ACCURACY OF MAP DIGITIZING BY USING DIGITAL CAMERA

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ABSTRACT**:** In the past, a large accurate image scanner was used for map digitizing. The image scanner is so expensive that it is difficult to use in general. Nowadays, digital camera with 10 mega pixels can be used in many fields. In the future, such digital camera will be able to replace the image scanner. Therefore, it is important to consider an accuracy of map digitizing by using digital camera. In this study, paper map was prepared for the experiment. In the paper map, four control points and two validation points were allocated. The paper map with transparent plastic board was taken by the digital camera. Coordinates of the control points were extracted 20 times by visual interpretation. And coordinates transformation was established by two-dimensional projection transformation. Then coordinates of validation points can be calculated by the transformation. And this calculated coordinates of validation points were compared with true points. As a result, coordinate of validation points had approximately 1mm error. If distortion by the transparent plastic board is eliminated, the accuracy will be improved.

KEYWORDS: map digitizing, digital camera, two-dimensional projective transformation

1. BACKGROUND

In the past, a large accurate image scanner was used for map digitizing. The image scanner is so expensive that it is difficult to use in general. Nowadays, a digital camera with 10 mega pixels can be used in many fields and it can be obtained comparatively cheaply. In the future, such a digital camera will be able to replace the image scanner. If such a digital camera can be used as the image scanner, the integration of GIS data will be improved. Therefore, it is important to examine the accuracy of map digitizing by using a digital camera.

2. OBJECTIVES

In this study, the accuracy of map digitizing by using digital camera will be discussed. Geometric transformation is established by two dimensional projective transformation. The accuracy of map digitizing is assumed an extraction accuracy of target points.

3. CAMERA SELECTION FOR DIGITIZING

In this study, the compact type digital camera was selected. Table 3.1 shows comparison between characteristic between single-lens reflex type digital camera and compact type digital camera. The compact type digital camera has a longer range in focus than the single-lens reflex type digital camera. Therefore, the compact type digital camera was suitable for map digitizing to keep good focus.

Table3.1 Comparison table of digital camera type

Characteristic	Single-lens reflex	Compact
Size of CCD	Large	Small
Length of lens focus	Long	Short
Depth of focus	Short	Long
Depth of field	Short	Long

4. TEST MAP

4.1 Test Map

The 1/25,000 map was assumed in map digitizing so that the test map was A3 size paper in this study. In the test map, four control points (C1, C2, C3, C4) and two validation points (V1, V2) were allocated using CAD (figure 4.1).

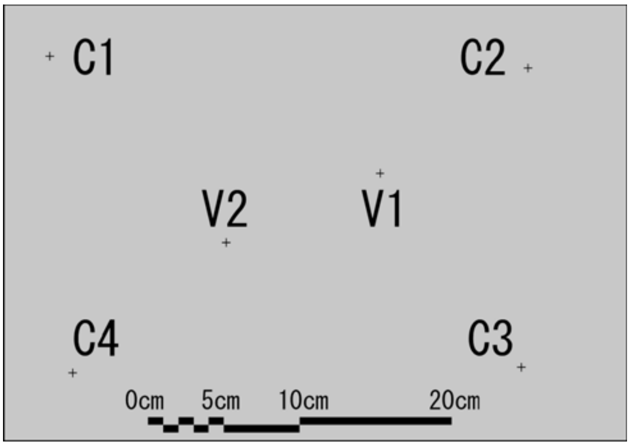

Figure4.1 Control points and validation points in the paper map

4.2 Figure of control points and validation points

Figure 4.2 showed distribution of control points and validation points. The cross figure was used and the size is 5.65mm by 5.65mm. Coordinates of control points and validation points was established as center of the cross figure.

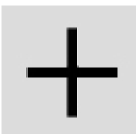

Figure4.2 Figure of control points and validation points

5. EVALUATION BY A SIMULATION

The extraction accuracy of target point can be evaluated by simulation.

5.1 Simulation Methodology

First, the camera coordinates of control points and validation points are calculated using collinear equation (equation (5.1)).

$$\begin{cases} u = -f\left(\frac{X_p}{Z_p}\right) \\ v = -f\left(\frac{Y_p}{Z_p}\right) \end{cases} \quad (5.1)$$

$$\begin{pmatrix} X_p \\ Y_p \\ Z_p \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{pmatrix}$$

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega \\ 0 & \sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} \cos\phi & 0 & \sin\phi \\ 0 & 1 & 0 \\ -\sin\phi & 0 & \cos\phi \end{pmatrix} \begin{pmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

where u and v are camera coordinates of control points and validation points; f is the focal length of the digital camera; X, Y and Z are the coordinates of control points and validation points in object space; X0, Y0 and Z0 are the position of the digital camera in object space; ω, ϕ and κ are the attitude of the digital camera;

To simulate the error of camera coordinate of the control point, random numbers in normal distribution are generated by using Box-Muller method, and then they are added to the camera coordinates of the control points. At this time the error of the control point is 0.5 mm in standard deviation and the error of the camera coordinate of the control point is 0.5 pixel in standard deviation. The camera coordinates of validation points including error can be calculated using two-dimensional projective transformation(equation (5.2)) from the camera coordinates of the control points including the error.

$$\begin{cases} x = \frac{a_1 u + a_2 v + a_3}{a_7 u + a_8 v + 1} \\ y = \frac{a_4 u + a_5 v + a_6}{a_7 u + a_8 v + 1} \end{cases} \quad (5.2)$$

where x and y are the coordinates of control points and validation points in object space; u and v are the camera coordinates of control points and validation points; a1, a2, a3, a4, a5, a6, a7 and a8 are transformation coefficients. Figure 5.1 showed flow of the simulation.

5.2 Simulation Result

Table 5.1 showed average and standard deviation of calculated error in object space by the simulation. The result showed enough accuracy for several purposes as GIS data.

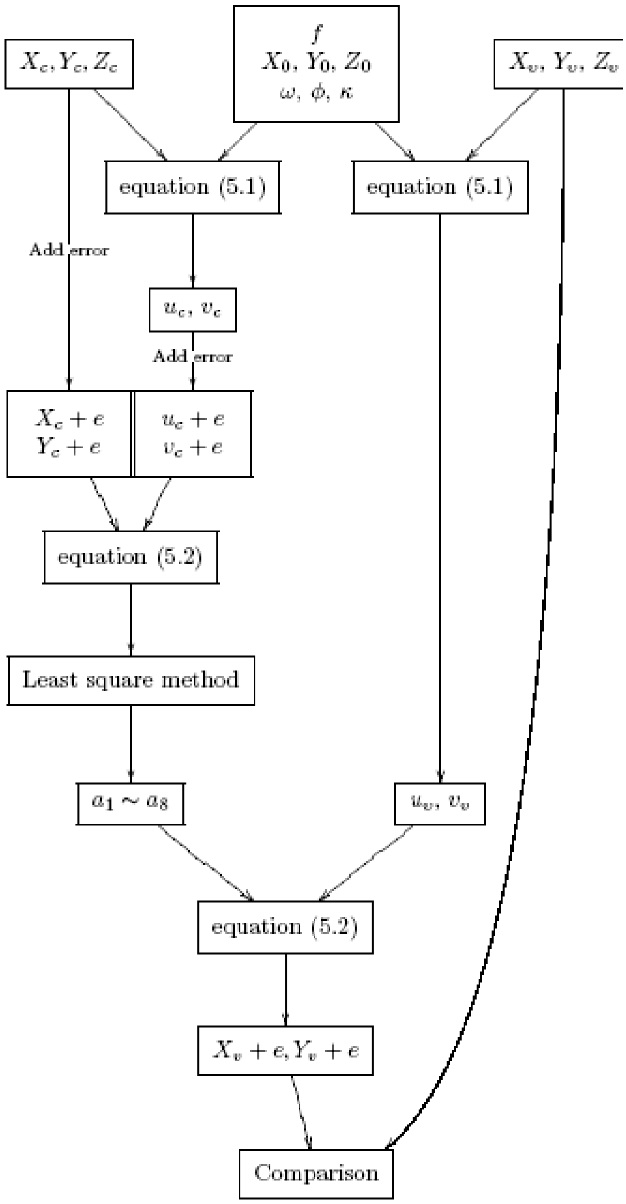

Figure5.1 Simulation flow

Table5.1 Average and standard deviation of calculated error in object space by the simulation (units : mm)

Points name	Error average	Error SD
V1	0.483	0.227
V2	0.467	0.225

6. METHODOLOGY

6.1 Camera Calibration

As a practical matter, the image which was taken the test map must be calibrated using equation (6.1). Center point of lens distortion was assumed as center point of the image. After that control points were extracted using calibrated image.

$$\begin{cases} \Delta x = -x_p + \left(k_1 r^2 + k_2 r^4\right)(x - x_p) \\ \quad + \left(r^2 + 2(x - x_p)^2\right) + 2(x - x_p)(y - y_p) \\ \Delta y = -y_p + \left(k_1 r^2 + k_2 r^4\right)(y - y_p) \\ \quad + \left(r^2 + 2(y - y_p)^2\right) + 2(x - x_p)(y - y_p) \end{cases} \quad (6.1)$$

$$r^2 = (x - x_p) + (y - y_p)$$

where Δx and Δy are revision value; x and y are camera coordinates of each pixel; x_p and y_p are center point coordinates of the image; k1 and k2 are lens distortion coefficients of radiation direction.

6.2 Conditions in the Experiments

The test map was taken by PowerShot A640 which is the compact digital camera with 10 mega pixel. Table 6.1 showed condition of digital camera when the test map was taken. The digital camera was mounted on a pedestal. Range from CCD of the digital camera to the test map is approximately 80 centimeter and test map is about parallel to the digital camera. The test map was covered 1 millimeter thickness transparent plastic board to press wrinkle. Condition of the digital camera was same condition with lens calibration. Focus was infinity, and F value was maximum to keep good focus condition. Table 6.1 showed conditions in the experiments.

Table6.1 Specification of Camera

Item	Value
Pixel number	3648*2736
F value	8.0
Focus	Infinity
Length of focus lens	7.3mm

6.3 Establishing Transformation

Camera coordinates of control points and validation points were extracted 20 times by visual Table 6.1 Specification of camera interpretation. The two dimensional projective transformation was established by least square method with 4 control points. After that coordinates of validation point in object space were calculated in object space. Then calculated validation point coordinates were compared with CAD data. Table6.2 showed experiments flow.

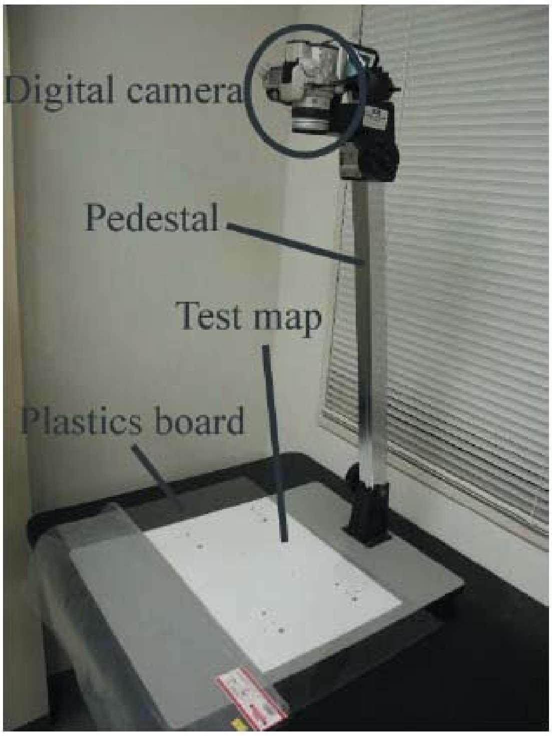

Figure6.1 Condition in the Experiments

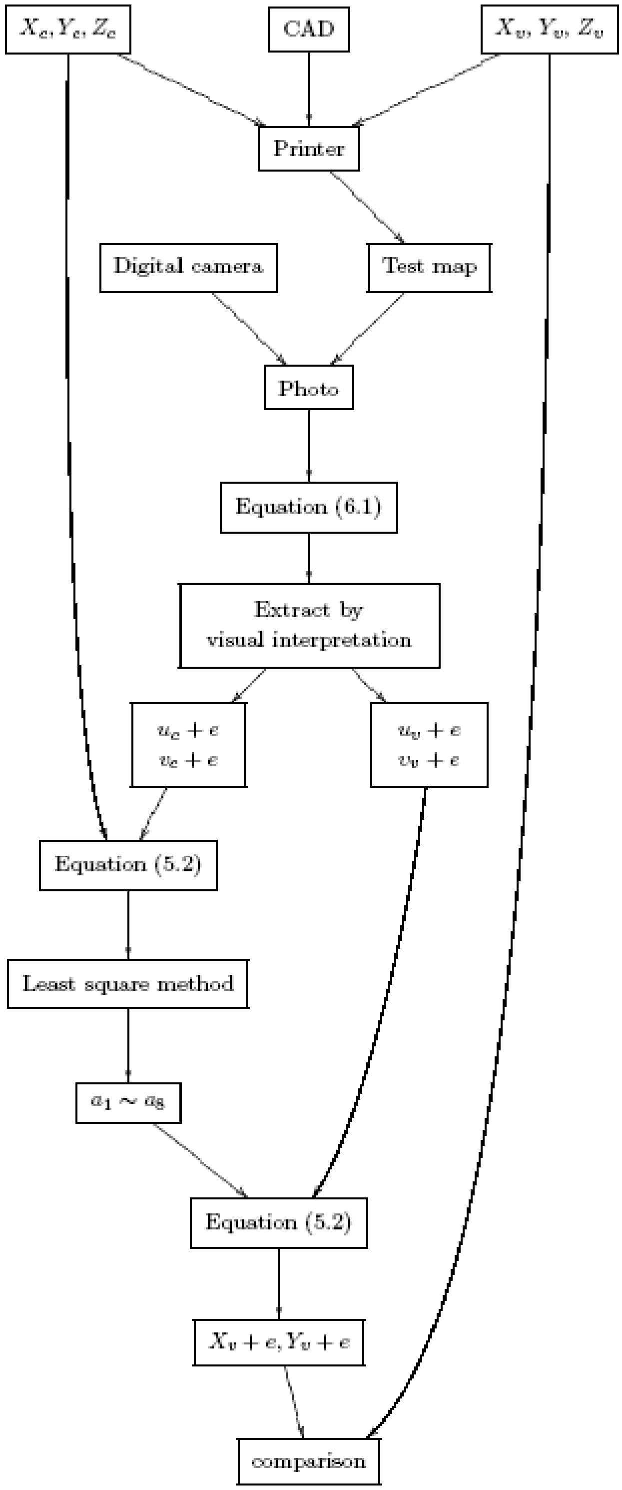

Figure6.2 Experiments flow

7. METHODOLOGY

Table 7.1 showed standard deviation of camera coordinates which were extracted 20 times. The standard deviations showed less than simulation.

Table7.1 Standard deviation of camera coordinates

Points name	SD(pixel)
C1	0.100
C2	0.040
C3	0.083
C4	0.105
V1	0.063
V2	0.092

Table 7.2 showed average and standard deviation of error in validation point in object space by experiments. The average of calculated error by experiments shows bigger than simulation. But calculated error in standard deviation by experiment showed smaller than simulation.

Table7.2 Average and standard deviation of calculated error in object space by experiments (units: mm)

Points name	Error average	Error SD
V1	1.023	0.046
V2	0.844	0.049

Covered plastic board might make distortion in the average because of refractive index.

8. CONCLUSIONS

Map digitizing by using digital camera with 10 mega pixels can extract the coordinates of target points in object space with approximately 1mm error in standard deviation. The average of calculated error in object space by experiments is bigger than simulation and the calculated error in standard deviation by experiments is smaller than simulation. As a result, refractive index of plastic board should be considered. Extraction accuracy of target point by experiments was examined in certain same situation. Therefore, various camera situations should be considered for practical map digitizing by using digital camera such as more control points, camera calibration that correspondence to various focus and various position of the digital camera.

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