OEEPE TEST ON INTEGRATED SENSOR ORIENTATION - STATUS REPORT

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ABSTRACT

The topic of image orientation by combined aerial triangulation with GPS/IMU, also called integrated sensor orientation, has received much attention lately. One of the main questions of fundamental relevance is, if and under which conditions the direct determination of the parameters of exterior orientation via GPS and IMU can be a complete substitute for aerial triangulation. A more practical question deals with the possibilities of an optimum combination of the different methods using a minimum of ground control points. The European Organisation for Experimental Photogrammetric Research (OEEPE) has embarked on a test investigating these issues. The main focus of the test is on the obtainable accuracy of integrated sensor orientation for large scale topographic mapping as determined at exterior orientation elements and at independent points on the ground.
In this paper we present the current status of the test. At present, the first phase of the test in nearly finished, and we have received results from 11 test participants. Phase 2 will start within the next months.

1 TEST OBJECTIVES AND EXPECTED RESULTS

The European Organisation for Experimental Photogrammetric Research (OEEPE) has embarked on a test investigating integrated sensor orientation using GPS and IMU in comparison and in combination with aerial triangulation. The test has been set up as a multi-site test. The Institute for Photogrammetry and Engineering Surveys (IPI), University of Hanover acts as pilot centre for the test. Data acquisition and pre-processing including the organisation of test flights and the necessary field work was carried out by the Department of Mapping Sciences (IKF), Agricultural University of Norway in Ås.

The main focus of the test is on the obtainable accuracy for large scale topographic mapping using photogrammetric film cameras. The accuracy of the results will be assessed by investigating the exterior orientation elements of an image block and in particular with the help of independent check points on the ground in the following scenarios:

- aerial triangulation,
- GPS/IMU observation for the projection centres only,
- combination of aerial triangulation with GPS/IMU.

The test is expected to demonstrate to which extent integrated sensor orientation using GPS and IMU with and without aerial triangulation is an accurate and efficient method for the determination of the exterior orientation parameters for large scale topographic mapping. A comparative analysis will show in which way the mentioned potential error sources and an integrated bundle block adjustment, with or without using a minimum of ground control points have an influence upon the accuracy of the derived orientation parameters and ground control co-ordinates. Furthermore, the potential and problems of integrated sensor orientation will be assessed based on the comments of the participants. A detailed investigation into the transformation of the raw GPS and IMU measurements into flight trajectories and attitude values (roll, pitch, and yaw as a function of time), however, is out of the scope of this test. Rather, the flight trajectories and the attitude values as computed by the GPS/IMU systems, are considered to be the input of the test, and are to be processed together with the image data.

2 ACQUISITION OF TEST DATA

Two companies producing suitable GPS/IMU equipment agreed to participate in the test, namely Applanix of Toronto, Canada, using their system POS/AV 510-DG (Hutton J., Lithopoulos E. 1998; Applanix 2000), and IGI mbH of Kreuztal (formerly of Hilchenbach), Germany, with the system AEROcontrol II (IGI mbH 1999). More details of the test can be found in Heipke et al. (2000). The test flights were carried out by the Norwegian companies Fotonor AS and Fjellanger Widerøe (FW) Aviation AS over the test field Fredrikstad in the south of Norway. The test field is maintained by IKF. In the following we shortly report on the status of the test as of January 2001.

The test imagery was acquired in October 1999. For each GPS/IMU system calibration flights in two different scales (1:5.000 and 1:10.000) followed by a flight over the actual test block in 1:5.000 were carried out. All three flights were carried out over the Fredrikstad test field, for further details see table 1 and 2 and Heipke et al. 2000).

		IGI mbH	**Applanix**
Image acquisition system		Zeiss RMK Top	Leica RC30
Focal length [mm]		153	153
Date of calibration protocol		Aug-03-1998	February-22-1999
Film material		Panchromatic (AP200)	Panchromatic (AP 200)
GPS receiver (aircraft)		Ashtech Z XII, (L1 and L2)	Ashtech Z Surveyor, (L1 and L2)
Data rate		0.5 sec	0.5 sec
PDOP		~1.5	~1.5
IMU			
Used gyros		Litef LCR-88	Litton LN-200
Data rate		50 Hz	200 Hz
GPS/IMU-System		AEROcontrol II	POS / AV 510-DG
Accuracies of combined GPS/ IMU post-processing according to companies	position [m]	< 0.1	< 0.1
	roll, pitch [deg.]	0.005°	0.005°
	yaw [deg.]	0.010°	0.008°

Table 1: Data acquisition equipment

	IGI mbH	**Applanix**
General		
Flight company	Fjellanger Widerøe Aviation AS	Fotonor AS
Date and time of data acquisition	October-07-1999, afternoon	October-07-1999, morning
Sequence of data acquisition	Cal. flight 1:10.000, cal. flight 1:5.000, test flight	Cal. flight 1:10.000, cal. flight 1:5.000, test flight
Calibration flight 1:5.000	2 strips North/South, 2 strips East/West (in opposite direction)	2 strips North/South, 2 strips East/West (in opposite direction)
No. of images	2*17 + 2*14 = 62	2*17 + 2*14 = 62
End overlap	l = 60 %	l = 60 %
Flying height [m]	800	800
No. of visible ground control points	25	25
Calibration flight 1:10.000	block with 5 strips followed by 2 strips at a 90 degree angle	Block with 5 strips followed by 2 strips at a 90 degree angle
No. of images	5*11 + 2*14 = 83	5*11 + 2*15 = 85
Overlap	l = 60 %, q = 60 %	l = 60 %, q = 60 %
Flying height [m]	1600	1600
No. of visible ground control points	50	50

Table 2: Details of data acquisition (to be followed on the next page)

	IGI mbH	Applanix
Actual test flight	block with 7 strips followed by 1 strip at a 90 degree angle	block with 9 strips followed by 2 strips at a 90 degree angle
No. of images	7*17 + 1*14 = 133	9*17 + 2*14 = 181
Overlap	l = 60 %, q = 60 %	l = 60 %, q = 60 %
Flying height [m]	800	800
No. of visible ground control points	50	50

Table 2: Details of data acquisition (second part)

The flight axes of the two calibration flights are shown in figures 1 and 2. These figures also show the ground control points employed for the reference bundle adjustment (see below). As can be seen in table 2, the actual test block flown by IGI contains less strips than the Applanix block. This difference is explained by the weather conditions. During the IGI flights clouds started to move into the test field area, prohibiting some of the schedules images to be acquired. The resulting differences in the block geometry have to be taken into account in the further processing and interpretation of the test results.

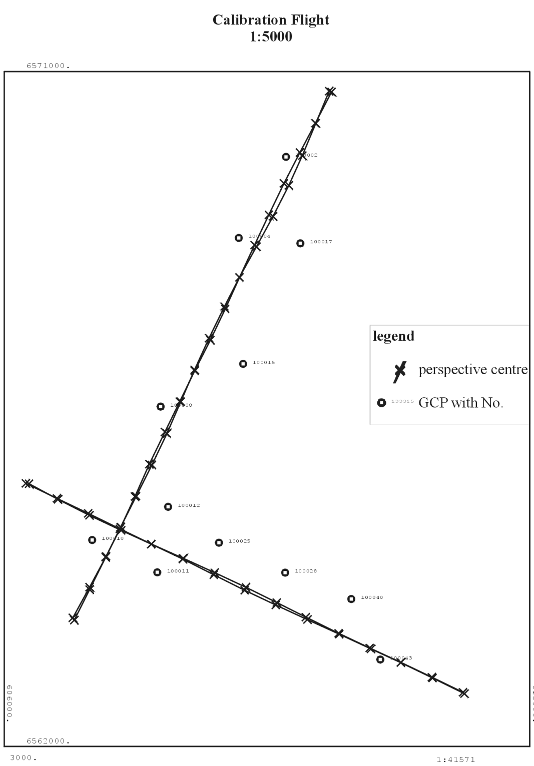

Figure 1: Flight axes of calibration flight 1:5.000

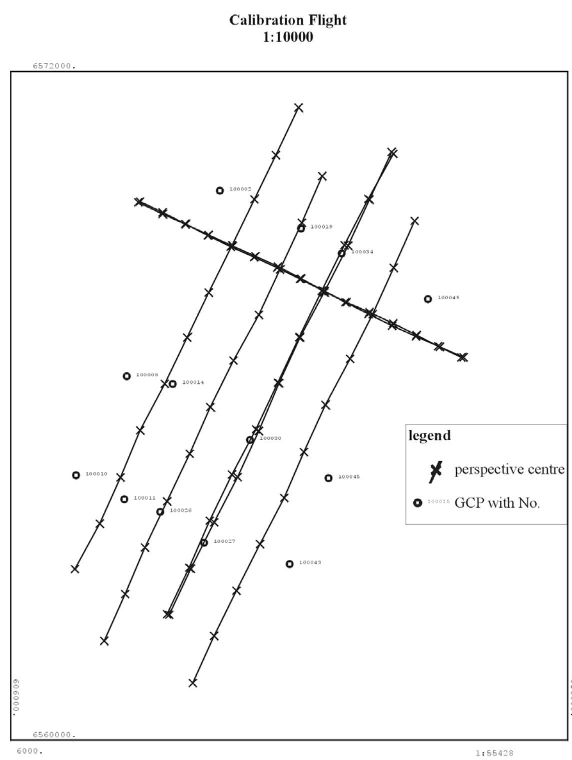

Figure 2: Flight axes of calibration flight 1:10.000

3 TESTS STATUS

The test consists of two phases. The first phase comprises the determination of so-called system calibration parameters. The second phase deals with the integration of the GPS/IMU data into the bundle block adjustment. Subsequent to data acquisition, the test data for first phase were assembled. The following steps were carried out

a) Generation of flight trajectories and roll, pitch and yaw values from the differential GPS carrier phase and IMU measurements by Applanix and IGI, respectively, by Kalman filtering. The employed reference station had been placed in the test field itself yielding an extremely short base line. The satellite constellation as expressed in the PDOP values was excellent. Details about the filtering processes are considered propriety information of the companies and are not discussed in this paper.
b) Interpolation of projection centre co-ordinates and roll, pitch, and yaw values for each image from the data computed in the previous step and the information from time synchronisation.
c) Photogrammetric bundle adjustment of all available imagery by the pilot centre in order to generate a reference data set for image orientations and object space co-ordinates. All image co-ordinate measurements were carried by an experienced operator using the Zeiss P1 analytical plotter. This system was chosen, because its accuracy is beyond any doubt. For each image 5 * 5 = 25 tie points were measured. The standard deviation of the image co-ordinates after bundle adjustment was approximately 5 µm, which lies in the expected range. In order to also enable a simultaneous adjustment of both image scales a large number of common tie points was acquired.
d) The imagery was also scanned at 12 µm per pixel in order to carry out an automatic aerial triangulation at a later stage of the test.

Subsequently, each test participant received a set of image co-ordinates (5 * 5 points per image) and a number of corresponding object co-ordinates of the ground control points (12 points for the scale 1.5.000, 13 points for the scale 1:10.000; see figures 1 and 2) in order to compute the boresight misalignment and possibly also additional parameters. 34 potential test participants have asked for the data. Results of phase 1 are currently being collected by the pilot centre, we have already received data from 10 participants. Table 3 shows some information about these 10 solutions. At this point in time, however, it is too early to present any more detailed results. We hope to be able to discuss them during the conference itself.

Test participant	**Abbreviation**	**Used software**	**Used object space co-ordinate system**	**Type of calibration employed** *
BAE Systems ADR, USA	ADR	BLUH	UTM	Two separate solutions for the two scales, 6 parameters each
GIP, Germany	GIP	BINGO	UTM	Simultaneous solution, 6 parameters
Inpho, Germany	Inpho	InBlock	UTM	Simultaneous solution, 6 parameters
ICC Barcelona, Spain	ICC	GeoTex	UTM and geocentric	Simultaneous solution, 9 parameters
LH Systems, USA	LHS	ORIMA and own development	UTM and local tangential	Simultaneous solution, 6 parameters
Politecnico di Milano, Italy	DIIAR	Own development	Local tangential	Simultaneous solution, 6 parameters
Technical University Vienna, Austria	IPF	ORIENT	UTM and local tangential	Simultaneous solution, 9 parameters
University of Hanover, Germany	IPI	BLUH	UTM and local tangential	Simultaneous solution, 9 parameters
University of Stuttgart, Germany	ifp	PAT B and own development	Local tangential	Simultaneous solution, 6 parameters
University of Udine, Italy	DGRT	GDS Geosoft and own development	UTM	Simultaneous solution, 6 parameters

Table 3: List of test participants (*: "simultaneous solution" denotes a simultaneous bundle adjustment of the 1:5.000 and the 1.10.000 scales; 6 parameters denotes three shifts and the 3 rotations of the boresight misalignment; 7 parameters denotes an additional correction to the focal length; 9 parameter denotes two additional co-ordinates of the principal point)

4 FURTHER PROCESSING

As soon as all active participants have returned their phase 1 results, we will analyse them and in parallel distribute the phase 2 test data. Phase 2 will mainly deal with a combined processing of the GPS/IMU and the photogrammetric information. A workshop for sharing experience and discussing the achieved results will be organised at the pilot centre in Hanover, Germany on September 17 and 8, 2001.

5 REFERENCES

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Web sites about this project:
http://www.nlh.no/ikf/projects/gpsins/
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