# EFFICIENT CALIBRATION OF AMATEUR DIGITAL CAMERA AND ORIENTATION FOR PHOTOGRAMMETRIC APPLICATIONS

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**Commission Youth Forum**

**KEY WORDS:** Photogrammetry, Calibration, Digital, Camera, Image, Cost, Software

**ABSTRACT:**

The change in photogrammetry from analog to digital means a change from film to CCD or CMOS sensor, and real-time imaging became possible. In particular, amateur digital cameras have been receiving attention as convenient equipment in digital photogrammetric fields since the numbers of pixel for amateur digital cameras have been amazingly increased by modern semiconductor and digital technology. As a result, convenient photogrammetry using amateur digital cameras are expected to contribute enormously to digital photogrammetric field. However, ground control points are needed for camera calibration, which requires huge labor and time for measuring ground control points.
Under these circumstances, the authors developed a calibration method without ground control points. However, some problems still remain. For example, the above calibration method is necessary to calculate interior orientation parameters such as focal length, lens distortion, principle points, and interior orientation should be performed previously using test target or test sheet.
In order to resolve the above problems, effective calibration method which does not need ground control points nor previous interior orientation procedures are discussed in this paper.

## 1. INTRODUCTION

Amateur digital cameras are expected to contribute enormously to digital photogrammetric field, and there are various photogrammetric software on the market to perform 3D measurement using amateur digital camera. However, ground control points or previous interior orientation procedures are needed for camera calibration.
In order to evaluate amateur digital camera, performance evaluation for armature digital camera were investigated by the authors(Kunii & Chikatsu, 2001). Furthermore, in order to resolve the above restrict problems, the authors have been concentrating on developing the convenient photogrammetric software, and software for low-cost digital photogrammery "3DiVision" was designed to perform convenient 3D measurement using amateur digital cameras(Chikatsu & Kunii, 2002), and an application was discussed(Nakada & Chikatsu, 2003). Figure 1 shows calibration concept of the 3DiVision.
However, previous interior orientation procedure is still issue for practical 3D measurement using amateur digital camera. Under theses circumstances, calibration method using triplet images are developed in this paper.

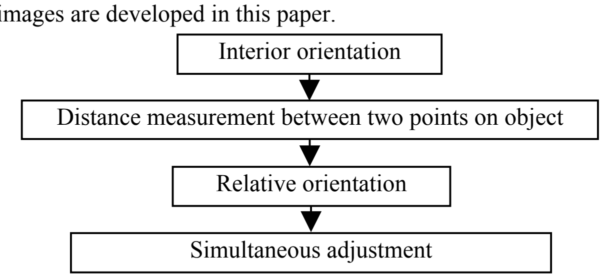


Figure 1. Concept of 3DiVision

## 2. CALIBRATION PROCEDURE

In order to remove previous interior orientation procedures using test target or test sheet, triplet images are taken from left, center, and right position. Figure 2 shows concept of imaging for triple image, and detail calibration procedures are as follows:
(a) Relative orientation using left and right image is performed. The focal length is assumed to be a nominal value, and neglect lens distortion at this stage.
(b) The characteristic 9 points which are common points to triplet images are selected, and these 9 points are defined as a temporal control points.
(c) Relative 3D coordinate to the temporal control points are calculated by using the calculated relative orientation parameters.
(d) Self-calibration for the center image is performed using relative 3D coordinate.
(e) Exterior orientation parameters for the center camera in relative coordinate system are calculated, but computed interior orientation parameters (f(focal length), $x_0$,$y_0$(principal point), $a_1$,$a_2$,$a_3$,$a_4$(scale factor), $k_1$(lens distortion parameter)) are defined as common to the three images.
(f) All of the calculated exterior orientation parameters for the left, center, right camera, 3D coordinates for the temporal control points and the interior orientation parameters are assumed to be initial valus.
As a next stage,
(g) Self-calibration for the three images are performed simultaneously using collinearity condition.
(h) Relative 3D coordinates to each measurement point within the object field are calculated.

(i) All points include temporal points are converted into the absolute coordinate from relative coordinates by using the distance (D) between two points on object field.

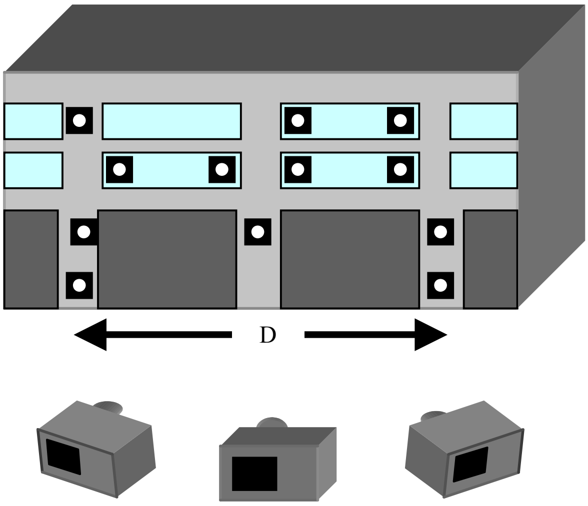


Figure 2a. Imaging of triple image.

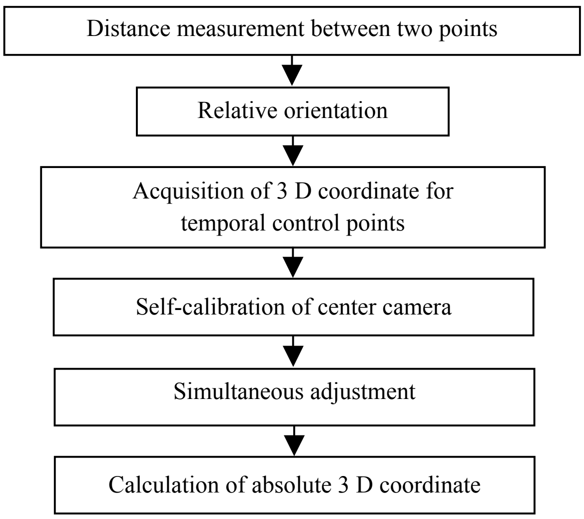


Figure 2b. Calibration procedures

Following equation shows collinearity equations,

$$\left.\begin{aligned} F &= (x - x_0)(1 + k_1 r^2) \\ &\quad + f\frac{m_{11}(X - X_0) + m_{12}(Y - Y_0) + m_{13}(Z - Z_0)}{m_{31}(X - X_0) + m_{32}(Y - Y_0) + m_{33}(Z - Z_0)} \\ G &= (y - y_0)(1 + k_1 r^2) \\ &\quad + f\frac{m_{21}(X - X_0) + m_{22}(Y - Y_0) + m_{23}(Z - Z_0)}{m_{31}(X - X_0) + m_{32}(Y - Y_0) + m_{33}(Z - Z_0)} \end{aligned}\right\} \quad (1)$$

where: $(X,Y,Z)$ are 3D coordinate for temporal GCP, $(X_0,Y_0,Z_0)$ are coordinate for exposure station, $(x, y)$ are image coordinates of temporal GCPs, $(x_0, y_0)$ are principal coordinate, $r$ is distance from principal point to image point, $k_1$ is lens distortion parameter, and $m_{ij}$ are rotation matrixes.

Image coordinate are transformed by following equations.

$$\begin{aligned} u &= u_0 + a_1 \cdot x + a_2 \cdot y \\ v &= v_0 + a_3 \cdot x + a_4 \cdot y \end{aligned} \qquad (2)$$

Where, $u$ and $v$ are sensor (pixel) coordinates, $u_0$ and $v_0$ are sensor coordinate for the principal point, $x$ and $y$ are image coordinate.

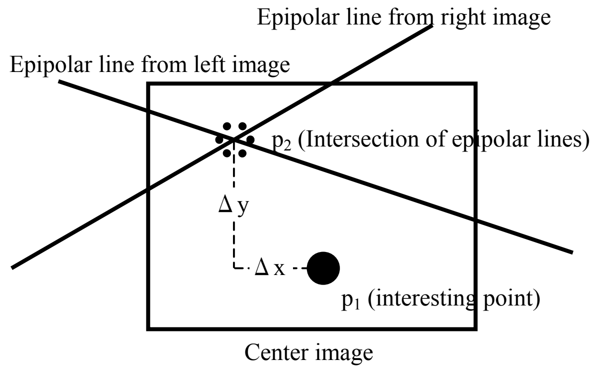


Figure 3. Correction of lens distortion

However, it should be note that the lens distortion is not considered for the computed 3D coordinates of the temporal points, nevertheless lens distortion influences 3D coordinate of the temporal control points.
In order to revise lens distortion, epipolar geometry is adopted in this paper.
Epipolar line for a temporal control point on the left image is obtained on the center image, similarly epipolar line for the same point on the right image is obtained on the center image. The correction of lens distortion is performed using these epipolar lines since two epipolar lines should be intersect at the same point on the center image if there are no lens distortion. In this method, the lens distortion was corrected by calculating the orientation parameters to minimize the difference between intersection point ($p_2$) and interesting point ($p_1$) at the center image by following equations.

$$H = \{[(\Delta x^2 + \Delta y^2)]\} \longrightarrow \min \qquad (3)$$

Where, $\Delta x = x_1(1+k_1r_1^2) - x_2(1+k_1r_2^2)$
$\Delta y = y_1(1+k_1r_1^2) - y_2(1+k_1r_2^2)$

Figure 3 shows the concept of the correction for lens distortion using epipolar geometry.

## 3. EXPERIMENTATION

In order to evaluate the calibration method which is proposed in this paper, triplet images were taken using amateur digital camera CP-900Z(EPSON). Figure 4 shows appearance of the CP-900Z, and Table 1 shows the specifications. Table 2 shows imaging conditions and Figure .5(a)-(c) shows the triplet images. 17 circular points are temporal control points and check points. 3D coordinate for these points were measured by the total station MET2NV(SOKKIA MET2NV, distance accuracy ± 1mm, angle accuracy ± 2″ ), and image coordinate for the points are given as the center of area gravity by image processing. Table 3 shows the exterior orientation parameters for each image, and Table 4 shows interior orientation parameters.

Figure 4. CP-900Z (EPSON)

Figure 5a. Left image

Figure 5b. Center image

Figure 5c. Right image

Table 1. Specifications of CP-900Z

| | |
|---|---|
| Sensor size | 1/1.8inch |
| Number of pixels | 3.34MegaPixcel |
| Compressed format | JPEG (Exif2.1) |
| Zoom | 7.0～20.0mm |
| Dimensions | W:108 H:89 D:65 (mm) |

Table 2. Imaging conditions

| | |
|---|---|
| Width of object | About 17m |
| Height of object | About 12m |
| Altitude | 20.7m |
| Base line | 7.0m |
| Base-height ratios | 0.34 |

Table 3. Enterior orientation parameters

| | Left | Center | Right |
|---|---|---|---|
| $X_0$ | 0mm | 5373.449mm | 11869.004mm |
| $Y_0$ | 0mm | -90.7818mm | 0mm |
| $Z_0$ | 0mm | -628.710mm | 0mm |
| $\omega$ | 0° | 0° 31′ 32″ | 2° 11′ 10″ |
| $\phi$ | 4° 1′ 5″ | -2° 22′ 18″ | -11° 55° 49″ |
| $\kappa$ | -0° 0′ 55″ | 0° 40′ 26″ | 2° 9′ 34″ |

Table 4. Interior orientation parameters

| | Calibration result |
|---|---|
| focal length $f$ | 7.1789 |
| principal point $x_0$ | 1011.288 |
| principal point $y_0$ | 773.176 |
| scale factor $a_1$ | 289.564 |
| scale factor $a_2$ | 0.078 |
| scale factor $a_3$ | 0 |
| scale factor $a_4$ | 289.811 |
| lens distortion parameter $k_1$ | $2.859 \times 10^{-8}$ |

## 4. PERFORMANCE EVALUATION

Performance evaluation is performed using RMSE for 8 check points. Result1 shows the RMSE by the proposed calibration method, and Result2 shows the RMSE by resection method using 9 GCP. Figure 6 shows horizontal error for check points.

It can be seen that horizontal accuracy is lower 5 times, and vertical accuracy is lower 2 times compare with the result of resection method with 9 GCP, but it can be expected that convenient digital photogrammetry using digital camera is achived by the proposed method because of this method doesn't need any GCP measurement on an object field nor previous interior orientation procedures.

Table 5. Accuracy

| | $\sigma_{xy}$(mm) | $\sigma_z$(mm) |
|---|---|---|
| Result1 | 12.013 | 13.762 |
| Result2 | 2.559 | 7.652 |

## 5. CONCLUSION AND FUTURE WORKS

Calibration method for convenient digital photogrammetry using triplet images which were taken by amateur digital cameras were investigated, and performance evaluation were performed in this paper. Accuracy by the proposed calibration method does not reach the accuracy which are calculated by resection method using 9 GCP.

It may be concluded that influences of lens distortion still remain, but it is concluded that low-priced, convenient digital photogrammetry using digital camera is achieved by the proposed method because of this method doesn't need any GCP measurement on an object field nor previous interior orientation procedures.

However, improvement of accuracy and efficient successive orientation for more two models are still further works.

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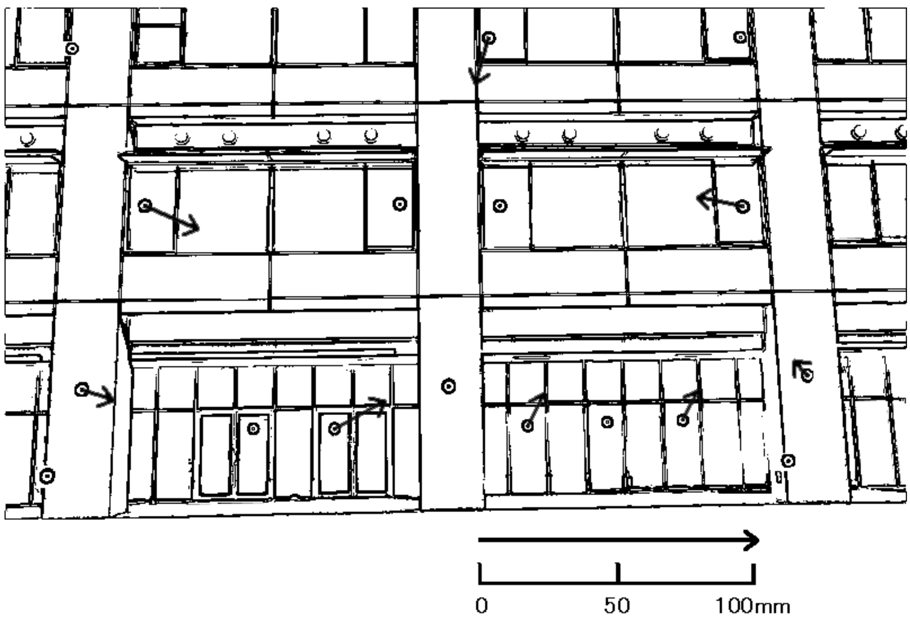


Figure 6. Error distribution