APPLYING INTEGRATED DGPS/IMU SYSTEMS TO STEREO PLOTTING

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ABSTRACT:

During recent years direct sensor orientation with GPS and IMU has gained popularity. The system can directly get exterior orientation elements without using ground control points. To achieve the full accuracy potential of direct sensor orientation, the compensation of systematic errors with the correct mathematical model and an optimum number of parameters for sensor calibration is required. However, experiments showed that there would be some problems with y-parallaxes of stereo models based on direct sensor orientation. In this paper we put up one method to resolve this problem. The method was the integration of GPS/IMU and (automatic) aerial triangulation (AAT) into bundle block adjustment, which was also called integrated sensor orientation.
From experimental results, we could get some conclusions that direct sensor orientation currently allows the generation of orthoimages of the small image scale. But it is not always suitable for stereo plotting because of the large y-parallaxes in some models. To resolve this problem, the combination of GPS/IMU observations with ground control points (integrated sensor orientation) should be preferred in some cases.

1. INTRODUCTION

In recent years direct sensor orientation with GPS and IMU, the new technology, has gained popularity, because the system can directly get exterior orientation elements without using ground control points. In fact, the system consists of an inertial measurement unit (IMU) device and a positioning and guidance function. However, in order to achieve the full accuracy potential of direct sensor orientation, a precise sensor calibration is necessary, so a correct mathematical model with an optimum number of parameters for sensor calibration must be found. In this way, the technology will open several new applications to photogrammetry and remote sensing in the futrue. This paper would introduce one method of applying integrated DGPS/IMU system to stereo plotting. Experimental results demonstrate that the proposed method is effective.

2. SENSOR CALIBRATION AND ORIENTATION

Since direct sensor orientation without ground control points relies on an extrapolation process only, remaining errors in the system calibration will significantly decrease the quality of object point determination. Traditional approach for system calibration is performed in a two-step procedure, where the directly measured GPS/inertial positions and attitudes are compared to the estimated exterior orientation elements based on conventional aerial triangulation. By analyzing position and attitude differences at each distinct camera station the most common six calibration parameters (translation offsets and misalignments between camera and GPS/inertial component) can be obtained. However, this approach almost neglects the existing correlations between the estimated orientation elements and interior orientation of the camera. To achieve better accuracy of direct sensor orientation, the compensation of systematic errors with a proper mathematical model and an optimum number of parameters for camera calibration is required. During this process a camera self calibration (focal length, principal point, additional parameters etc.) in advance need to be performed under operational conditions.

2.1 Test Data description

In order to analyze the mathematical model with an optimum number of parameters for sensor calibration, one test field was selected for getting the proper mathematical model with the optimum number of parameters for camera calibration. In the experiments, we successfully acquired 2,000 km^2 GPS/IMU data with aerial photo at 1: 25,000 photo scales in one test area by installing the integration of Zeiss' RMK TOP and IGI's AeroControl Ⅱd on YUN-5 (non-hermetic) aircrafts. The claimed accuracy of system is for the positions better than 0.1m, in roll, pitch better than 0.005 degree and in yaw better than 0.008 degree.

The aircraft was flown at an altitude of 3400-3500 meters above the ground. In order to achieve a good initial alignment for the IMU axes with the gravity field, the aircraft made an S-like turn before the first flight strip.

2.2 Sensor Calibration

The proper mathematical model was put forward according to experiments in the calibration field, which consisted of two strips in the east and west directions. Each strip contained 11 images and was flown twice in two opposite directions. In virtue of the corresponding mathematical model and the optimum number of parameters for camera calibration, the compensation of systematic errors could be achieved (Table 1). Then, with these calibration parameters, exterior orientation elements of all images were renewed.

Parameters	Values	Stand. Dev.
IMU shift	$\triangle$roll=0.266^0	$\pm 0.06^0$

	$\triangle$pitch=0.126^0 $\triangle$yaw=-177.937^0	$\pm$0.05^0 $\pm$0.12^0
GPS shift	dX_0=-14.632m dY_0=-3.049m dZ_0=-5.581m	$\pm$0.06m $\pm$0.05m $\pm$0.24m
Interior Orientation	dx_0=-8.9μ dy_0=70.2μ df=-6.5μ	$\pm$1.2μ $\pm$0.8μ $\pm$3.1μ

Table 1 Calibration values with nine parameters

2.3 Direct Sensor Orientation

For the sake of checking the accuracy of the results (direct exterior orientation), 36 ground control points (GCP's) were selected as check points (ICP's). And the measured image coordinates of ICP's were transformed into object space via the least-squares forward intersection with the exterior orientation elements of the calibrated GPS/IMU observations (six system calibration parameters from calibration flight) as constant values. At last the results were compared with the known values of the corresponding ICP's. The results showed that the calibration model as mentioned above could achieve better accuracy than that of the traditional calibration method. The accuracy of direct sensor orientation (root mean square differences at independent check points, RMS) was in the range of 4.0139 m in planimetry and 1.9331 m in height at independent check points and at approximately 30 μ in image space.

However, when we directly used these exterior orientation elements for stereo plotting, there would be some problems with y-parallaxes of stereo models. Based on these models, via least square forward intersection, object coordinates of all ICP's could be determined and were compared with the known values. The results showed that the model accuracy in object space the maximum residuals were 8.5625 m in planimetry and 5.17 m in height, while the minimum residuals were 0.6982 m in planimetry and 0.017 m in height. And in image space, the results showed that not all models based on direct sensor orientation could be used for stereo plotting. And about 40% of the models had y-parallaxes exceeding 40 μ (stereo plotting became less comfortable) and some stereo models had y-parallaxes larger than 100 μ (stereo plotting became cumbersome). The results were presented in table 2.

RMS differences at ICPs			% of models with RMS y-parallaxes	
X[m]	Y[m]	Z[m]	> 40μ	> 100μ
3.3941	3.5178	1.9331	40	5

Table 2 Accuracy of models in object and image space

2.4 Integrated Sensor Orientation

To resolve this problem, this paper put up an improved method, which applied the image orientation method in the test field by combining automatic aerial triangulation (AAT) with GPS and IMU. In fact, the improved method was the integration of GPS/IMU and AAT into bundle block adjustment, and was also called integrated sensor orientation. In addition, the corresponding mathematical model of the bundle block adjustment combined the INS/DGPS-derived exterior orientation elements with ground control points. Since the accuracy of INS/DGPS-derived exterior orientation elements as mentioned above was not better than that of ground control points. Therefore in the adjustment we assigned some weights, about one tenth of that of ground control points, to the exterior orientation elements. When the combined adjustment was completed, we got the new exterior orientation elements of every image in the test field. The accuracy of the improved method (root mean square differences at independent check points, RMS) was in the range of 1.5354 m in planimetry and 0.8605 m in height at independent check points and at approximately 10 μ in image space. When we used the new exterior orientation elements for stereo plotting, only 1% of these models had y-parallaxes exceeding 40 μ and the rest models could be used for stereo plotting. The results were presented in table 3. The results showed that the improved method could improve the accuracy, stability and reliability of calibration parameters and get higher accuracy exterior orientation elements for stereo plotting than that of direct sensor orientation.

RMS differences at ICPs			% of models with RMS y-parallaxes	
X[m]	Y[m]	Z[m]	> 40μ	> 100μ
1.1458	1.022	0.8605	1	none

Table 3 Accuracy of models in object and image space

3. CONCLUSION

From the above experiments, we can draw some conclusions that direct sensor orientation is a good alternative to aerial triangulation, especially in the case of the small image scale. In fact, direct sensor orientation currently allows the generation of orthoimages. However, directly using direct sensor orientation for stereo plotting is not always suitable because of the large y-parallaxes in some models. To resolve this problem, the combination of GPS/IMU observations with ground control points (integrated sensor orientation) should be preferred in some cases.

REFERENCES

Ackermann, F., Schade, H., (1993). Application of GPS for Aerial Triangulation, Photogrammetric Engineering & Remote Sensing, 59(11), 1625-1632.

Cramer M., Stallmann D., Haala N., (2000). Direct georeferencing using GPS/INS exterior orientation for photogrammetric applications. In:Int. Arch. of Photogrammetry and Remote Sensing, Vol.33, Part B3/1, 198-205.

Ebner H., (1976). Self-Calibrating Block Adjustment. Bildmessung und Luftbidwesen, 44, 128-139.

Helge Wegmann., (2002). Image Orientation by Combined (A)AT with GPS and IMU. Proceeding of ISPRS Commission I Symposium, 2002, Denver, USA(on CDRom).

Skaloud, Jan and Schwarz, Klaus, P., (1998). Accuracy orientation for airborne mapping system. In:Int. Arch. of Photogrammetry and Remote Sensing, Vol.32, PartB2, 283-290.

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