ESTABLISHMENT OF CONTROL POINTS FOR DIGITAL PHOTOGRAMMETRY TO ARCHIVE 3D MODEL OF RELICS

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ABSTRACT: In a surveying of ruins, many hangovers must be quickly archived as digital data. For example, a hundred pieces of hangovers are extracted a day in Dederiyeh Cave, Syria. The detail must be recorded in each change scene for the archeologist. Digital photogrammetry is very efficient for 3D modeling. In this study, control frame is suggested to improve efficiency of digital photogrammetory. Control frame was based on polygon shape. Target of control point was located at apex of the polygon. This control frame will be efficient to setup control point. When the shape of control frame was fixed always, it is not necessary to measure 3D coordinates of all control points. Control frame was tried to design. 134,594 combination of control point were calculated. However, critical combination pattern was not found. Systematic analysis will be required to find optimum special distribution of control point.

1. BACKGROUND

Today, surveying technology is needed in archeology field. Authors joined archeological excavation investigation as surveyor. Many hangovers were measured in Dederiyeh Cave, Syria. A lot of 3D models of the hangovers were built. Figure 1 showed example 3D model of one hangover. Building 3D model spent much time because of control point measurement. Archeologist can't excavated when the photogrammetry was carried out. In the photogrammetry, some control points must be setup. The control points were measured 3D coordinates by total station accurately. This setup and measuring control points must be carried out many times when the hangovers were appeared. Therefore, quick setup and quick measurement of control points is required.

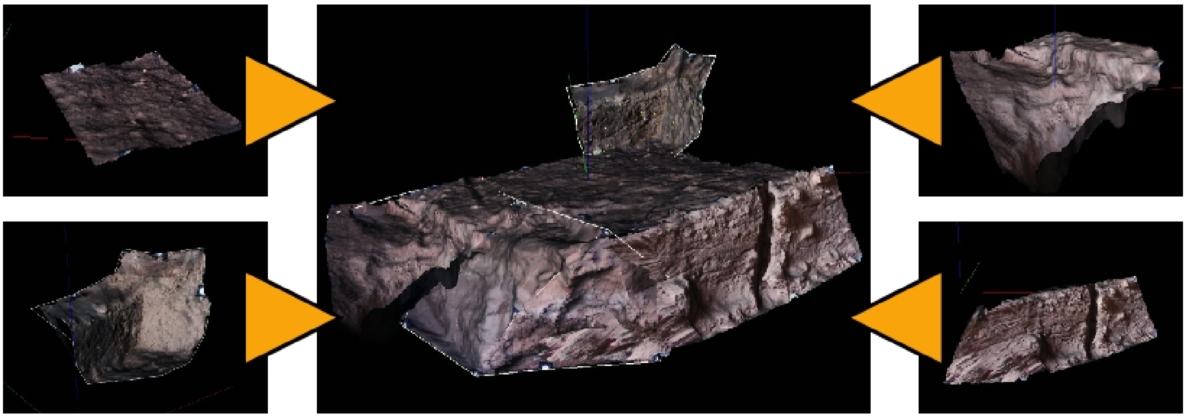

Figure 1: 3D Model of One Hangover by Topcon PI3000

In this study, control frame was tried to designed. Control frame was based on polygon shape. Target of control point was located at apex of the polygon. This control frame will be efficient to setup control point. When the shape of control frame was fixed always, it is not necessary to measure 3D coordinates of all control points.

2. OBJECTIVES

In order to design control frame, an optimum spatial distribution of control point must be found. Therefore, 24 control points were measured. These control points were located randomly. And 6 control points were selected for exterior orientation. There are 134,596 combinations to select 6 points from 24 control points.

In each combination, error of exterior orientation will calculated. The error means distance between transformed coordinate by the orientation and true coordinate at validation point. The validation point was established at the center in 24 control points.

In 134,586t combinations, the optimum combination will be found by evaluation of the error, control frame will be designed.

3. METHODOROGY

3.1 Establishment of Control Points

Figure 2 showed grid sheet for setting control points. Grid sheet was drawn in 5*5 intervals by CAD software.

Figure 3 showed 25 control points was arranged on the grid sheet, and 25 numbers were assigned. The 13th target which is center of 25 control points is used as validation point. X Y coordinates of control points are measured from position of grid. These heights were measured with steel ruler. Table 1 showed ground coordinates of control points.

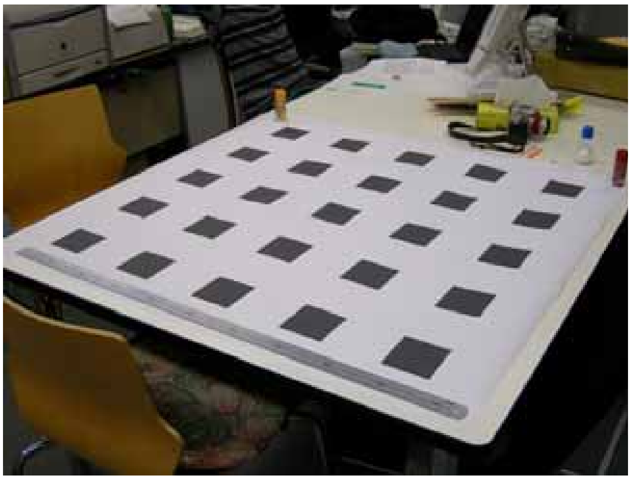

Figure 2: Grid Sheet for Setting Control Points

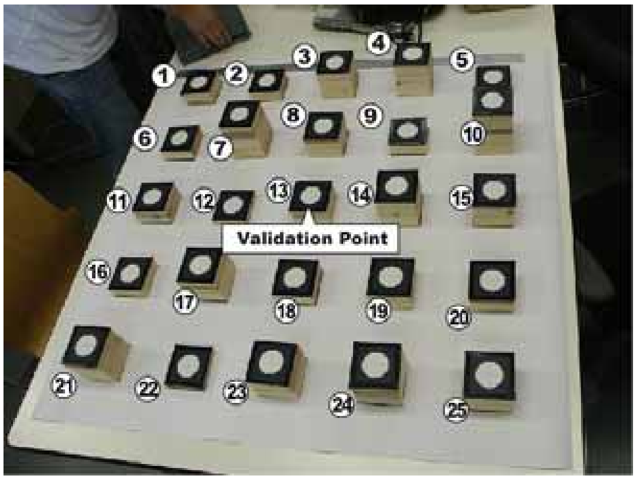

Figure 3: Arranged 25 Control Points on Grid Sheet

Table 1: Ground Coordinate of 25 Control Points

Target	X(mm)	Y(mm)	Z(mm)	Target	X(mm)	Y(mm)	Z(mm)
1	0	840	50	14	630	420	96
2	210	840	41	15	840	420	86
3	420	840	94	16	0	210	35
4	630	840	111	17	210	210	88
5	840	840	18	18	420	210	41
6	0	630	41	19	630	210	57
7	210	630	126	20	840	210	57
8	420	630	72	21	0	0	95
9	630	630	41	22	210	0	18
10	840	630	143	23	420	0	79
11	0	420	56	24	630	0	94
12	210	420	18	25	840	0	79
13	420	420	58				

3.2 How to Take Stereo Pair Photos

Figure 4 and Table 2 showed the appearance and the specification of “Minolta Dimage 7i” which is used camera in this study.

Figure 4: Minolta Dimage 7i

Table 2: Specification of “Minolta Dimage 7i”

Image Size	2560*1920(pixel)
CCD size	8.8*6.6(mm)
Focal Length	7.254494(mm)
Image Resolution	0.0034375(mm/pixel)

In this study, 2 photos were taken for experiment. These photos were taken from different angles (Figure 3). Figure 4 and 5 showed taken photos in this study.

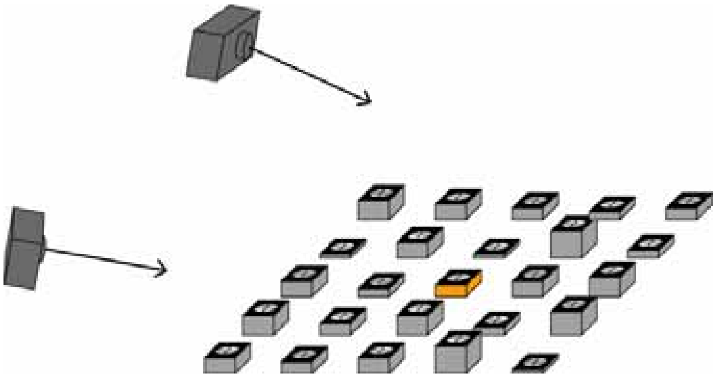

Figure 5: Outline of How to Take Photos

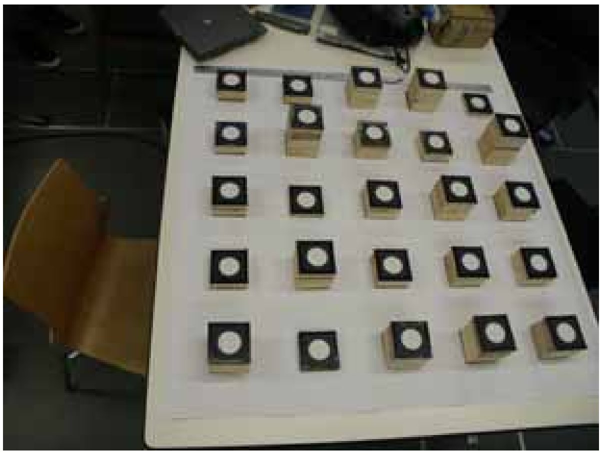

Figure 4: Taken photo of Targets from Left

Figure 5: Taken photo of Targets from Right

3.3 Orientation

First, 6 control points are selected from 24 control points for camera orientation. 134,596 combinations are calculated. Camera position (X_0, Y_0, Z_0) and camera angle (ω, φ, κ) is calculated with collinearity equation from 6 control points. Following equation is collinearity equation.

$$u = -f\,\frac{x_p}{z_p} = -f\,\frac{a_{11}(X - X_0) + a_{12}(Y - Y_0) + a_{13}(Z - Z_0)}{a_{31}(X - X_0) + a_{32}(Y - Y_0) + a_{33}(Z - Z_0)}$$

$$v = -f\,\frac{y_p}{z_p} = -f\,\frac{a_{21}(X - X_0) + a_{22}(Y - Y_0) + a_{23}(Z - Z_0)}{a_{31}(X - X_0) + a_{32}(Y - Y_0) + a_{33}(Z - Z_0)}$$

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

(X, Y, Z) ; Ground Coordinate of Target P

(X_0, Y_0, Z_0) ; Ground Coordinate of Camera Point

f ; Focal Length

(u, v) ; Photographic Coordinate of Target P on Photograph Image

a_{ij} ; Element of Rotation Matrix by $(\omega, \varphi, \kappa)$

Figure 6 showed outline of collinearity equation.

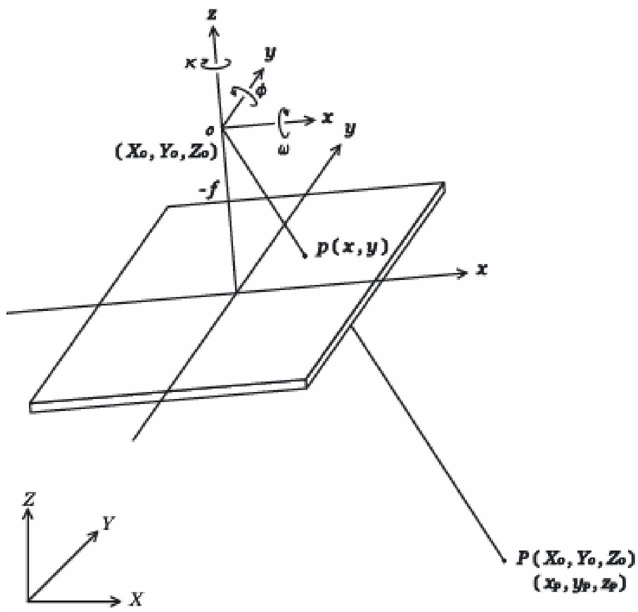

Figure 6: outline of collinearity equation

3.4 Evaluation Method of Error

When the orientation is finished, (X_0, Y_0, Z_0) and $(\omega, \varphi, \kappa)$ can be calculated. For evaluating the orientation, validation point which is the 13th target was used. When the ground coordinate of validation point are input to collinearlity equation, photographic coordinate (u, v) can be calculated. Then, error can be measured between calculated photographic coordinate and real photographic coordinate. The real photo graphic coordinate was pointed out by visual interpretation.

The orientation result in each combination pattern of control point can be evaluated by the error calculation.

4. RESULT

In table 3, good results in each combination pattern were listed. Figure 7 showed image of combination pattern of control point. There are no trend in the results.

Table 3: 10 Combination Pattern When Small Error

Combination Pattern							Photographic Cooridnate Error Left Camera X(mm)	Left Camera Y(mm)	Right Camera X(pixel)	Right Camera Y(pixel)	Left Camera Error Distance (pixel)	Right Camera Error Distance (pixel)	Average of Error Distance (pixel)
①	2	3	4	5	8	10	0.0684	-0.1577	-0.0771	-0.0448	0.1719	0.0892	0.1305
②	2	3	7	23	24	25	0.4684	0.2231	-0.0148	-0.1681	0.5188	0.1688	0.3438
③	1	2	4	5	8	11	0.2191	0.1391	-0.4279	0.1612	0.2595	0.4573	0.3584
④	1	2	3	8	9	11	-0.0439	-0.1722	-0.4591	-0.3028	0.1777	0.5499	0.3638
⑤	3	5	9	10	12	23	-0.2662	-0.0655	0.4698	0.0652	0.2741	0.4743	0.3742
⑥	4	8	10	12	17	19	0.1574	0.1452	-0.2060	-0.5292	0.2141	0.5678	0.3910
⑦	4	7	15	18	19	20	0.0335	-0.0407	0.7060	0.2225	0.0527	0.7403	0.3965
⑧	5	7	12	21	24	25	-0.5615	0.1268	-0.2813	0.0079	0.5756	0.2814	0.4285
⑨	1	4	5	6	8	11	0.0052	0.7904	0.0381	0.0599	0.7904	0.0710	0.4307
⑩	1	2	3	5	6	11	0.0474	0.4314	0.4090	-0.2351	0.4340	0.4717	0.4529

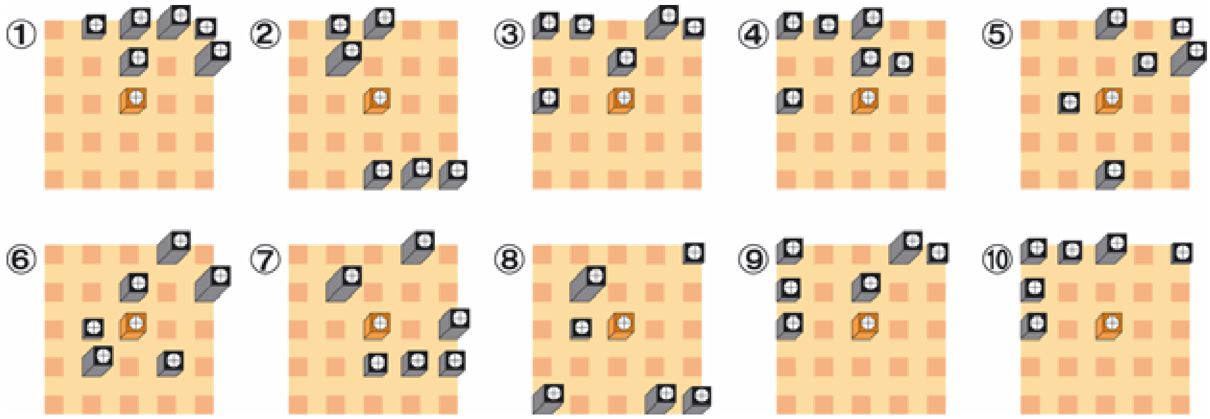

Figure 7: Arrangement Pattern at Good Result

5. CONCLUSIONS

In this study, designing control frame was tried. 134,594 combination of control point were calculated. However, critical combination pattern was not found. This time one stereo pair photograph and one distribution of 24 control points were used. Systematic analysis will be required to find optimum special distribution of control point.

6. REFERENCES

Jong Hyeok JEONG and Masataka TAKAGI, Bridge Monitoring System Using Close Range Digital Photogrammetry and Web GIS, Proceeding of the 27th Asian Conference on Remote Sensing, Ulaanbaatar MONGOLIA, 2006

Jong Hyeok JEONG, Crack Monitoring Using a Digital Camera and in Image Total Station, Proceeding of the International Symposium on Social Management Systems, 2007

Shunji MURAI (1983) “Kaiseki Shasin Sokuryo” [Analytical Photogrammetry], Japan Society of Photogrammetry and Remote Sensing, pp.46-56

KONICA MINOLTA HOLDINGS, INC., “MINOLTA Dimage 7i User’s Manual”