A COMPARISON ACCURACY STUDY OF GPS PHOTOGRAMMETRIC BLOCK ADJUSTMENT AND INDEPENDENT MODEL APPROACH

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Ground control point data collection is one of the most expensive and time consuming phases of a photogrammetry based mapping projects. Nowadays, Global Positioning System (GPS) is broadening its role in photogrammetric activities and mobile mapping from reaping Ground Control Points (GCPs) and measuring image center coordinates to rotating elements of camera system. Recently, lots of researches have realized to evaluate and study of using GPS data and their combination with INS (Inertial Navigation System) data to decrease the number of GCPs, for large scale mapping.

In this paper, we evaluate and compare the results of GPS based Bundle Adjustment (BA) with Independent Model (IM) approach in Iran's 1:25000 scale maps blocks adjustment. The results demonstrate the sufficiency of the estimated accuracies for this scale.

1. Introduction

In photogrammetric mapping process, for orientation of photogrammetric models, we need either to know the external orientation parameters of camera at an acceptable accuracy level or to have sufficient number of ground control points. Ground control point collection has high cost and takes time in photogrammetric mapping projects. Therefore, the photogrammetrists look forward the ways to reduce the map production costs using new technologic possibilities and analytical approach. The utilization of global positioning system in photogrammetric mapping began almost from the inception of GPS technology. Initially, GPS was used to obtain ground control point coordinates for aerotriangulation. It may grantee the lower costs, shorter time, less labor exigency, higher quality and more reliable data than conventional methods in Photogrammetry. GPS gives photogrammetrists the opportunity to minimize the amount of ground control points needed for a needed accuracy level. Airborne GPS is used to measure the position of the camera at a given instant of exposure. It gives the (X, Y, Z) coordinates of projective center. GPS data can also be used to derive the angles parameter of exterior orientation. Unfortunately, the derived angular relationships only have a precision of about 1' of arc, while photogrammetrists need to obtain these values to better than 10" of arc. To measure the position of the camera center, during flight, two *Dual Frequency GPS* receivers are commonly employed. One is placed over a well known ground station and the other is mounted on the aircraft. Then, the carrier phase/code data are generally collected by both receivers with a sampling rate of 0.5 or 1 second and for integer ambiguity resolution, On The Fly (OTF) technique is used (Salsig and Grissim, 1995; Corbett and Short, 1995; Bains, 1995; Merchant 1992). Lapine (1995) in National Oceanic and Atmospheric Administration (NOAA) aerial mapping projects utilized airborne GPS because of efficiencies in reduction the amount of needed ground control points. The origination of the paper is as the fallow: in the first phase we present the methods of Antenna Placement. Then Flight Planning using Airborne GPS is discussed. In third section, we explain the architecture of triangulation in GPS based photogrammetry. The experimental results are presented in next section. Finally, the evaluation and conclusion are addressed.

2. Antenna Placement

The position of the antenna on the aircraft should be precisely measured. Although any point on the topside of the plane could be considered, two locations are more convenient. The first is on the fuselage and behind the cabin, directly above the camera, and the second one is the top of the vertical airplane tail. By our experience, in the experimental mission done by Iranian National Cartographic Center (NCC), the best place for the antenna placement is the direction of optical axis. The offset between the GPS antenna and the perspective center must then be measured accurately. Table I illustrates the measurements of the offset distance obtained by setting up of a micro geodesic network, (see Figure. 1).

Table I

The results of offset measurements

d_x(m)	d_y(m)	d_z(m)	σ_x	σ_y	σ_z
-0.010	0.0096	1.485	0.0005	0.0003	0.0008

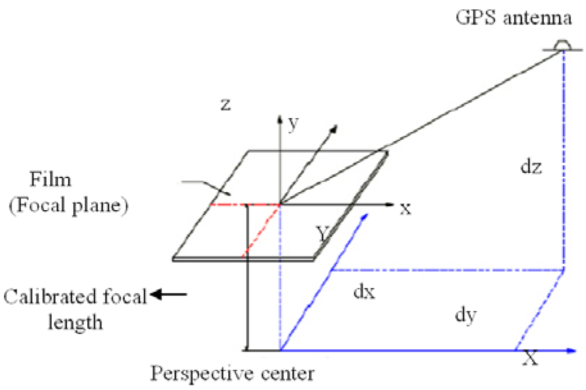


Figure 1. The GPS offset illustration

It is worth mentioning that measurements accuracies of lengths are done by 2 mm, heights by 1 mm and angles by 7 seconds.

3. Flight Planning for Airborne GPS

When planning for an airborne GPS project, special consideration must be taken into account for the addition of the GPS receivers that will be used to record the location of the camera. The first issue is the form of initialization of the receiver to fix the integer ambiguities. Next, when planning the flight lines, the potential loss of lock on the satellites has to be accounted for. Depending on the location of the airborne receiver, wide banking turns by the pilot may result is a loss of the GPS signal. Banking angles of 25° or less are recommended which results in longer flight lines (Abdullah et al., 2000).

The location of the base receiver must also be considered during the planning. Will it be at the airport or near the job site? The longer the distance between the base receiver and the rover on the plane the more uncertain will be the positioning results. It is assumed that the relative positioning of the rover will be based upon similar atmospheric conditions. The longer the distance, the less this assumption is valid. Deploying at the site requires additional manpower to deploy the receiver and assurances that the person who is occupying the base is collecting data when the rover is collecting the same data.

When planning, try to find those times when the satellite coverage consists of 6 or more satellites with minimum change in coverage (Abdullah et al., 2000). Also plan for a PDOP that is less than 3 to ensure optimal geometry. Additionally, one might have to arrive at a compromise between favorable sun angle and favorable satellite availability.

Make sure that the GPS receiver has enough memory to store the satellite data. This is particularly true when a static initialization is performed and satellite data is collected from the airport. There may also be some consideration on the amount of side lap and overlap when the camera is locked down during the flight. This will be important when a combined GPS-INS system is used. The limitations attributed to the loss of lock on the satellite places additional demands on proper planning. These problems can be alleviated to some degree if additional drift parameters are used in the photogrammetric block adjustment.

4. Architecture of triangulation in GPS photogrammetry

Because of the rectangular shape of the most photogrammetric blocks, there are 3 type of architectures as below (see Figure.3):

a) Only one full ground control point at each corner

b) One full control point in the corners and a chain of height control point in each side of block

c) One full control point in the corners, one height control point and also two cross line of flight on each side

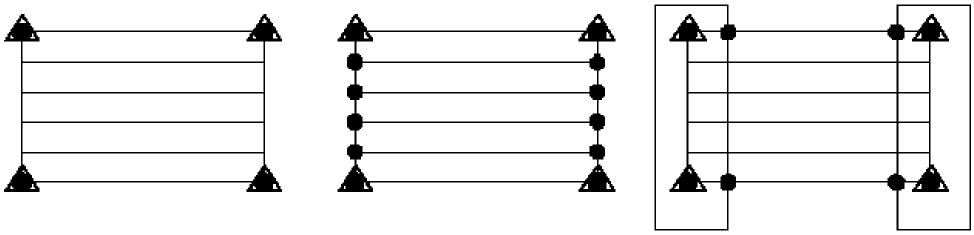
In the presence project, all of above configurations are planed and evaluated in experimental tests.

5. Experimental results

An imagery mission was maintained based on above planning and GCPs configuration. Table II presents the characteristics of this mission.

Then using a *DSR14 analytical plotter*, the photographic control points were measured by 10μm accuracy. In other hand, using GPS receivers in static mode, the ground control points were collected by 10 cm accuracy, and the projection centers were measured by 20 cm of accuracy for (x, y, z). Then, BA is applied using an analytical program coded by Visual C+ language. The IM also is applied using the *Paradeyes*, which is a photogrammetric program provide by NCC.

The figure 5a and 5b show the results of IM calculation for altimetric and planimetric points. The total number of GCP's used in this test was about 300 point. For IM the maximum error for height control points is about 2.5 m, and for planimetric control points the maximum error is about 1.5 m for x-coordinates and about 1.3 m for y-coordinates.



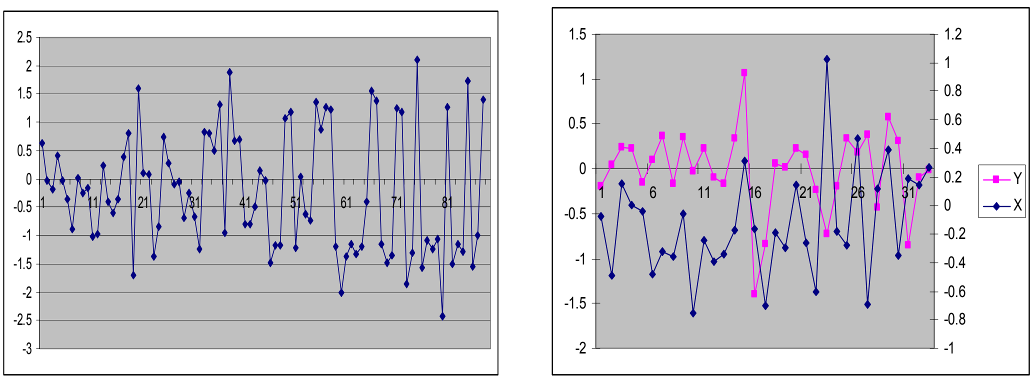
(a) (b) (c)

Figure 3. Three cases of ground control point configuration

Table II

Presents the characteristics of this mission

Area: part of block 22 of Saeendez	Photo Scale: 1:40000
Flight Direction: East- West	Forward Overlap: 60% minimum
Side-lap: 30%	Focal Length: 153.24
Format: 230 x 230 mm	Camera: Wild RC 20
Exposures per Strip: 33	Sun Angle: 30° minimum
Cloud Cover: None	GDOP: #4
Flying Height: 6100 meter	Number of strips: 9



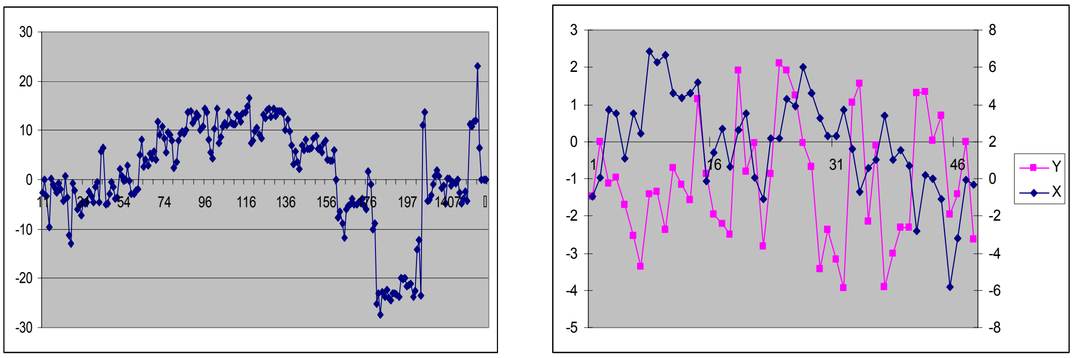
(a) (b)

Figure 5. Results of IM adjustments for altimetric (a) and planimetric (b) control points

In a second, more than 280 check points were used to calculate the RMS error of BA concerning to configuration case (a). The figures 6a and 6b illustrate these results. The maximum error, in this test, for altimetric points is about 27 m and for planimetric points is about 4 m for x and 6.88m for y coordinates.

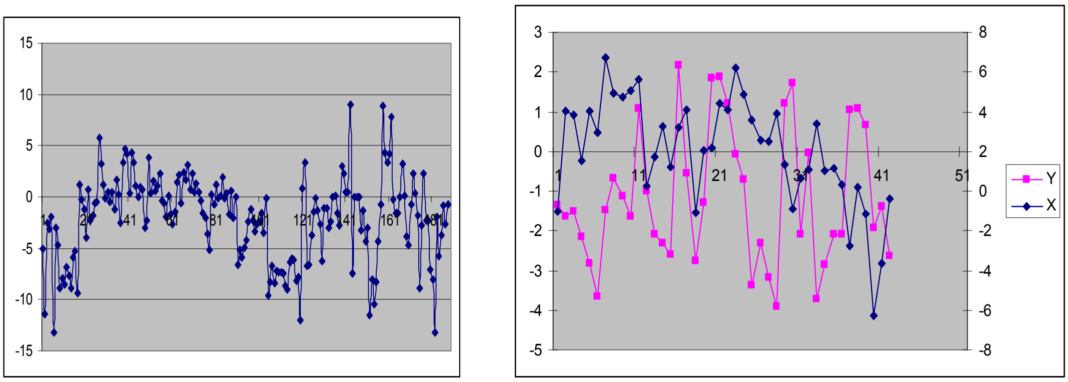
For configuration case of (b) the similar calculations were realized using about 250 check points. In this case the maximum error for altimetric check points is about 14 m and for planimetric check points is about 4 m for x and 6.88 m for y coordinates. Figure 7a and 7b presents these results.

The final test is concerning the configuration case c. More than 270 check points were used to calculate the RMS errors using BA. The maximum error for altimetric check points is about 7m and for planimetric check points is about 3.5m for x and 6.5 m for y coordinates. Figure 8a and 8b show the results of this adjustment.



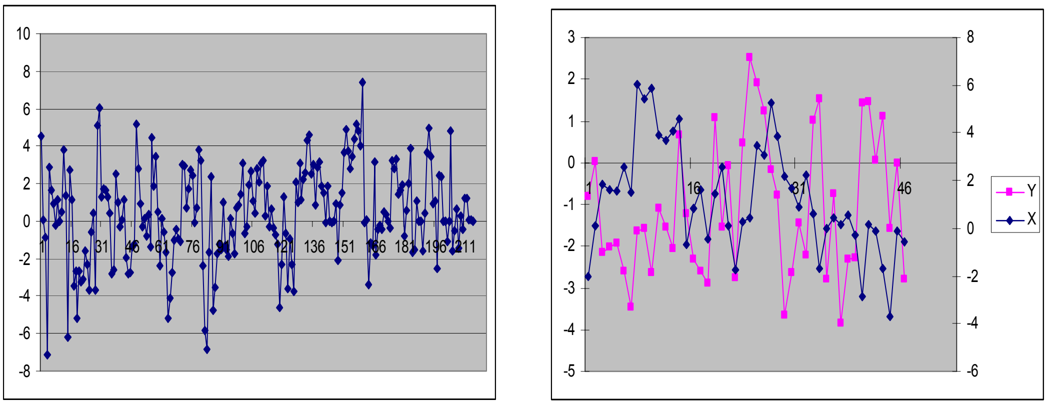
(a) (b)

Figure 6. Results of BA for altimetric (a) and planimetric (b) check point for case a



(a) (b)

Figure 7. Results of BA for altimetric (a) and planimetric (b) check point for case b



(a) (b)

Figure 8. Results of BA for altimetric (a) and planimetric (b) check point for case c

6. Evaluation and conclusion:

The results of Independent Model adjustment, naturally, are more reliable and accurate because it uses a lot of GCPs. Therefore it seems to be logic to consider these results as a basic reference to evaluate the results of GPS based Bundle Adjustments. The BA adjustments need too less GCPs, as objective of this research we need to evaluate the accuracy and reliability of BA. Table III presents a summary of the comparison results between all three BA cases and IM.

Table III

Presents a summary of the comparison results between all three BA cases and IM

Difference(IM-BA)	Max ΔX	Max ΔY	Max ΔZ	Mean ΔX	Mean ΔY	Mean ΔZ
IM-BA(case a)	4	4	17	2	2.5	4.5
IM-BA(case b)	4	4	10	2	2.5	3.5
IM-BA(case c)	4	4	5	2	2	2

As we can see, the configuration case of (c) seems more accurate. Case c needs one full control point in the corners, one height control point and also two cross line of flight on each side. Thus, regarding 1:25,000 scale standard accuracies, (3m for planimetric and 3.33m for altimetric accuracy), this case can be used in map production chains because of need to less number of GCPs and consequently less costs and labor activity. So using GPS BA, an estimation of 25% reduction may be generally achievable comparing the conventional approach.

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