FUNDAMENTAL STUDY ON THE DEVELOPMENT OF THE PHOTOGRAMMETRY USING INERTIAL NAVIGATION SYSTEM

Tatsuo NAKANO
Product Development Dept.,
Yamayo measuring tool CO., LTD,
2-23-13, Adachi, Adachi-ku, Tokyo, 120-0015, Japan
E-mail: k2yamayo@intacc.ne.jp

Yasuyuki SHIRAI
Dep. Precision Eng., Associate Professor, Chiba Institute of Technology
E-mail: shirai@cc.it-chiba.ac.jp

Atsuro TAKEMOTO
Dep. Computer Center, Associate Professor, Chiba Institute of Technology
E-mail: atakemoto@cc.it-chiba.ac.jp

Toshio KOIZUMI
Dep. Civil Eng., Professor, Chiba Institute of Technology
E-mail: koizumi@ce.it-chiba.ac.jp

Commission V, Working Group V/2

KEY WORDS: Inertial navigation system, Photogrammetry, Exterior orientation element

ABSTRACT

When the position and inclination (exterior orientation element) of a camera at the time of photography are searched for by conventional photogrammetry, the standard point ground coordinates must be known, and time and labor are needed for the survey or installation work. In recent years, development of the device which determines the position and inclination of a camera at the time of photography using GPS and the fiber optical gyroscope has been achieved. However, the price of such device is also high and it is hard for it to be used widely generally. This study is a fundamental study in which the accelerometer and the inexpensive vibration gyroscope were used, and the information about the position and inclination of a camera at the time of photography was acquired, and was examined in connection with the application to the photogrammetry of an inertial navigation system. The camera used was a general single lens reflex camera. By this experiment, we could get various basic data required in order to make it apply to the photogrammetry. Moreover, by searching for the position and inclination of a camera with the accelerometer and the vibration gyroscope, and treating as an exterior orientation element of a camera, simple photogrammetry could be performed. Consequently, rough form or position relating to a photographic subject could be expressed. The apparatus used in this experiment has also accomplished technical progress fast every day, and is considered to be able to give more accurate results.

1. INTRODUCTION

Distance and angle can be calculated with a gyroscope and an accelerometer which are inertial device. Therefore, calculation of position and inclination of camera become possible by installing the gyroscope and accelerometer in the camera.

This study is the fundamental research on photogrammetory using camera equipped with inertial device. If a position and an inclination of camera which are exterior orientation element are obtainable without control point, it would save much time and labor to be spent for the control survey prevailed by this time and also, would contribute greatly for simplifying the photogrammetory. With regard to the photogrammetory without control point, method of using GPS, Gyroscope, and Theodolite with camera is developed and studied generally so far to perform photogrammetory.

However, the method of using GPS is still not used widely because of price and the fact that it cannot be used in a place where an electric wave cannot be received. Method of using Theodolite enables to obtain the inclination of camera, however, there is a problem about mobility in the site because the position of camera cannot be determined. The inertial device used in this study is a self-contained navigation device which is able to calculate the position

and inclination by the movement of itself, and has some features compared with the method of using GPS and Theodolite. Under the present conditions, effectiveness is found in the photogrammetory in the ground and the local region where an electric wave can not be received.
In addition, it is thinkable that a result in higher accuracy may be obtained by using more expensive and accurate devices. However, as this is fundamental research, development and study were performed in the hope of developing inexpensive system. Therefore, the result here was obtained using the device adopted in this study.

2. COMPOSITION OF THIS SYSTEM

In the system of the photogrammetory done with an inertial device, a gyroscope and an accelerometer which were installed at right angles to each other were equipped with camera in this study. Data from gyroscope and accelerometer is converted from analogue into digital through the A/D conversion board, and is taken into the personal computer. Then, the position and the inclination of camera at time of taking a picture are calculated.
On the other hand, the photograph taken with the camera is measured using a digitizer, and a analysis of the photograph is performed in the position and the inclination of a camera which were obtained from the gyroscope and the accelerometer.

3. INERTIAL DEVICE

3.1 Vibration gyroscope

Vibration gyroscope was used for the gyroscope in this study. The vibration gyroscope used for this measurement is the ENV-05A piezo-electric vibration gyroscope of Murata Mfg. Co., Ltd. which is shown in Figure 1.

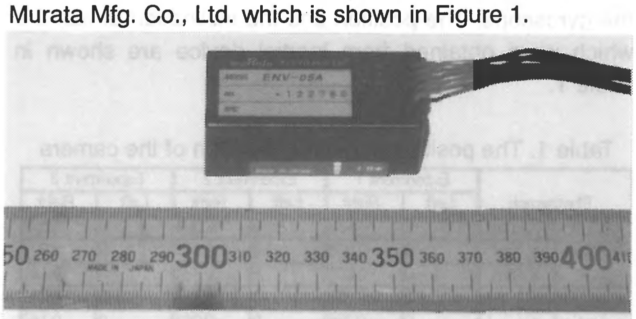

Fig.1 Vibration gyroscope

3.2 Accelerometer

The accelerometer used for this measurement is the JA-5VC1 accelerometer of Japan Aviation Electronics Industry., Ltd. which is shown in Figure 2.

4. Experiment

In the photogrammetory done with an inertial device described in of this study, measurement is done by calculating from gyroscope and accelerometer, the position and the inclination of camera at time of taking a picture, i.e., an exterior orientation element.
The camera used in this study is a non-metric camera. Therefore, there is no fiducial mark in the camera, and geometrical elements such as principal point position, principal distance, lens warp, and flatness of film are not given accurately.

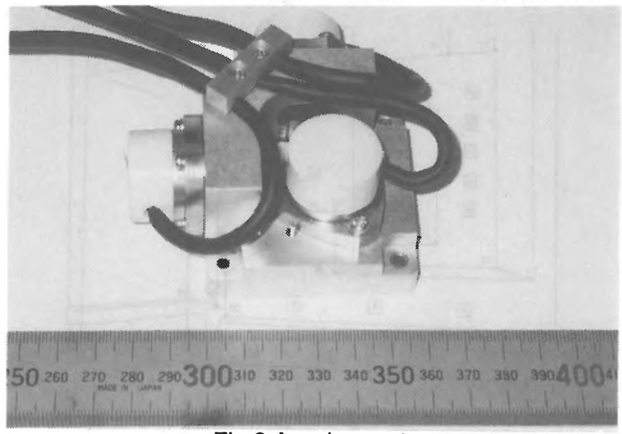

Fig.2 Accelerometer

Then, the interior orientation element is requested from the control point arranged in three dimensions of the use to analyze a usual photograph at each experiment in this study.

4.1 Experiment device

The experiment device equipped with the inertial device in the camera is defined in this study as inertial camera. The inertial camera made for this study is shown in Figure 3. The camera used is a general single lens reflex camera.

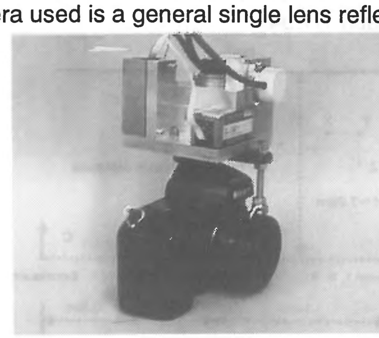

Fig.3 Inertial camera

The gyroscope and the accelerometer which are installed at right angles to each other are equipped with the camera. As a result, the three dimension position and the inclination of the camera when taking a picture are required.

4.2 Three dimensional (3-D) measurement with inertial camera

Experiment for three dimensional measurement with inertial camera was carried out outdoors as follows.

4.2.1 Installation of object (point of measurement and control point)

The object where 16 plastic sheets (15.6cm×15.6cm size) assumed to be point of measurement and control point were attached was made and affixed at the elevator tower on the rooftop of the fourth pavilion of Chiba Institute of Technology which is shown in Figure 4.

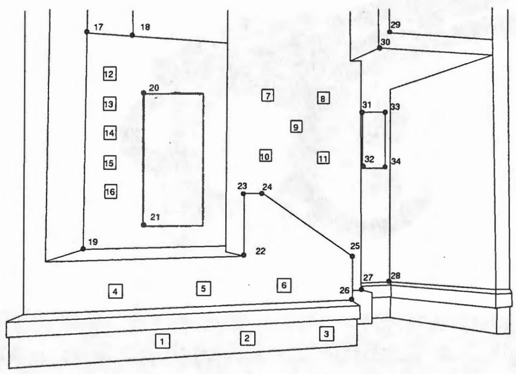

Fig.4 Object

4.2.2 Photographing

The experiment was carried out under the photography conditions shown in Figure 5.
The experiment was performed three times under the following conditions:
Experiment 1: Taking a picture at a distance of 7m and base-height ratio 1/3.89
Experiment 2: Taking a picture at a distance of 7m and base-height ratio 1/2.59
Experiment 3: Taking a picture at a distance of 7m and base-height ratio 1/1.94

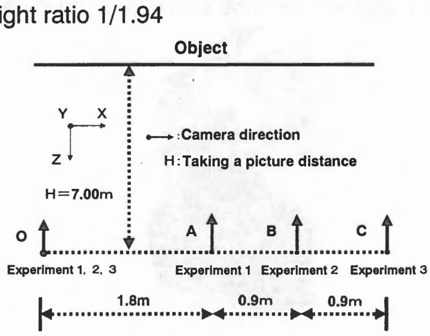

Fig.5 Photography condition

As for movement and photography of camera, photograph is taken by moving tripod after determining the leg position of tripod in the front of a photographic subject in advance. In the experiment, shutter of a camera is pressed at point O first, and after operating the inertial device, the camera is moved from point O to point A and then, the shutter pressed again to take 1 set of stereo photograph. Furthermore, inertial camera has to be moved on to point O where measurement by the inertial device is finished. Moreover, the release is used to prevent the camera from vibration when taking a picture.

As for the synchronization of both taking data from the inertial device and taking a picture, method of inputting the electric signals at time of taking a picture was examined. However, since there is the passage of time in a certain period of time even though the electric signals was instantaneously input, synchronization of taking a picture and taking data was found difficult at this stage. Then, in this study, a photograph was taken by making movement of the camera stop at time of photographing. By doing this, signal output from the inertial device is the one under the condition of no motion of camera and through the signal it is confirmed of no motion in the camera. The position where the inertial device had stopped was decided by the data obtained while no movement was confirmed by eyes, and the data analyzed considering as the place where inertial device stopped and the position of taking a picture were the same.

4.2.3 Decision of interior orientation element of camera

Because of using a non-metric camera, the interior orientation element of camera is unknown. Then, the interior orientation element such as "coefficient of polynomial by which analytical film curved surface is given", "coefficient of function which gives lens warp", "principal distance", and "gap of principal point position of the camera" was required from 16 control points of the object.

4.2.4 Decision of exterior orientation element of camera

The position and the inclination of camera when taking a picture were calculated by using the accelerometer and the gyroscope. The position and the inclination of camera which were obtained from inertial device are shown in Table 1.

Table 1. The position and the inclination of the camera

Photograph		Experiment 1		Experiment 2		Experiment 3	
		Left	Right	Left	Right	Left	Right
Position	X (m)	0	1.685	0	2.381	0	3.679
	Y (m)	0	0.036	0	0.117	0	0.007
	Z (m)	0	-0.001	0	0.184	0	-0.181
Inclination	ω (°)	0	-0.324	0	-0.54	0	-0.249
	ϕ (°)	0	-0.256	0	-0.043	0	0.187
	κ (°)	0	0.306	0	0.68	0	0.246

4.2.5 Measurement and analysis of photographic coordinates

The photographic analysis was measured with digitizer. The digitizer used was A2-50 made by the PHOTRON Company, and it's resolving power was 0.025mm.

4.2.6 Analysis

In this analysis the total 34 points were measured (set 18 surveying points selected from object and 16 control points attached on the object). The photograph used for analysis is enlarged in about 20cm×25cm size.

4.3 Result of analysis

Photography was performed almost horizontally to the photographic object. The measured value by the total station was set as true value and it was compared with the value measured from the photograph.

In the analysis, first of all, the interior orientation element of camera was determined based on control point taken a picture. The result is shown in Table 2.

Table 2. Interior orientation element

Gap of principal point position	xo (m)	-0.00028
	yo (m)	0.00018
Principal distance	f (m)	0.02891
Coefficient of function which gives lens warp	d1	-0.0065
	d2	0.057
	d3	-0.172
Coefficient of polynomia by which analytical film curved surface is given	p1	0.00638
	p2	-0.00138
	p3	0.01
	p4	0.24725
	p5	-0.05938
	p6	-0.012

Next, the orientation of camera was done based on the obtained interior orientation element, the position and the inclination of camera when taking a picture obtained from inertia device.

As for measuring the point on photograph, the photograph was enlarged in about 20cm×25cm size, and then, the coordinates were measured with the digitizer. Number of points of measurement used for the analysis was totaling of 34 points and there are 16 control points among them, and they are the universal point of measurement in experiment 1, 2, and 3. Average of standard deviation in the error of the measurement value becames "The direction of X·Y (plane) was 0.25m" and "The direction of Z(interior taking) was 0.57m " when compared using the mean.

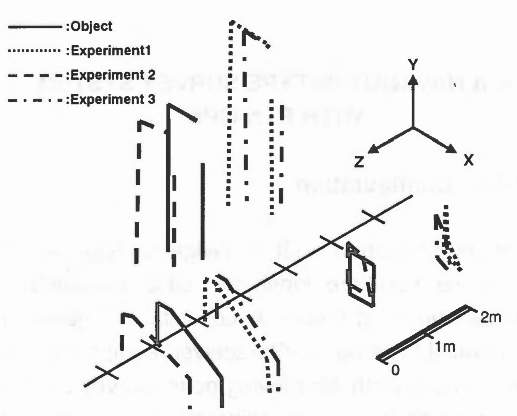

Fig.6 Outline drawing

A part of the building was shown in the outline drawing based on the experiment result. The outline drawing is shown in Figure 6.

5.CONSIDERATION

At present, the error of external orientation element obtained from inertial device is larger than that from photographic analysis. Regarding this, the gap between lens center and inertial device center and detection accuracy of inertial device, etc. are considered as a cause of the error.

Because as point O is a point of taking a stereo picture in the actual experiment, frequency of movement of the inertial device is few. The error increases along with time due to the feature of the inertial device. Under the constant speed of moving inertial device, it will take more time according to the longer distance of movement and in this respect, range of error will increase. However, if it is made to move too quickly, an excessive vibration etc. will occur. If it is made to move slowly, it will cease to obtain effective acceleration and angle velocity by the relation with the resolving power of device. As for plenty of elements in relation to the error and time, the clear relationship between them cannot be understood yet despite it's outline can be grasped.

Effective range is seemed within about 3-4m which is possible to move the inertial device in this stage.

6. CONCLUSION

This study is the one having aimed at the development of photogrammetory which does not need the control point. As for this method, it is what development was carried out through a new aspect in the use of the accelerometer and the gyroscope, besides the method by the GPS and the gyroscope that is generally the main current of the present research.

The result of this study is summarized below.

(1)The position and the inclination of camera when taking a picture were calculated by installing the accelerometer and the gyroscope in the camera, and owing to this it was confirmed that an exterior orientation element was obtained through the experiment.

(2)The method adopted in this study has some merits in comparison with the method by GPS, and enables to perform photogrammetory without control point in the buildings, undergrounds, mountains, etc, where electric waves do not reach.

(3)Improvement for accuracy is further necessary on the device through, sufficient materials have been obtained as a basic research for future study.

7. REFERENCE

Takayuki.A., 1996. Fundamental Study on Inertial Surveying In: The International Archives of Photogrammetry and Remote Sensing, Vienna, Vol.XXXI, Part B1, pp.6-12