DGPS/IMU-based Photogrammetry in China

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Abstract: People's Republic of China is one of the most rapidly developing countries in the world today. There is a great demand on highly actual and accurate spatial information of the whole country, especially of West China which becomes the focus of development of the Chinese government right now and in the next years, but where still not enough topographic maps are available. This raises great challenges to the surveying and mapping community in China. Facing the new challenges the Chinese Academy of Surveying and Mapping (CASM) started its pioneer work early 2002 to explore new techniques and technologies available today toward increasing the map productivity. With import of a CCNS/AEROcontrol system in November 2002 the first DGPS/IMU-based photogrammetric project in China was successfully accomplished jointly by CASM and the Germany-based companies IGI and Techedge. Two photogrammetric blocks of 1:4,000 and 1:20,000 photo scale, respectively, were flown in Anyang, China. Direct georeferencing and integrated sensor orientation were conducted. Results achieved were proven by using ground check points and compared with those of aerial triangulation. Orthophotos generated based on direct georeferencing shows the high efficiency and quality, and thus proved the promise of the new technology. Furthermore several DGPS/IMU-based photogammetric projects was accomplished one by one and a big project of more than 100,000 km2 in the Inner Mongolia will be started in August 2003. The paper presents experiences with DGPS/IMU-based photogrammetry in China. Results achieved in concrete projects are shown and evaluated. Politic and technical specialties in China are discussed. Conclusions outline the potential of DGPS/IMU-based photogrammetric production in China.

Keywords: Differential Global Position System (DGPS), Inertial Measurement Unit (IMU), Direct Georeferencing (DG), Integrated Sensor Orientation (ISO), Photogrammetric Processing and Production

1. Introduction

People's Republic of China is one of the most rapidly developing countries in the world today. There is a great demand on highly actual and accurate spatial information of the whole country, especially of West China which becomes the focus of development of the Chinese government right now and in the next years, but where still not enough topographic maps are available. According to the State Bureau of Surveying and Mapping of China (SBSM) there are nation-wide still quite a few territories (mainly in West China) without maps of 1:10,000, 1:25,000 and 1:50,000 scale, and about one-third of the available maps were produced based on aerial photographs taken in the seventies and the eighties of the last century (Table 1). This cannot keep up with the situation of rapid development in China and raises great challenges to the Chinese surveying and mapping community indeed.

Map scale	No. of map sheets total	No. of map sheets available	Percentage available
1:10,000	372325	163823	44%
1:25,000	96398	23525	24%
1:50,000	24091	19297	80%
1:100,000	6170	6170	100%
1:250,000	819	819	100%
1:500,000	252	252	100%
1:1,000,000	77	77	100%

Table 1: Overview of nation-wide map production of China (from Web-SBSM, 2003).

On the other side, large scale maps are highly demanded in the well developed regions, e.g. the coastal area in the east of China. Information contents have even to be updated frequently since changes may occur so rapidly in months, weeks and even days. According to a recent news report, e.g. in Beijing, you may find every 7 days a new several-stories high

building constructed. It is quite hard job for the Chinese surveying and mapping community right now to keep up with such a speed of development, although there are more than 260,000 professionals working in the country.

With the latest development in techniques and technologies digital processing has already replaced analytical plotting in the photogrammetric production of China since the nineties of the last century. Each provincial Bureau of Surveying and Mapping is well equipped with a large number of Chinamade digital photogrammetric workstations (DPWS). Once digital or digitized images are available, the automated photogrammetric production is carried out. Automation of major photogrammetric procedures replaces the most time-consuming labor work by computers, and thus, speeds up the entire production considerably already. However, there are still some major obstacles to the efficiency of production and intensive human work is still required, e.g. photographs have to be digitized, cartographic features should be extracted, and ground control points (GCPs) must be collected and measured in the field. Image digitization can be accelerated considerably by adding some automatic mechanisms on the film scanner, or ignored completely when digital aerial cameras are applied. Feature extraction can profit a lot from DPWS automated functions being improved gradually with the current technical progress. Now, the task of GCP collection and measurement remains the inevitable labor work, which slows down the production directly on the one hand, and makes mapping of e.g. desert and inaccessible regions in west China very hard or even impossible on the other.

Thus, aerial photogrammetry without any ground control or with a limited number of GCPs is the prerequisite for speeding up the map production so as to meet the demands of rapid development in China and closing the map gap in the country's western regions, in particular.

2. DGPS/IMU-Based Photogrammetry

Recent developments in Differential Global Positioning System (DGPS) and Inertial Measurement Unit (IMU) technologies make direct measurement of sensor Exterior Orientation parameters (EO) possible, so as that the image orientation can be without or just with a limited number of GCPs determinable. In this kind of DGPS/IMU-based photogrammetry the traditionally dominating Aerial Triangulation (AT) becomes now a supporting role in the image orientation. Depending on how AT is used in the whole procedure, we can distinguish a Direct Georeferencing (DG) from an Integrated Sensor Orientation (ISO) conceptually.

2.1. Direct Georeferencing

Use of the image EO determined based on direct DGPS/IMU measurements for photogrammetric data processing without conducting an AT over the entire image block presents the principle of Direct Georeferencing. Advantages herewith are obvious: No tie point determination (either manual or automatic) is necessary, no GCP is required and, as a matter of fact, no AT has to be performed for the entire image block anyway. Nevertheless, for purpose of a so-called boresight alignment highly accurate AT results of a small calibration field are still needed to determine the attitude differences between the image sensor coordinate system and the IMU one (e.g. Cramer, 2002). Some simple geometrical considerations (Kremer, 2002) show that DG is quite suitable for small and medium scale mapping, especially for orthoprojection, and for large scale mapping, however, there may be certain limitations using this approach.

2.2. Integrated Sensor Orientation

Simultaneously processing DGPS/IMU data and image information in a combined AT over the entire image block can be referred to as Integrated Sensor Orientation. Obviously, this approach combines advantages of conventional AT and modern DG, and compensates for their weaknesses. For instance, based on tie points well-distributed over image areas and GCPs over the block AT is capable of eliminating systematic errors by means of a self-calibrating adjustment, and thus reaches the highest accuracy and stability of image orientation. With the direct EO measurements provided by the DGPS/IMU approach the best initial values are available for both the bundle block adjustment and the automatic tie point determination in an automatic AT (e.g. Tang, 1999). Fully profited from the stable geometry supported by the direct EO measurements the number of GCPs required for AT can be reduced to the minimum, and the performance of the entire image orientation procedure is tremendously improved after all.

What a kind of approach to be chosen for a specific project depends on many factors, e.g. the accuracy required, the image scale, the availability of ground control information and GPS base stations and accessibility of the project area. For large scale mapping projects it would be better to use the integrated sensor orientation, in general.

3. First Project

With the successful import of a CCNS/AEROcontrol system (Grimm, 2003) in November 2002, Chinese

Academy of Surveying and Mapping (CASM) organized the first DGPS/IMU-based photogrammetric project in China in cooperation with the Germany-based companies IGI and Techedge. Anyang, a city of Province Henan, Located about 500 km south of Beijing, was chosen for the test flights. CASM was responsible for all administrative as well as operational issues of the project. The German team, consisting of the authors, was in charge of workflow design, system installation, personal training and technical consulting within the project.

3.1. Project Realization

Two missions of aerial photography were planned and conducted for a photo scale of 1:4,000 (for 1:1,000 scale mapping) and 1:20,000 (for 1:5,000 scale mapping), respectively. Concerning many special cases in China (e.g. inaccessible regions) investigating effects of GPS base station location was also one of the objectives. Thus, several GPS base stations of different distances to Anyang were simultaneously used for the missions. Table 2 shows the major mission parameters.

3.2. Mission A Results

To prove the applicability of the DGPS/IMU technology for topographic mapping in China we chose four modes for accuracy analysis, i.e. AT, DG, ISO without any GCP and ISO with 4 GCPs. Table 3 shows sample results of Mission A. Besides the obvious efficiency, our major findings are:

- ISO with 4 GCPs delivered the best fit in comparison to AT results and was favorable.
- ISO without any GCP could even improve the results considerably.
- DG had problems in vertical determination, but was still suitable for orthoprojection.

The loss of orientation quality due to a long distance of a GPS base station to the mission area could be tolerable, especially in case of an ISO solution.

	Mission A			Mission B		
Photo scale	1:4,000			1:20,000		
Map scale	1:1,000			1:5,000		
Terrain type	flat			flat/hilly		
Area	5 km × 2.5 km			14 km × 22 km		
Block size	5 strips ×18 photos			7 strips ×16 photos		
Calibration field	Inside block, additional 11 photos			outside block, 2 strips of 11 photos each		
GSP base station	Anyang	Hebei	Beijing	Anyang	Zhengzhou	Beijing
Distance to block	-	212km	451km	-	150 km	451 km
Flight date	18/11/02	19/11/02		03/01/03		

Table 2: Major mission parameters of the Anyang project.

GPS base station	Mode	Check points	RMS (m)				Max (m)	
			ÄX	ÄY	ÄDistance	ÄZ	ÄDistance	ÄZ
Anyang	AT	31/15	0.091	0.067	0.113	0.078	0.236	0.124
	DG	109			0.244	0.197	0.54	0.604
	ISO+0GCP	45	0.104	0.082	0.133	0.078	0.242	0.177
	ISO+4GCPs	41	0.115	0.089	0.146	0.078	0.255	0.152
Beijing	DG	109			0.291	0.191	0.475	0.659
	ISO+0GCP	45	0.149	0.221	0.267	0.116	0.412	0.374
	ISO+4GCPs	41	0.138	0.095	0.168	0.114	0.356	0.238

Table 3: Sample results of the Anyang Mission A.

3.3. Mission B

Due to bad weather conditions in Anyang the planned Mission B (cf. Table 2) had to be postponed. The real flight was carried out on January 3, 2003, shortly before the first Chinese workshop on DGPS/IMU-based photogrammetry, held from January 11 to 13, 2003, in Beijing. First experiences and results achieved from the Anyang project were presented and discussed on the workshop, signifying the real start of DGPS/IMU-based photogrammetry in China.

4. Further Projects

In the following we just give an overview of DGPS/IMU projects conducted by the CASM team independently since the start work.

4.1. Xingtai Project

Xingtai Highway runs along the east-west direction, located about 100 km north of Anyang. Another DGPS/IMU project was conducted there on December 29, 2002. The corridor flight covered a route length of about 251 km. The image scale was 1:8,000. There were totally 14 strips or 368 photos taken. Figure 1 shows a part of trajectory of the flight.

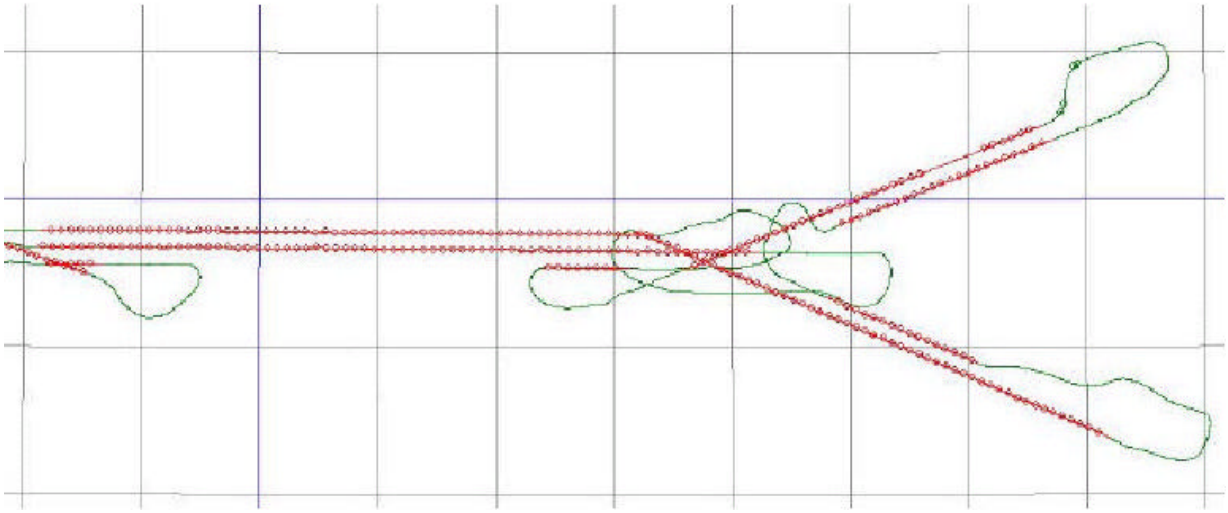

Figure 1: A part of trajectory of the Xingtai highway project.

4.2. Tianjin Project

Recently the CASM team has accomplis hed a DGPS/IMU project in the Haihe river to Bohai See mouth area in Tianjin, about 100 km southeast of Beijing. That was a color photography of 1:8,000 image scale. There were 29 strips designed and 1035 photos taken totally. Due to some circumstances flights were carried out on June 15, 16, 25 and 26, 2003, respectively. After direct georeferencing of aerial imagery orthoimages of the first two flights were generated. Figure 2 shows the mission planning results of the project. A mosaic of 5 × 10 orthoimages is shown in Figure 3.

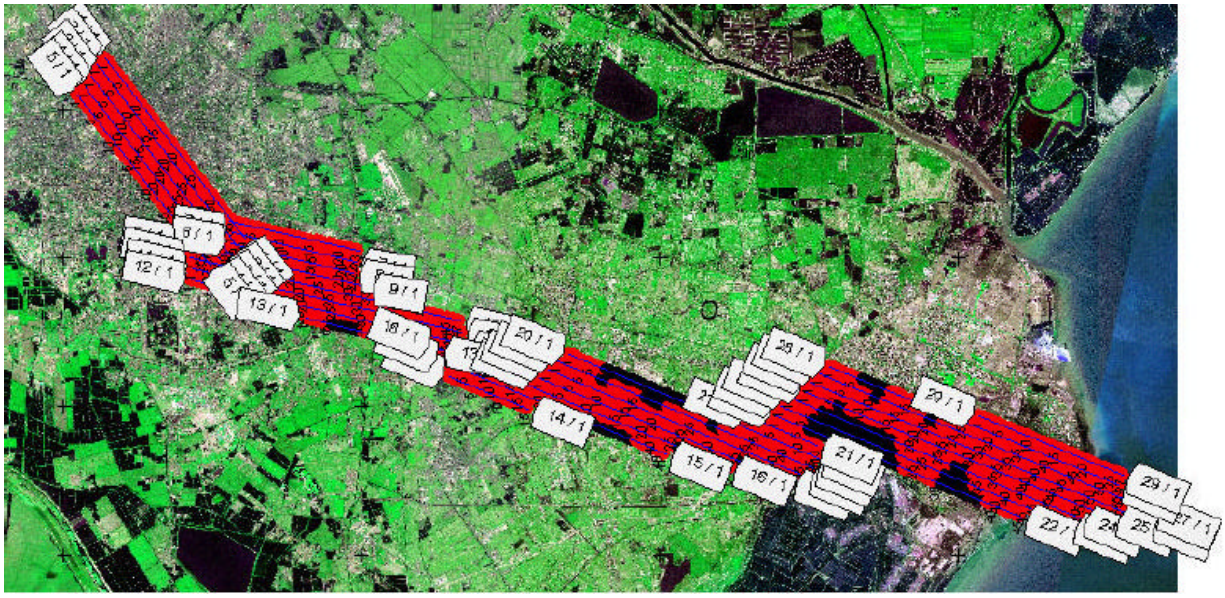

Figure 2: Mission planning of the Tianjin Haihe river project.

4.3. Xilinhaote Project

Very recently CASM won the xilinhaote project of about 100,000 qkm in the Inner Mongolia from the State Bureau of Surveying and Mapping of China for this summer, dedicated to use of the DGPS/IMU technology. It is 255 km from West to East and 580 km from North to South in this aera. There are two parts in this project, one of the 1:32,000 photo scale, the other is 1:50,000 photo scale. Now the mssion is progressing steadily. Table 4 shows the major project parameters.

	Part I		Part II		
Area	35360qkm		65180qkm		
Photo scale	1:32,000		1:50,000		
Map scale	1:10,000		1:50,000		
Blocks	A	B	C	D	E
No. of flight lines	33	32	78	15	15
No. of total photos	1804	1192	1168	639	518

Table4: Major parameters of the Xilinhaote project.

5. Experiences

In the following, we will just mention some major Chinese specialties for running DGPS/IMU-based photogrammetric projects we learned through these projects.

5.1. Hardware Montage

In China aircraft for aerial photography belongs to a third party, in general. In most cases, the contractor party of conducting a mission of aerial photography rents an aircraft, mounts its aerial camera or other necessary hardware in it, and removes all the equipment after the mission. This makes the montage of GPS antenna on top of an aircraft quite problematic.

Figure 3: A mosaic of 5 × 10 orthoimages of the Tianjin Haihe river project.

5.2. Coordinate Systems

Since there are very rigorous restrictions to deal with transformations between global and local coordinate systems in China, transformation parameters between

the WGS84 coordinate system and any local Chinese one are hardly to get directly. Therefore, software requiring those transformation parameters has either to make the interface open or to provide tools to generate those parameters based on conjugate points.

5.3. System Calibration

To signalize GCPs in the calibration field can hardly be accepted by practitioners in China. Nature object points have to be chosen. There are some good AT software packages made in China which may be adapted for the calibration. GeoLord-AT we used this time is a good example. Now we are able to use an adapted version to work on our project.

5.4. Administrative Restrictions

Because there are quite a few administrative restrictions with respect to e.g. flight permission, aircraft montage (e.g. GPS antenna) and map information or data access as well as use. Since all institutions or companies conducting aerial photography in China are still state-owned, it would hardly be expected not to have any bureaucracy during procedures. Flight permission, for instance, has to be applied for quite a time before the real flight and the flight height once permitted is hardly to change later. All these factors have to be taken into account for a successful mission anyway.

6. Conclusions

The new DGPS/IMU technology for topographic mapping has adopted in China. Our findings thereof could confirm again that

· direct georeferencing would be suitable for direct orthophoto generation even of large scales;

· integrated sensor orientation using a limited number of ground control points can compensate systematic errors and makes the best way to replace the conventional aerial triangulation;

· for small scale mapping direct georeferencing should be good enough to meet the accuracy requirements.

According to the latest information, there are three company has imported (or in progress)DGPS/IMU system for mapping applications expect CASM. Using digital aerial camera and airborne laser scanner (LIDAR) mounted on a unique platform supported by DGPS/IMU technology and making use of the global DGPS networks it is to be expected in the near future that spatial information would be deliverable within 24 hours from its acquisition (Tang, 2004). We could expect that DGPS/IMU-based photogrammetry would be going to dominate the topographic mapping in China soon.

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