the overall configuration of the system. This is then followed by a report of the first series of experiments made on a piece of reinforced concrete.

2. DATA ACQUISITION

The general workflow of the data acquisition procedures is as follows:

- (1) Construction of the control network to be used for the camera calibration,
- (2) Selection of an appropriate film sensitivity,
- (3) Determination of the camera placement for the stereo coverage of the object,

- (4) Photography and processing,
- (5) Scanning,
- (6) Monoscopic image point measurement.

The camera calibration is performed by means of a control network whose coordinates are determined by geodetic surveying method. The object to be measured is placed in front of the control network in such a way that the control points cover the periphery of the object. These control points are photographed simultaneously with the object and are utilized for the determination of the camera internal geometry as well as the camera exterior orientation parameters.

The photography is carried out under the strict condition of the object and the camera being in stationary mode. Thus, the image resolution can be improved by choosing slow speed high resolution films.

Our system operates on digitized images; therefore, scanning analogue negative images is indispensable. A photogrammetric scanner may be employed for the digitization process. Alternatively, a desktop scanner may be used for this purpose provided that scanner is calibrated for its distortion pattern. Scanning pixel size is determined based on the lens/film overall resolution.

The image coordinates of the target points are measured via a cursor controlled by a mouse in a menu driven environment.

3. DATA PROCESSING

In the initial state, an approximate interior orientation is carried out by means of corners of the image frame. These corners are determined by intersecting the perpendicular lines of the frame edges. These lines are determined by a simple least squares line fitting to series of points marked on the frame edges by the operator (figure 1). The corner points then serve as quasi-

fiducial marks. The coordinates of these fiducials are then determined with respect to the nominal principal point coordinate system. The principal point is defined as the point of intersection of the lines that join two opposite quasi-fiducials (Fryer, 1993). The approximate interior orientation process is then completed by transferring the measured coordinates of the arbitrary points, acquired during the data acquisition stage, into the principal point coordinate system. This transformation is just a simple coordinate shifts in the x and y directions respectively (Cruz, 2000).

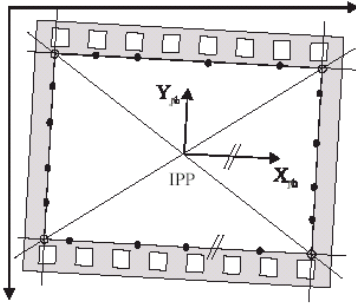


Figure 1. Interior orientation stage.

Having performed the approximate interior orientation, a simultaneous space resection/intersection is pursued using Moniwa (Moniwa, 1977) self calibration approach given by:

$$\begin{aligned} x-x_0+\Delta x_p &= -c \frac{(X-X_c)m_{11}+(Y-Y_c)m_{12}+(Z-Z_c)m_{13}}{(X-X_c)m_{31}+(Y-Y_c)m_{32}+(Z-Z_c)m_{33}} \\ y-y_0+\Delta y_p &= -c \frac{(X-X_c)m_{21}+(Y-Y_c)m_{22}+(Z-Z_c)m_{23}}{(X-X_c)m_{31}+(Y-Y_c)m_{32}+(Z-Z_c)m_{33}} \end{aligned} \quad (1)$$

in which:

- $\Delta x_p = dr_x + dp_x + dg_x$
 - $\Delta y_p = dr_y + dp_y + dg_y$
 - $dr_x = (x-x_0)(K_1r^2 + K_2r^4 + K_3r^6)$
 - $dr_y = (y-y_0)(K_1r^2 + K_2r^4 + K_3r^6)$
 - $dp_x = p_1(r^2 + 2(x-x_0)^2) + 2p_2(x-x_0)(y-y_0)$
 - $dp_y = p_2(r^2 + 2(y-y_0)^2) + 2p_1(x-x_0)(y-y_0)$
 - $dg_x = A(x-x_0)$
 - $dg_y = B(y-y_0)$
- where
- c = focal length
 - x, y = image coordinates
 - x_0, y_0 = principal point coordinates
 - X_c, Y_c, Z_c = coordinates of projection center
 - X, Y, Z = object coordinates
 - $m_{11}, m_{12}, m_{13}, m_{21}, m_{22}, m_{23}, m_{31}, m_{32}, m_{33}$ = elements of orientation matrix
 - $\Delta x_p, \Delta y_p$ = function of additional parameters
 - dr_x, dr_y = radial lens distortion correction
 - dp_x, dp_y = tangential lens distortion correction
 - dg_x, dg_y = film deformation correction
 - K_1, K_2, K_3 = radial lens distortion parameters
 - p_1, p_2 = tangential lens distortion parameters
 - A, B = film deformation parameters

The self calibration parameters are intended for the modeling of remaining errors of the interior orientation parameters as well

the imperfections of the internal geometry of the camera under the condition that the camera internal geometry is time invariant.

For the solution of the self-calibration equations, approximate values for the unknown parameters are required. This is achieved by a direct linear transformation (DLT) method (Abdel-Aziz, 1971; Cattafesta, 1996). The well-known DLT is given by:

$$\begin{aligned} x &= \frac{L_1X + L_2Y + L_3Z + L_4}{L_9X + L_{10}Y + L_{11}Z + 1} \\ y &= \frac{L_5X + L_6Y + L_7Z + L_8}{L_9X + L_{10}Y + L_{11}Z + 1} \end{aligned} \quad (2)$$

where L_1, \dots, L_{11} = transformation coefficients
x, y = image coordinates
X, Y, Z = object coordinates

The approximate values for the exterior orientation parameters are then calculated by:

$$\begin{aligned} \begin{bmatrix} X_c \\ Y_c \\ Z_c \end{bmatrix} &= - \begin{bmatrix} L_1 & L_2 & L_3 \\ L_5 & L_6 & L_7 \\ L_9 & L_{10} & L_{11} \end{bmatrix}^{-1} \begin{bmatrix} L_4 \\ L_8 \\ 1 \end{bmatrix} \\ \omega &= \tan^{-1}(-L_{10}/L_{11}) \\ \phi &= \sin^{-1}\left(-L_9/\sqrt{L_9^2 + L_{10}^2 + L_{11}^2}\right) \\ \kappa &= \cos^{-1}\left((L_1 - x_0L_9)/(c \cdot \cos\phi \cdot \sqrt{L_9^2 + L_{10}^2 + L_{11}^2})\right) \end{aligned}$$

where X_c, Y_c, Z_c = coordinates of projection center
 ω, ϕ, κ = orientation angles of camera

4. TEST RESULTS

Our system is evaluated by measuring nearly 100 points located on a piece of reinforced concrete for a civil engineering project.

A Zenit 122 amateur camera conducts data acquisition stage (figure 2). The control network is established by series of regularly distributed target points fixed on a framework. The coordinates of these points are determined by the Sokkia Power Set 1000 total station using reflector sheets. A posteriori evaluation indicates accuracies of ± 0.1 mm and ± 1 second for the distance and the angle measurements respectively.



Figure 2. Zenit 122 amateur camera.

The final accuracy for the measured coordinates of the points is within 0.2 mm (rmse) evaluated on the check points.

5. CONCLUSION

The first experiment conducted by our system reported in the preceding section indicates that a low cost photogrammetric system can indeed perform the 3D coordinate extraction reliably by a self-calibration collinearity model that incorporates calibrating targets.

The functionality and the user friendly environment of our system are under further development and enhancement. More details about the enhanced version of the system will be reported in due course.

6. REFERENCES

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