Discussion on the simplified 3-dimensional measuring method using video images

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Abstract

For the purpose to measure the locus of airplane flying over the limited area, we have developed the 3-dimensional measuring method by the combination of only the general purpose apparatus such as digital video equipment placing higher importance on the processing speed and lower cost rather than the accuracy. As a result, we could obtain the positional accuracy of around 50 m within a short time.

1. Purpose

A stunt flying show (Aerobatics) has been planed at TWIN RING MOTEGI Circuit located at Motegi Town of Ibaraki Prefecture, and the environment assessment data were required for that purpose. The show is scheduled in autumn this year, but the experimental stunt flights were conducted before that to obtain the environment assessment data for the coming show. The measurement of noise was the main objective of this investigation. This paper describes the measurement of position of airplane at that investigation. The measurement results were analyzed together with the measured values of noise and atmosphere and used as the environment assessment data. The requirements imposed on this study were to make measurement within a short time at low cost rather than to obtain a high accuracy.

2. Scope of analysis and discussion on the method

Since the flying conditions of airplane had been indicated to us in advance, we prepared to measure the position of an airplane within those conditions. The flight time was about 10 minutes and the flying range was cubical space of 1 km. We discussed the method based on required accuracy and scope of analysis (Table. 1). As a result, we decided to take pictures of ground objects by plural number of digital video cameras, to mount handy type GPS receiver on the airplane and to jointly shoot aerial photographs.

(1) We took video pictures by 6 camera located at 4 places in a manner to enclose all the analysis scope (Figure. 1). We fixed the elevation angle from horizontal to about 30 degrees in order to include the ground objects as much as possible which would be used for orientating the direction at the time of analysis. 4 cameras at 2 locations were fixed at horizontal angle and the angle of 2 cameras at 2 locations was variable. As for shooting condition, the focus was fixed at infinite, and the zoom was fixed at wide side. Fisheye lens was used where possible. (Table. 2)

(2) We used 12 XL made by Garmin of U.S.A as GPS receiver, and applied point positioning. Considering the flight time and memory capacity, we recorded the data for each 5 seconds on the memory of receiver. Also, we connected PC by serial cable and recorded the data for each 1 second on the hard disk.

(3) We took aerial photographs of one flying course at

the scale of 1 : 10,000 on a later day in order to connect the analysis results with the ground coordinates.

3. Analysis result

(1) First of all, the acquired data were converted by a capture board into frame data of each 1 second. Synchronization of video camera was performed only by the clock incorporated in camera. We decided the frame size to be 640 x 480 pixels (vertical x horizontal). We used Photo Modeler Pro 3.0 made by Eos System of U.S.A. for the analysis, and analyzed the data of each 10 seconds (Figure. 2, 3). During the flight time of about 600 seconds, there were 2 cases where 5 or more cameras missed the flying object at the same time, resulting in the interruption of data. The reason was that the visual range of video cameras was around 1.5 km in spite of fine weather, which was far below our expectation. The scenes available for the analysis was 45 scenes out of total 60 scenes. The cameras used for analysis were 2.8 on average out of 6 cameras. The intersecting angle of bundles was 63 degrees on average.

(2) The data of each 5 seconds retained in GPS receiver were outputted to PC and coordinates conversion was carried out. External output of data was possible only for the position of plane surface. Therefore, the use of these data was limited to the supplementation of interrupted portion of video data. The PC mounted on the airplane seemed to have acquired the data but have failed to function correctly because of the gravity and vibration.

(3) The aerial photograph was orientated by digital photographic survey system using the existing 1 : 5,000 map, and then the orientation points were measured and schematic map was constructed.

4. Discussion and evaluation of accuracy

Prior to the analysis, calibration was made to video data using Photo Modeler Pro 3.0. We also made correction to format size, focal distance, position of principal point and distortion (Table. 3). As a result of verification of measurement using optional 2 frames, the deviation between known point on ground and measured value was 45 m when the calibration was made and 173 m when the calibration was not made. Especially, the errors larger than we expected were observed at the peripheral portion of fisheye lens, we decided to apply calibration in all the analyses.

Two big factors are considered as the reason of error. The first factor is divergence of synchronization among the video cameras. In general, the airplane flies at the speed of 100 - 200 km, which is 56 m per second. The incorporated clocks were able to be adjusted relatively at the accuracy of 0.2 second. On the other hand, capturing of data had a possibility to yield an error of around 0.5 second. Based on these facts, it can be considered that the data may have included an error of about 30 m. In addition, measurement itself may have contained an error of around 45 m. Adding these factors together, it can be assumed that the measuring accuracy of video image was approximately 50 - 100 m.

Since many parts of GPS data were missing due to the attitude of airplane and altitude data were not acquired, GPS did not seem to be suitable for measuring method employed in this study. However, assuming that the accuracy based on point positioning is about 100 m, it is considered to be effective for the supplementation of video data.

Considering that the purpose of present investigation was the measurement of noise as a data of environment assessment and required accuracy was about 100 m, the obtained results can be comprehensively evaluated to be effective enough.

5. Discussion on processing time

Photo Modeler Pro 3.0 was used for the analysis of video data in present investigation, and it was possible to analyze 60 scenes within 2 days. The processing time per one scene was about 15 minutes. It will take long time to analyze all the video data using this method. However, if only the necessary scenes are selected as in the case of present investigation, it is possible to analyze them in a very short time. Considering that the works necessary on the day of investigation were only to take pictures by video camera, the comprehensive processing time can be said to be very short and can be highly evaluated.

6. Summary and future issues

We believe that the method we used this time is adequately effective to reduce the site works and curtail the cost only if the field of application is proper. Especially, it should be highly evaluated that the site work is only the video picture taking and does not necessitate specialized engineers. On the other hand, this method has also left many problem. Since the airplane itself is used as the object point in the orientation, we cannot deny the existence of dilemma that when the airplane is at a high altitude, it is geometrically strong but difficult to discover on one hand, and when it is at a low altitude, it is easy to discover but it is geometrically weak. Also, it can be pointed out that the exterior orientation factor of used video cameras was not used in this investigation. The reliability of video analysis was reduced to large extent because cameras of different models as well as fixed cameras and movable cameras were mixedly used. If these problems are solved in the future, it will not only largely improve the reliability of analysis but also reduce the processing time significantly.

Behavior investigation of large sized birds in the environment monitoring can be considered one of the application field of this method. We are considering to do the works such as to conduct the fixed point observation at a site and measure the flying range of the birds.

7. References

Klaus Hanke (1998), Accuracy Study Project of Eos System's Photo Modeler

Shiro Ochi, Ayako Kawakami (1997), Discussion on the method to verify and correct the errors of handy GPS used for leisure, pp. 255 - 258, Collection of Papers Presentted at Japan society for Photogrammetry 1997 Annual Academic Lecture Meeting (Japanese)

Table. 1 : Discussion on measuring method

Method	Merit	Demerit
Picture taking on the ground by a general purpose camera	Low cost	Difficulty in synchronization and data analysis
Video shooting on ground	Low cost Easy synchronization	Low resolution comparing with photograph
Aerial video shooting by airplane	Synchronization and analysis are easy	Stereo photographing is difficult High cost
Observation by video theodolite	High accuracy	Tracing is difficult High cost
Mounting GPS Receiver on airplane	Lost cost Easy analysis	Interruption of data is expected due to the movement of airplane

Table. 2 : Video cameras

Point	Model	Installation condition	Remark
A-R	SONY VX1000	Fixed	x 0.55 fisheye lens
A-L	SONY VX1000	Fixed	x 0.55 fisheye lens
B-R	SONY VX1000	Fixed	x 0.55 fisheye lens
B-L	SONY VX1000	Fixed	x 0.55 fisheye lens
C	SONY PC10	Movable	
D	SONY TRV7	Movable	

Table. 3 : Result of calibration

Model	Format Size(mm)		Focal Length(mm)		Principal Point(mm)		Radial Distortion(mm)	
	Inputted value	Calibrated value	Inputted value	Calibrated value	P1	P2	K1	K2
VX1000	4.800 x3.600	4.823 x3.600	3.245	3.104	0.002524	-0.001609	-0.01131	0.001848
PC10	4.800 x3.600	4.752 x3.600	4.400	5.795	-4.08E-005	-0.0007201	-0.01505	0.002769
TRV7	4.800 x3.600	4.748 x3.600	4.000	5.433	-0.0001943	7.08E-005	-0.00709	0.0007679

* The values of VX 1000 are the values when the fisheye lens was used

Figure 1 : Flight range of airplane and location of video cameras

Figure 2 : Analysis of video image by Photo Modeler Pro 3.0

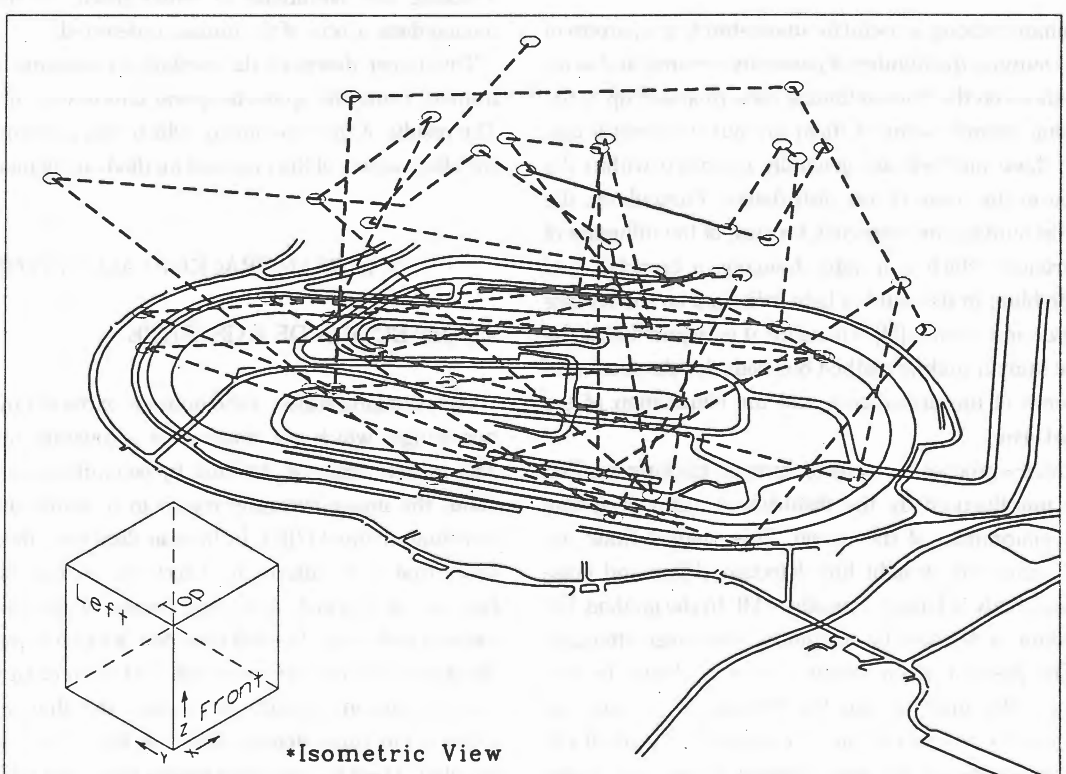

Figure 3 : Analysis result of video image