

INTEGRATION OF 3D MODELS FROM MULTIPLE CAMERA STATIONS

H. Yanagi ^a, H. Chikatsu ^b

^a Architecture, Civil and Building Environmental Engineering, Graduate School of Advanced Science and Technology, Tokyo Denki University, Hatoyama, Hiki-gun, Saitama 350-0394, JAPAN - 07uda02@ms.dendai.ac.jp

^b Department of Civil and Environmental Engineering, Tokyo Denki University, Hatoyama, Hiki-gun, Saitama 350-0394, JAPAN - chikatsu@g.dendai.ac.jp

KEY WORDS: Digital cameras, 3D measurement, 3D modeling, Multiple images, Lagrange's method of undetermined coefficients

ABSTRACT:

Recently, the pixel numbers of consumer grade digital cameras have been increasing rapidly because of developments in semiconductor and digital technologies, and many low-priced consumer grade digital cameras are available on the market. In these circumstances, there is a requirement for performing convenient 3D measurement using consumer grade digital cameras in various application fields. However, there is issue for convenient 3D modeling from multiple images which are taken multiple camera stations.

In order to resolve the issue, Lagrange's method of undetermined coefficients is applied for panoramic modelling. The most remarkable point of the adjustment is its ability to combine multiple models without tie points that have exact 3D coordinate.

1. INTRODUCTION

Recently, digital documentation of cultural heritages has been receiving attention. In order to document for cultural heritages, 3D measurements have been conducting by photogrammetry, and terrestrial laser scanners are often used for this purpose since they can be used to acquire 3D data in real-time (Akca, et al., 2007). However, there is issue for convenient 3D modeling from multiple images which are taken multiple camera stations. In order to resolve the issue, bundle adjustment is extensively used in photogrammetry for reconstructing a 3D model, and iterative closest point (ICP) algorithm has been used in the field of computer vision for the registration and integration of multiple images (Bergevin, 1996). However, there is a problem with bundle adjustment: while performing 3D measurement, the position of the ground control points (GCPs) must be acquired by a control point survey. Similarly, there is a problem with the ICP algorithm: the initial alignment is set manually.

On the other hand, recently, the pixel numbers of consumer grade digital cameras have been increasing rapidly, and many low-priced consumer grade digital cameras are available on the market. Thus, convenient 3D measurement using consumer grade digital cameras are enormously expected in various application fields. Therefore, the performance evaluations for consumer grade digital cameras have been investigated from the viewpoint of digital photogrammetry (Fraser, 1997, Kunii, et al., 2001, Noma, et al., 2002; Habib, et al., 2003).

In these circumstances, convenient 3D measurement using consumer grade digital cameras and convenient integrated method of multiple images without GCPs are expected.

The authors have been attempting to develop convenient 3D measurement software called "3DiVision" by using consumer grade digital cameras (Chikatsu, et al., 2006). 3DiVision has the capability to perform exterior and interior orientation simultaneously without GCPs.

With this motive, in this study, the authors have attempted to develop a convenient integration method using Helmert transformation and Lagrange's method of undetermined coefficients for independent models for different coordinate systems obtained by 3DiVision.

2. LAGRANGE'S METHOD OF UNDETERMINED COEFFICIENTS

Generally, in a control point survey, the start point does not correspond with the end point when observed from reference point to next reference point in an enclosed place (Figure 1). However, the start point must ideally correspond with the end point. In this case, the error of closure is adjusted by Lagrange's method of undetermined coefficients by using latitude distance and longitude distance, which are calculated from the positions of two adjacent observed points (Figure 2). In this study, such adjustment was used for integrating models.

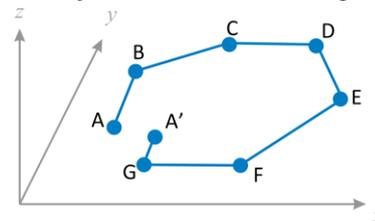


Figure 1 Observed points (without adjustment)

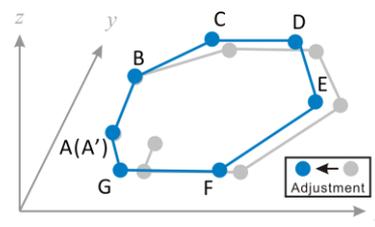


Figure 2 Adjusted points

3. INTEGRATION OF MODELS

3.1 Integration of models using Lagrange's method of undetermined coefficients

In this study, the fundamental procedure for integrating models using Lagrange's method of undetermined coefficients was implemented in the following steps.

Step 1

Pass points from the models adjoining each model are extracted. In this case, the number of points to be extracted from each model is the same (Figure 3).

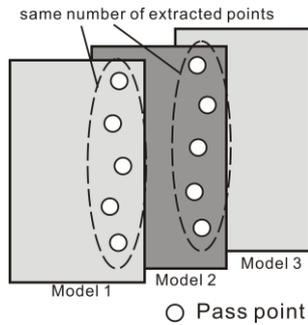


Figure 3 Extracted pass points

Step 2

Independent models for different coordinate systems are integrated into the same coordinate system by the Helmert transformation (equation (1)) using extracted points.

$$\left. \begin{aligned} x' &= m a_{11}x + m a_{12}y + m a_{13}z + x_0 \\ y' &= m a_{21}x + m a_{22}y + m a_{23}z + y_0 \\ z' &= m a_{31}x + m a_{32}y + m a_{33}z + z_0 \end{aligned} \right\} \quad (1)$$

Where

(x', y', z') : Transformed point, (x, y, z) : Initial point,

(x_0, y_0, z_0) : Translation value, m : Scale, $a_{11} \sim a_{33}$: Rotation matrix

Step 3

Loops having the same number of extracted points are formed (Figure 4). However, the loops are not yet closed. For example, five points are extracted in each model shown in Figure 3. Therefore, five loops are formed.

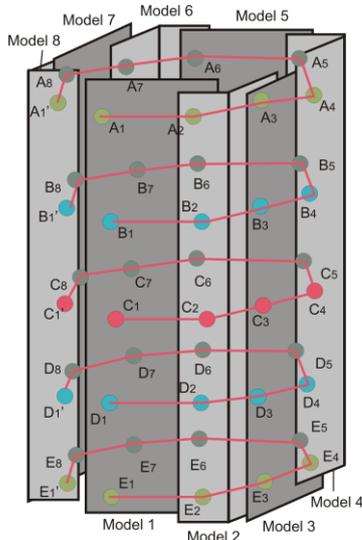


Figure 4 Formation of open loops

Step 4

Each open loop is adjusted using Lagrange's method of undetermined coefficients.

Step 5

Independent models are integrated by the Helmert transformation (equation (1)) using the adjusted points in each loop (Figure 5).

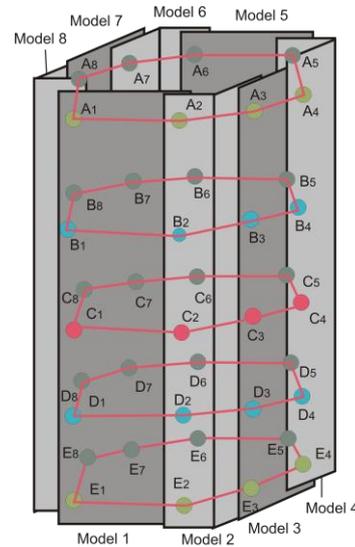


Figure 5 Integration of models

3.2 Simulation

In order to verify the integration of models, sample data formed virtually were investigated. Figure 6 shows the sample data used in this study. Eight independent models (Model 1–Model 8) were formed.

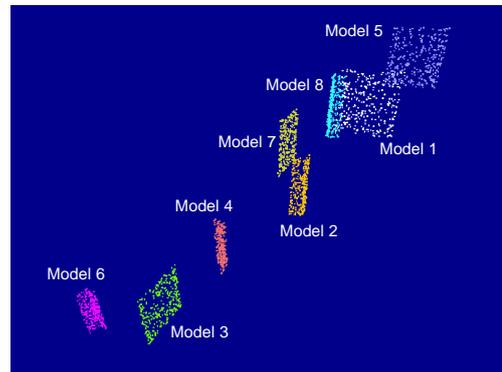


Figure 6 Sample data

Figure 7 shows the result of integration of models using the Helmert transformation. Figure 8 shows an enlarged image of the circle marked in Figure 7, from a different angle. From Figure 8, it is clear that Model 8 does not correspond with Model 1.

Figure 9 shows the result of integration of models using the method described in section 3.1. Figure 10 shows an enlarged image of the same part (similar to that enlarged in Figure 8) shown in Figure 9.

From this figure, it is clear that Model 8 corresponds with Model 1.

Therefore, the simulation results show that the proposed method is effective in the integration of independent models.

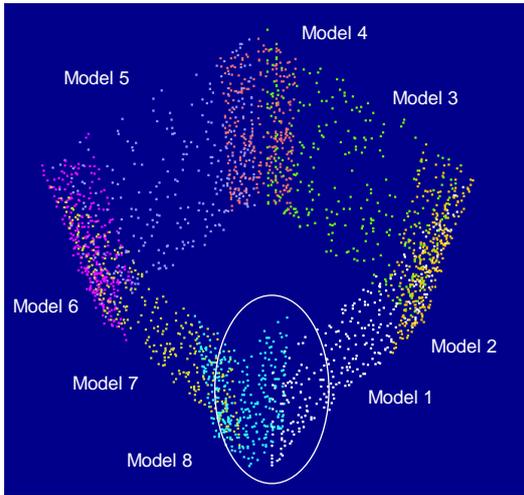


Figure 7 Integration of models using Helmert transformation

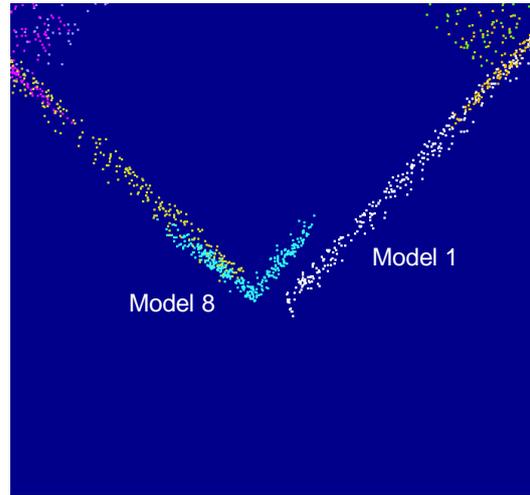


Figure 8 Nonintegrated models

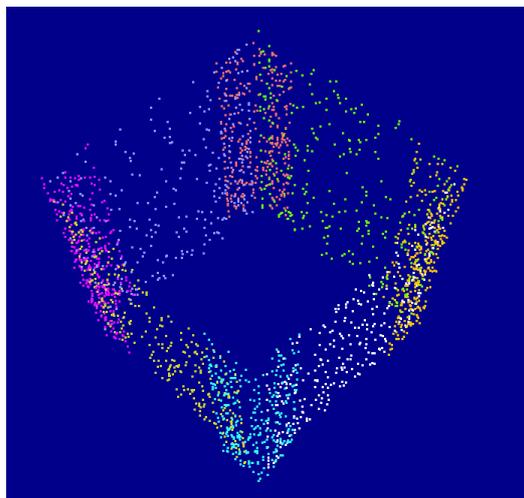


Figure 9 Integration of models using proposed method

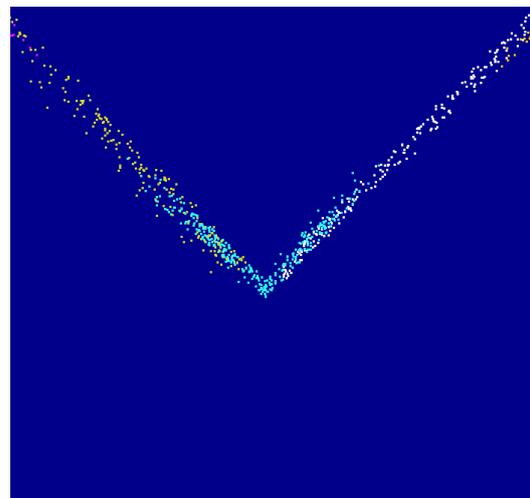


Figure 10 Integrated models

4. ARCHAEOLOGICAL 3D MODELING

In Japan, many stone statues are placed along roads; these stone statues were mostly erected in the Edo period (1603–1868). Stone statues usually depict figures belonging to regional faiths. It was believed that praying to stone statues placed on roads would ensure safety during traveling. Therefore, the distribution of stone statues on roads often provides useful information for studying ancient local history, customs, and regional faith.

Figure 11 shows one such stone statue; it is called “Thousand-armed Kannon” because the Goddess of mercy in the statue has many hands with an eye on the palm, which demonstrates her limitless ability to save humans in times of need.

In order to investigate the adaptability of the proposed method to the 3D modeling of figures in cultural artifacts this stone statue was reconstructed by 3D modeling. For 3D modeling, images of the stone statue were taken from eight directions, and eight independent models were reconstructed using 3DiVision. Ten loops were used for adjustment.

Figures 12 (a) and (b) show the result of integration of the models using Helmert transformation. From Figure 12 (b), it is clear that the integrated model is imperfect. Figures 13 (a) and (b) show the result of integration using the proposed method.



Figure 11 Thousand-armed Kannon

In comparison with Figure 12, the starting model appears to correspond with the end model. From these results, it can be concluded that the proposed method can be effectively used for the documentation of cultural heritage.



(a) front (b) side

Figure 12 Result obtained using Helmert transformation



(a) front (b) side

Figure 13 Result obtained using proposed method

5. CONCLUSION

The effectiveness and practicability of the proposed method for the documentation of cultural heritage, 3D modeling, and visualization of historical stone statues were investigated in this study. Consequently, results obtained in this study show that the proposed method can effectively be used for the integration of independent models.

References

- Akca, D., Gruen, A., Breuckmann, B. and Lahanier, C., 2007. HIGH DEFINITION 3D-SCANNING OF ARTS OBJECTS AND PAINTINGS. *Optical 3-D Measurement Techniques VIII*, pp. 50-58.
- Bergevin, R., Soucy, M., Gagnon, H. and Laurendeau, D., 1996. Towards a General Multi-View Registration Technique. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 18, No. 5, pp. 540-547.

- Chikatsu, H. and Ohdake, T., 2006. UBIQUITOUS DIGITAL PHOTOGRAMMETRY BY CONSUMER GRADE DIGITAL CAMERA. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVI, Part 5 (CD-ROM), ISSN 1682-1750.

- Fraser, C.S., 1997. Digital camera self-calibration. *ISPRS Journal of Photogrammetry and Remote Sensing*, Vol. 52, No. 4, pp. 149-159.

- Habib, A. and Morgan, M., 2003. Automatic Calibration of Low-Cost Digital Cameras. *Journal of Optical Engineering*, Vol. 42, No. 4, pp. 948-955.

- Kunii, Y. and Chikatsu, H., 2001. On the Application of 3 Million Consumer Pixel Camera to Digital Photogrammetry. *Videometrics and Optical Methods for 3D Shape Measurement, Proceeding of SPIE*, Vol. 4309, pp. 278-287.

- Noma, T., Otani, H., Ito, T., Yamada, M. and Kochi, N., 2002. NEW SYSTEM OF DIGITAL CAMERA CALIBRATION, DC-1000. *Proceedings of the ISPRS Commission V Symposium*, pp. 54-59.