DEVELOPMENTS IN AERIAL TRIANGULATION AND SITUATION IN TURKEY

Gonul TOZ[1], Oktay AKSU[2]
[1]ITU Department of Geodesy and Photogrammetry-Istanbul
[2]General Command of Mapping-Ankara

Summary

Kinematic GPS supported aerial triangulation and digital aerial triangulation methods have been applied for almost three years in Turkey. Considering the existing situation, some conclusions are given in this paper.

1. Introduction

Significant developments in research and practical areas relating to aerial triangulation have occurred since 1990's, especially in Europe. The main subjects in that field are kinematic GPS-supported aerial triangulation and automatic aerial triangulation method. As is well known, OEEPE has carried out various research and test projects concerning these topics since 1992, and the last one "Performance of tie point extraction in automatic aerial triangulation" was initiated in 1997 and has almost been finished.

Universities, public and private mapping organizations especially General Command of Mapping (GCM) emulate these developments and provide the required hardware and software for use in practical applications.

Acquired conclusions and evaluations by means of carried out activities at GCM, relating to the above mentioned topics, are given in this paper.

2. Kinematic GPS Supported Aerial Triangulation

Applications of kinematic GPS supported aerial triangulation, which may be described as calculation of approximate and/or (nowadays) absolute coordinates of projection centers of aerial camera at the time of exposing by processing relative kinematic GPS data acquired at ground and on moving stations, and to use them in combined block adjustment, have been used at GCM since 1995.

Revision of 1:25000 scale topographic maps constitutes the majority of the activities and 1:35000 scale aerial photographs are used for that purpose. Large scale applications are also carried out time to time for requirement of other organizations. As an example, the results of the last application in 1:4000 scale is given at below table.

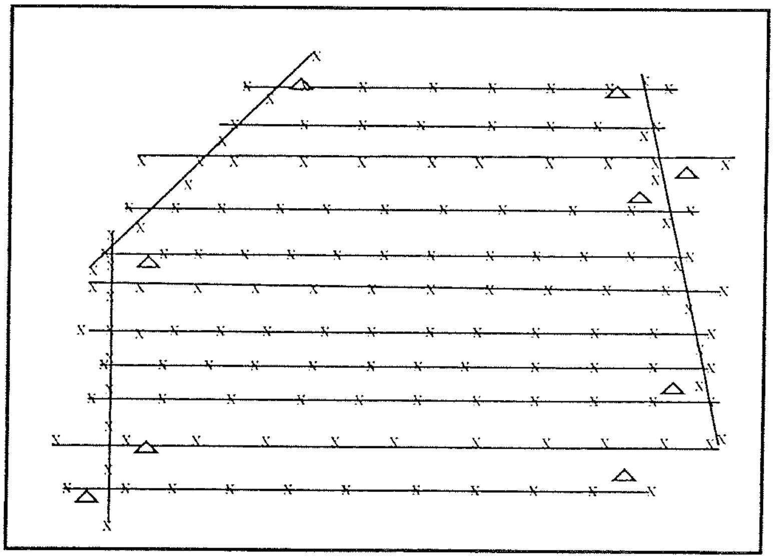

Figure 1. An example block for kinematic GPS supported aerial triangulation

Table 1. Results of the block adjustment

Number of observations	7042
Number of unknowns	3501
Redundancy	3541
Number of image points rms x/y (μm)	3272 4.13/3.84
Number of control points rms X/Y/Z (cm)	9 4.0/3.2/3.8
GPS measurements rms X_0, Y_0, Z_0	157 7.0/6.9/3.6
σ_0	5.55 μm : 2.5 cm
Mean standard deviation of exterior orientation parameters ω (grad) φ κ pX (m) pY pZ	 0.0065 0.0052 0.0020 0.111 0.137 0.073
Standard deviation of tie points (mean) X, Y, Z (cm) (minimum) (maximum)	 3.0/3.2/9.8 2.0/2.0/4.5 7.6/8.1/22.0

Trimble 4000 GPS receivers, RMK-TOP aerial camera, SKIP and PATB-GPS are some of the hardware and software used in routine applications.

According to annual revision plan, a broad application was carried out last summer in a project area covering 240 map sheet at 1:25000 scale. More than 3000 aerial photographs at 1:35000 scale were taken and GPS data were recorded at 1 second data rate in three (two of them on the ground) stations. 55 ground control points were planned and 3 people worked on the project area during one month for geodetic activities. Selected control points from the existing network were only checked with control measurements and signalized for photography.

Almost half of the existing blocks in the project area were measured and adjusted up to now. One of the blocks was almost 180 km away from the ground stations and the results obtained are given as an example as follows :

- scale of photographs 1:35000
- 10 normal, 2 crossing strips and 152 images
- 5 control points
- r.m.s. of image measurements (x,y) : 5.03μ / 4.17μ
- r.m.s of GPS measurements : 5.3 cm / 4.8cm / 8.2 cm
- σ_0 : 6.5 μ = 24.2 cm
- r.m.s of terrain coordinates of tie points (mean) : 31.5 cm / 31.4 cm / 52.6 cm.

On the other hand in the classical way, where selected control points from the existing triangulation network according to flight plan in almost 2b distance, were only being signalized formerly, almost 1000-1200 points would be signalized for the same revision area. In that case six people would work in the field during three months. Naturally, the results of such an application will not be as good as results of kinematic GPS supported application.

Kinematic GPS supported applications may not be significant in some countries, where geodetic substructure has already been completed and well maintained, and it is possible to find control points on the ground at required time and places. But that method provides very significant time and cost economy in countries such as Turkey, where it is hilly and requirement to the various scale mapping increases day by day.

We are using SKIP (1.2) software for GPS data processing at present. Nowadays commercially available SKIP (2.2) eliminates some deficiencies of the former version, such as using only L1 frequency, the necessity of same type of receivers and the same data rate on the ground and in the aircraft. Also there is a possibility to use absolute solution for phase ambiguity and to eliminate using cross strips in the blocks in that version.

Considering the possibility of using it at various scales including large scale, it can be stated that the kinematic GPS supported aerial triangulation method should be used extensively by mapping organizations in Turkey.

3. Digital Aerial Triangulation

Private and public sector have been using digital photogrammetric workstations (Softplotter, Phodis, etc.) for almost two years in Turkey. Some of them have applied manual and semi-automatic aerial triangulation methods. But, we prefer using the automatic method and from that point, we have evaluated the existing situation considering our experiences obtained up to present.

It is obvious that the main steps in analytical aerial triangulation such as block preparation, block measurement and block adjustment are also valid in digital methods. But the first attractive difference appears in time consumption between these two methods. In the case of automatic aerial triangulation method, there is no need for preparation work with diapositives and positive printings for tie points. Also, another advantage of automatic point detection is, to prevent wrong numbering for tie points on printings as occurred very often in the analytical method. So, one of the main error resources in block adjustment is eliminated in automatic methods.

According to our experiences with automatic aerial triangulation, there is a rate *1/3* in time consumption as an advantage than the analytical method.

On the other hand, the scanning time for roll films or diapositives during the block preparation step may be evaluated as a disadvantage compared with the analytical method. But the use of digital images become an advantage when the overall system performance in digital production steps such as orthophoto, mosaics, etc. are considered.

Kinematic GPS supported aerial triangulation also provides an advantage to the automatic aerial triangulation by means of derived projection center coordinates to be used in block topology.

As is well known, only two images can be used at the same time for measurement in analytical method. The homologous points can be measured in six or more images at the same time in most of the digital methods.

Normally a human operator is not required for automatic tie point extraction. However, manual tie point measurement is required when the results of the block adjustment are transferred to the analog or semi-analytical instruments.

On the other hand, manual measurements of the control points are rather difficult and time consuming process, when the circular shape for signalisation of ground control points is used. There may be many white dots on the image and they may cause to confuse the correct places of points. Easily definable shapes for signals may be a solution.

It is very difficult to have good results with automatic tie point extraction in some blocks which include forestry area or coastal lines. Also, photo laboratory process should be done carefully. The lines on the films because of drying process, cause problems in automatic aerial triangulation.

We had to measure tie points manually in such a block which has 174 images at 1: 35000. Resulting accuracy was slightly worse than a similar block which was measured by analytical instruments.

Following are the results related to a large scale application. The image scale is 1: 4500 and number of images is 72 in standard overlaps (%60,30)

Table 1. Comparative results of the block

	Digital	Analytical
Number of observation	50765	3714
Number of unknowns	32076	1833
Redundancy	18689	1881
Image points x,y rms x/y (μm)	25265 1.76/2.28	1684 3.26/3.54
Ground control points X,Y Z rmsX/Y/Z (cm)	8 9 7.6/7.1/10.3	8 9 5.3/7.2/15.1
Check points X,Y Z rmsX/Y/Z (cm)	41 36 7.4/8.1/14.6	45 39 3.7/5.3/3.8
A posteriori σ_0	3.38μ= 1.6 cm	4.92μ= 2.3 cm
Mean stand. deviation of PC	6.9/8.8/4.7 cm	10.7/12.3/4.7 cm
Mean stand. deviation of $(\Omega, \phi, \chi)^{cc}$	39/29/9	62/49/19
Mean stand. deviation of tie points	2.1/2.3/7.6 cm	2.2/2.4/7.4 cm
Minimum stand. deviation of tie points	1.1/1.6/3.4 cm	1.2/1.2/3.1 cm
Maximum stand. deviation of tie points	10.3/4.2/33.7 cm	6.8/6.6/19.7 cm

Table 2. Time consumption in analytical method

Analytically	**Hours**
Preparation	12
Point transfer	16
Measurement	40
Block adjustment	1
TOTAL	69

Table 3. Time consumption in digital method

Digital	**Hours**
Scanning	16
Block definition	0.25
Pyramid computation	2.25
Automatic interior orientation	1
Automatic tie point detection	3

GCP measurement	2
Block adjustment	1
TOTAL	25.5

Although some existing problems, automatic aerial triangulation is highly favorable when the results and time consumption is considered.

References

G. TOZ, O. AKSU A Comparative Application of Automatic Aerial Triangulation, Photogrammetric.Fernerkundung.Geoinformation 3/1998, pp.151-156

O. MUSTAFA et.al. Report of GCM on the OEEPE/ISPRS test project "Performance of tie point extraction in automatic aerial triangulation" , Cambridge, 1998

W. MAYR Aspects of Automatic Aerotriangulation, Photogrammetric Week'95,Herbert Wichmann Verlag, Karlsruhe, pp.225-234

Phodis Manual Carl Zeiss, Revision 9707