AUTOMATIC ORIENTATION OF MOBILE MAPPING SYSTEM

Yeu, Bock-Mo*, Kim, Gi-Hong*, Kim, Uk-Nam, Joo, Hans*****
*Yonsei University, Korea
Dept. of Civil Engineering
yeubm@yonsei.ac.kr
gihong33@hotmail.com
**Shingu College, Korea
Dept. of Cadastral Registration
kun@ns.shingu_c.ac.kr
***Daelim Industrial Co.
GrearJoo@dic.co.kr

Working Group III/1

KEY WORDS: Orientation, Automation, Mobile mapping system.

ABSTRACT

Changes in land use and increasing demand for high quality GIS (Geographic Information System) make GIS related work difficult to solve. Updating database steadily has only been possible to a limited extent, since keeping map and GIS data up-to-date is a labor-intensive task. Even many conventional hard copy maps have been converted into digital map, the fundamental problems of make digital maps up-to-date remains a hard task. With the advent of technology, we can easily adapt to the quickly changing environment. Mobile mapping system is the one that can be readily applied to the quickly changing landscapes. Korea is one of the countries in the world that landscapes are changing very quickly. We developed our own cheap mobile mapping system and tested in the urban environment. Accurate calibration of all sensors of the integrated system is essential to ensure accurate positions of the object. We developed PC based interface for calculating 3 dimensional object from the stereo images captured by CCD cameras. The position of CCD camera has been supported by the integration of the GPS and INS configuration.

1 INTRODUCTION

Locating and updating the conditions of civil infrastructure such as road, bridge, and other utilities is very labor intensive. These tasks require collecting vast quantities of data and processing them efficiently. A mobile mapping system can offer opportunities to greatly improve our effectiveness for this kind of task (Galtier, 1992; Guangping, 1996). Mobile mapping system usually consists of three major components. They are stereo CCD cameras, GPS receiver, and INS system.

CCD cameras collect highly detailed information about transportation network and road facilities. They capture stereo image pairs that provide a full coverage of the road and its surroundings. GPS receiver accurately determines the global location of the system. The accuracy of kinematic GPS positioning ranges from centimeters to meters (Kubik, 1992). Because of obstructions such as buildings and trees, GPS alone sometimes can not meet the requirement for mapping accuracy. The addition of INS improves the overall accuracy of mobile mapping system a lot.

In order to perform precise positioning with mobile mapping system, it is necessary to calibrate each component of the system thoroughly. Accurate camera geometry using GPS and INS must be performed. The geometry of camera may be constant for long time, but the relative position and rotation offsets may change between the different missions.

We performed the entire system calibration into two parts. The first part is to calculate camera parameters using known control points in a test-field. Second part consists of the calculation of the relative orientation parameters of system sensors such as CCD, GPS and INS. It is generally recommended that the relative orientation of sensors is performed before data acquisition.

2 CONFIGURATION OF MOBILE MAPPING SYSTEM

The mobile mapping system we tested consists of two Reica SR9500 GPS receivers, two Hitachi VK-C370 color CCD cameras, and a Crossbow IMU-VG. The overall configuration of the system is shown in Figure 1. The cameras that provide stereo images are progressive scan CCD units with auto iris wide-angle lenses. The size of CCD camera is 640x480 pixels and focal length is 16mm. As shown in Figure 1, the GPS receiver, INS and two CCD cameras are mounted on a stationary platform. Their relative position is assumed to be stable during the survey.

Once camera parameters and the relative orientation parameters are determined, the three-dimensional local coordinate of the object can be calculated from the left and right image coordinates. After mathematically calculating the position and rotation offsets between CCD cameras, GPS receivers, and INS unit, the local coordinates can be transformed into a mapping coordinate system.

Figure 1. Mobile mapping system

3 AUTOMATIC ORIENTATION OF MOBILE MAPPING SYSTEM

Georeferencing is defined as the problem of transforming the 3-D local coordinates calculated from the stereo image pairs of CCD camera into the mapping coordinate system. Every image pairs taken by the stereo cameras are georeferenced by using three positional parameters, three rotation parameters, and a scale factor. Accurate georeferencing required the calibration of the interior, relative orientation, and offset parameters between the different sensors. The three-dimensional local coordinates of the object are calculated by using the photogrammetric intersection procedure from the stereo image pairs (Merchant, 1979). The following formula is used to transfer local coordinates to the mapping coordinate system.

$$C_i^m = S^m R^m \left\{ \left(S^i R^i C_i^p + \begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix} \right) + \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} \right\} + \begin{bmatrix} X_g^m \\ Y_g^m \\ Z_g^m \end{bmatrix} \tag{1}$$

Where

C_i^p : 3-D local coordinate of the object calculated from the stereo image pairs,

C_i^m : 3-D coordinate of object in mapping coordinate system,

S^i : Scale factor between 3-D local coordinates of C_i^p and INS coordinate system,

S^m : Scale factor between GPS frame coordinate system and mapping coordinate system,

R^i : Rotation from local coordinate system of C_i^p to INS coordinate system,

R^m : Rotation from GPS frame coordinate to mapping coordinate system,

$\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix}$: Offset between the origin of C_i^p and the origin of INS coordinate system

$\begin{bmatrix} Xo \\ Yo \\ Zo \end{bmatrix}$: Offset between the origin of INS coordinate system and the of GPS frame coordinate system

$$\begin{bmatrix} X_g^m \\ Y_g^m \\ Z_g^m \end{bmatrix}$$: Offset between the origin of GPS frame coordinate system and the origin of mapping coordinate system.

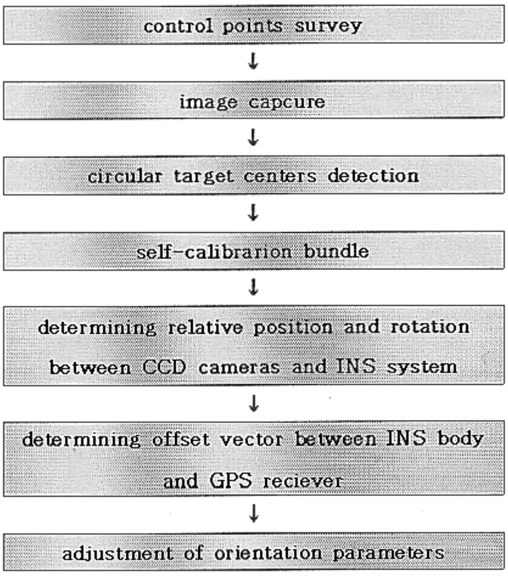


Figure 2. The procedure of georeferencing.

Detail procedures of the georeferencing are presented in Figure 2. Each step for georeferencing may require a number of ground control points. A test-field of circular reflective targets was used as the control points. To accurately locate the center coordinates of circular targets in the image following formula is used (Jensen, 1986). Mapping coordinates of each target points were determined by using the total station system and GPS receivers.

$$T_g = 0.5(C_g + B_g) \tag{2}$$

$$x_c = \frac{\sum_{f(x,y)>T_g} \{(f(x,y) - B_g)x\}}{\sum_{f(x,y)>T_g} \{(f(x,y) - B_g)\}}$$
$$y_c = \frac{\sum_{f(x,y)>T_g} \{(f(x,y) - B_g)y\}}{\sum_{f(x,y)>T_g} \{(f(x,y) - B_g)\}} \tag{3}$$

Where

B_g : Mean of gray value in background

C_g : Mean of gray value in circular targets

Interior orientation is a standard procedure that has to be performed before using any non-metric cameras. To estimate the interior orientation parameters of CCD cameras, a bundle adjustment with self calibration is used. It also solves for the location of the perspective center and rotation matrix for each camera (exterior orientation parameters).

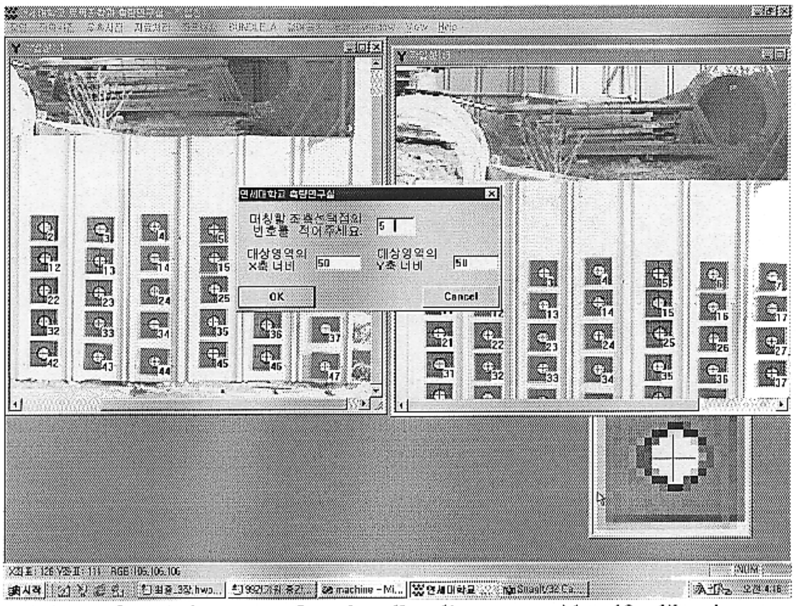


Figure 3. Part of procedure to perform bundle adjustment with self calibration.

PC-based software was developed under visual C++ environment to do whole procedure of georeferencing. The software developed under the graphic user interface (GUI). Portions of the procedure to do a bundle adjustment with self calibration are shown in Figure 3. Left window is used for measuring the coordinates of left image of CCD camera. The right window is for measuring the coordinates of the right image. The lower right window shows the portions of zoomed image.

After obtaining the exterior orientation parameters of CCD cameras, we performed relative orientation. Relative orientation parameters define the relative positions and rotations between the cameras and navigation sensors, including INS and GPS receiver. The equation (1) is valid only under the assumption that cameras, INS and GPS are fixed during the mission. Figure 4 shows the procedure for relative orientation. The accurate coordinates of distributed circular center and the offset between INS and GPS were measured by using total station system.

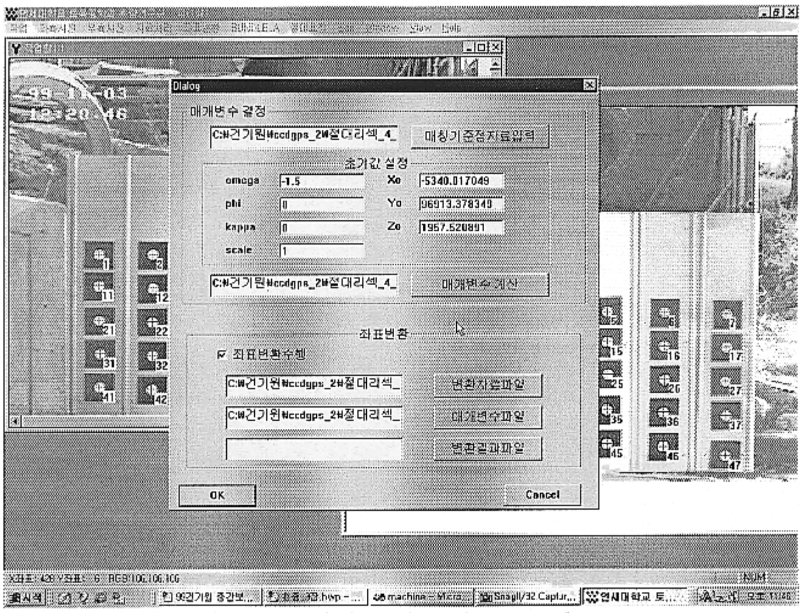


Figure 4. Relative orientation procedure

3-D mapping coordinates of target centers are obtained from the combined results of bundle adjustment parameters, relative orientation parameters, and the output of INS and the coordinates of GPS receivers. Figure 5 shows the procedure for determining 3-D mapping coordinates.

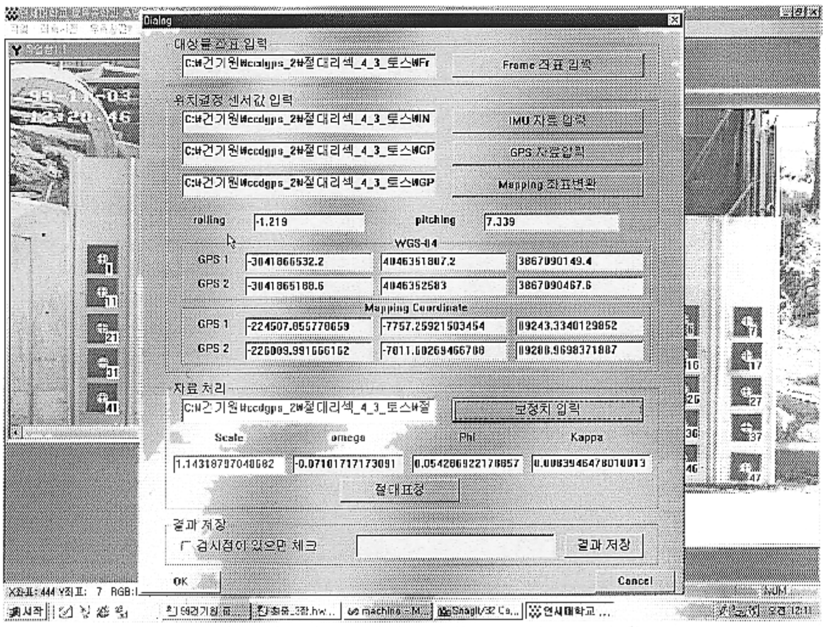
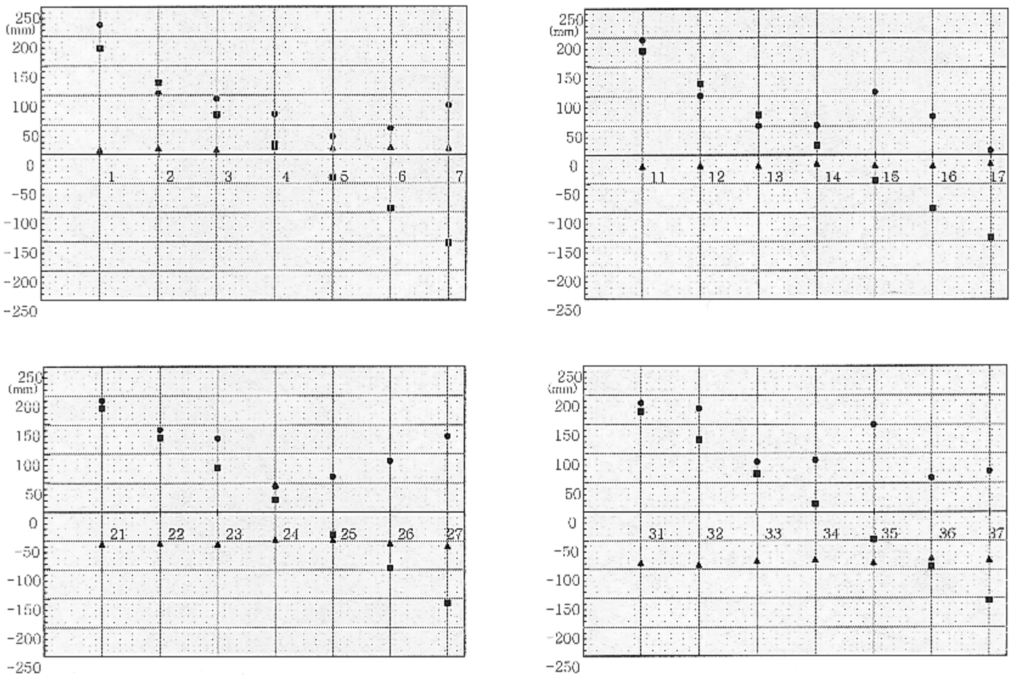


Figure 5. Procedure for determining 3-D mapping coordinate system

4 ACCURACY OF GEOREFERENCING

All orientation parameters are calculated from available sets of control point. After estimating all parameters, we used same sets of control points as check points. Check point analysis was performed one day after all parameters were calculated. Figure 6 shows the differences between the coordinates calculated from the control point survey and the coordinates estimated from the Mobile mapping system. 3-D coordinates of 35 check points are computed from two stereo images using the bundle adjustment with self calibration. The distance between targets and cameras was approximately 10m. The RMSE of the difference in X coordinates is 10.6cm, Y coordinates is 9.6cm, and Z coordinates is 5.8cm, respectively.



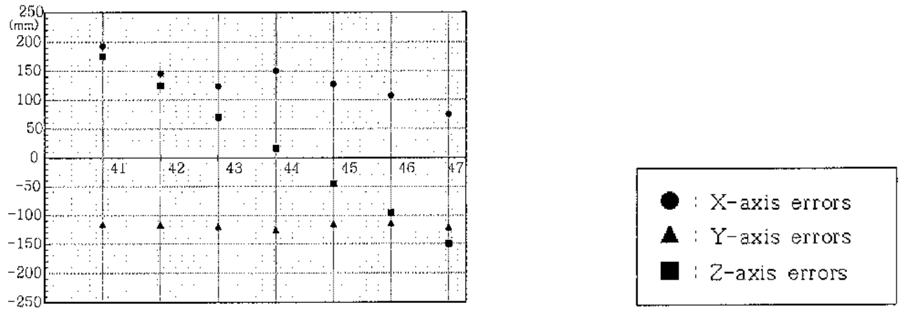


Figure 6. Positional accuracy of Mobile mapping system.

5 CONCLUSION

Mobile mapping system has been widely used to obtain the 3-D coordinates and image information of the objects. In this study, the PC based software for automation of orientation for mobile mapping system is developed. Results show that positional accuracy of 15cm (RMSE) in mapping coordinate system can be obtained.

6 REFERENCES

Jensen, J., 1986, Introductory Digital Image Processing, Prentice Hall.
Merchant, D. C., 1979, Analytical Photogrammetry-Theory and Practice, Lecture Notes, Department of Geodetic Science, The Ohio State University.
Galtier, B., 1992, GPS Utilization for Image Maps Production, IUSM.
Kubik, K., 1992, Aspects of GPS USE for Aircraft Positioning", IUSM.
Guangping, H., 1996, Design of a Mobile Mapping System for GIS Data Collection, ISPRS, Vol. XXXI, Part B2, Vienna.

ABSTRACT

Changes in land use and increasing demand for high quality GIS (Geographic Information System) make GIS related work difficult to solve. Updating database steadily has only been possible to a limited extent, since keeping map and GIS data up-to-date is a labor-intensive task. Even many conventional hard copy maps have been converted into digital map, the fundamental problems of make digital maps up-to-date remains a hard task. With the advent of technology, we can easily adapt to the quickly changing environment. Mobile mapping system is the one that can be readily applied to the quickly changing landscapes. Korea is one of the countries in the world that landscapes are changing very quickly. We developed our own cheap mobile mapping system and tested in the urban environment. Accurate calibration of all sensors of the integrated system is essential to ensure accurate positions of the object. We developed PC based interface for calculating 3 dimensional object from the stereo images captured by CCD cameras. The position of CCD camera has been supported by the integration of the GPS and INS configuration.