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An Investigation of Direct and Indirect Geo-Referencing Techniques on the Accuracy of Points in Photogrammetry

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Abstract**—**Advances technology in the field of photogrammetry replaces analog cameras with reflection on aircraft GPS/IMU system with a digital aerial camera. In this system, when determining the position of the camera with the GPS, camera rotations are also determined by the IMU systems. All around the world, digital aerial cameras have been used for the photogrammetry applications in the last ten years. In this way, in terms of the work done in photogrammetry it is possible to use time effectively, costs to be reduced to a minimum level, the opportunity to make fast and accurate.

Geo-referencing techniques that are the cornerstone of the GPS / INS systems, photogrammetric triangulation of images required for balancing (interior and exterior orientation) brings flexibility to the process. Also geo-referencing process; needed in the application of photogrammetry targets to help to reduce the number of ground control points. In this study, the use of direct and indirect geo-referencing techniques on the accuracy of the points was investigated in the production of photogrammetric mapping.

Keywords**—**Photogrammetry, GPS/IMU Systems, Geo-Referencing.

I. Introduction

PHOTOGRAMMETRY and surveying science disciplines rather than as independent of each other, they are known as sciens that integrally with each other, use common data. In photogrammetric mapping, along with digital camera and GPS / IMU systems are used in, in connection has changed the scope of geodetic activities.

Changing and developing technologies have also significantly affected the science of photogrammetry. With this rapid development technology in the field of photogrammetry, digital cameras with GPS/IMU system have taken usually only replace analog cameras with GPS system in aircraft. In this system, when determining the position of the camera with the GPS, the simple rotations are determined by IMU systems. With this technology at photogrammetric mapping, costs could be reduced to a minimum level and making fast and accurate study opportunities occurred. [1].

At the stage of processing and evaluation GPS / IMU kinematic data which obtained by Digital camera systems, plane during the flight and the flight was established in the areas of GPS data is needed. On the plane and on the ground at the same time making observation the same GPS satellites, satellite orbit and clock errors are resolved. For this, in the area of flight during flight of a GPS station should be established to make observations or in that region of CORS-TR point data must be used as a benchmark. The main purpose is that photo representing the image coordinate system and objects representing the land coordinate systems are to provide the basic relationship between. This process is called geo-referencing. [2].

The conversion process between Photographs or images coordinate system is obtained by the detection system and objects (land) coordinate system which results will be presented of the product is called geo-referencing (the orientation). The most general sense is making associated with the earth and aerial images. This association, the GPS / INS systems that are the cornerstone of Geo-referencing techniques brings flexibility photogrammetric images required for balancing the process of triangulation. In addition, geo-referencing helps to reduce the number of ground control points are needed in the application of photogrammetry. [3].

Exterior orientation elements which product as a result of the measurements performed during the flight by using GPS / INS systems can be calculated directly. Geo-referencing is based on equality that finding corresponding pixels in the image on the linearity of the land (collinearity). Exterior orientation parameters are obtained by using directly GPS / INS integration costs have shorten ortho-image generation process in terms of time and reduced costs drastically. [4].

Reach oriented images (photographs) to the real plane is called indirect geo-referencing, obtaining oriented photographs from actual plate called indirect geo-referencing.

Indirect geo-referencing, camera orientation and position of during image acquisition is defined. In the images taken with the help of parameters, guided imagery reduced to the actual coordinate system. Shortly, it allows determination to actual position of the image of the space plane. The details on the photos are defined with image coordinate system. This system during capture, image signals which are determined on the midpoint of finder is made by combining the coordinate system (Fig. 1).

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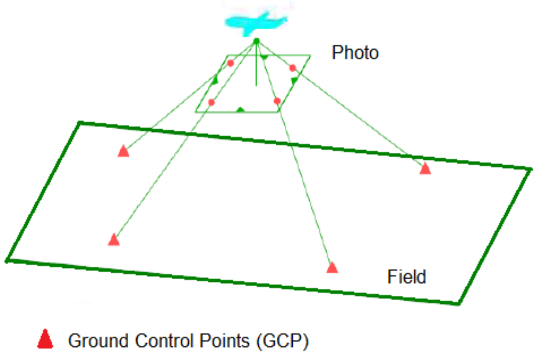

Fig. 1 Indirect Geo-Referencing

Land coordinate system allows determination positions of points in the object space. This coordinate system is expressed in ellipsoidal parameters and datum. Terrain coordinate system can be national reference systems as well as may be regional coordinate system. Indirect geo-referencing is provided by linearity condition which is the relationship between the image coordinate system to land the coordinate system. This process is usually done by Bundle Block Adjusment.

Direct geo-referencing: GPS atmosphere, orbit and signal-dependent error sources which will be calculated at the reference station with adjustments to correct the rover receiver are called as Differential Global Positioning System–DGPS. Thanks to the use IMU along with DGPS exterior orientation parameters of the direct detection of the INS solution to the direct geo-referencing process (Direct Georeferencing) is called (Fig. 2).

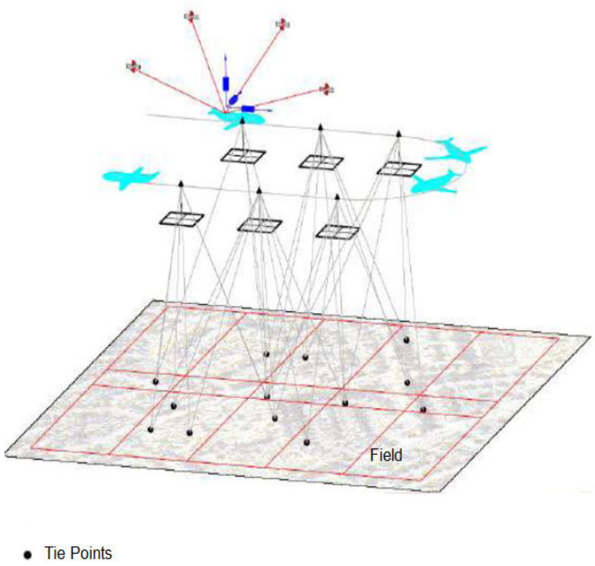

Fig. 2 Direct Geo-referencing

The basic principles of direct geo-referencing, depending on the type of sensor used in the time of recording the position and orientation information is determined in the reference coordinate system. Navigation systems are used, if consisting of the position and orientation data provide sufficient accuracy, this information is available for this purpose. The navigation system can be used for this purpose must meet the following three conditions [5]:

- For position and orientation data, determine displacement between the navigation coordinate system and the image coordinate system sufficient accuracy,
- Determined of displacement, is fixed or changes can be modeled,
- The sensors used for this purpose is synchronized with sufficient accuracy.

In this study, the GPS / IMU data photogrammetric evaluation of its contribution to kinematic was investigated. Time, cost and obtained changes accuracy were examined.

II. Purpose of the Study

For this purpose, the prepared three components in a test device were prepared. In the first test set, without using GPS/ IMU, using only ground control points photogrammetric triangulation measurement and block adjustment have been carried out, in the second test set, without the ground control point data, GPS/IMU data, triangulation photogrammetric measurement and block adjustment have been produced. In the third test set, using ground control point data and GPS/IMU data together photogrammetric triangulation measurement and block adjustment were performed. According each of the three test sets; comparison in terms of cost and accuracy were obtained.

Flight operations of digital photogrammetric flight parameters are summarized below.

Digital Camera : Vexcel ULTRACAM-X
Pixel Number : 9420 * 14430
Pixel Size : 7.2 micron
Camera Focal Length :100.5mm (Panchromatic+Multispectral),
Flight height : 2510 m
Ground Sampling Distance : 18 cm (GSD)
Approximate Image Scale : 1 / 25000
End Lap / Side Lap : %60 / %30
Flight Direction : East-West
Number of Ground Control Points: 16 (XYZ), 4 (Z)
Number of Columns : 6+2
Camera Serial No. : UCX-SX-1-60216654
Camera Manufacturers : Vexcel Imagine GmbH, A-8010- Graz, Austria
Calibration Date : 14 September 2010
Calibration Report Date : 20 September 2010
Direct Geo-Referencing System : IMU 40 (Leica)

A. Workspace

In this study, Ankara (Turkey) belonging to 20.5km*15.5km in size, covering an area of 318km^2 with Microsoft Ultracamx digital photogrammetric aerial camera aerial photographs taken with the year 2012 were used (Fig. 3). The average land elevation is 1100m.

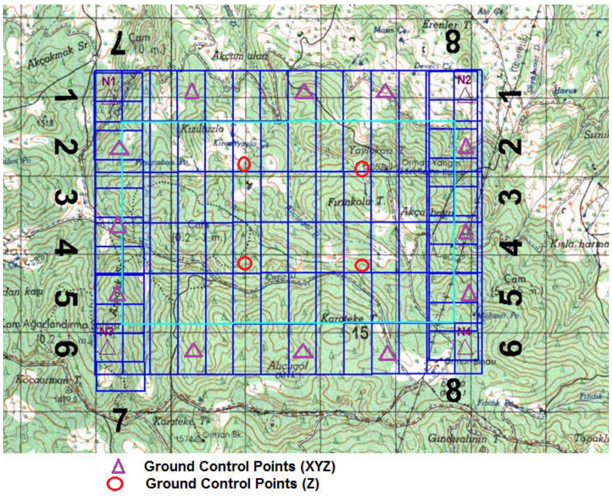

Fig. 3 Test Field and Photogrammetric Block

Homogeneously dispersed to the corners and edges of the block 16 ground control points (XYZ), homogeneously dispersed within 4 blocks of height control point has been established. In the GPS / IMU measurements evaluation region 38km away CORS-TR point data were used.

B. The First Test Application

For this application, the land will hit the block to the corners and edges, 16 pieces (XYZ) Ground Control Points, 4 height point through the interior block has been established, marking made and (XY) coordinates is determined by GPS, level (Z) is determined by leveling techniques. Photogrammetric triangulation measuring was performed with the software the Z/I (Zeiss / Intergraph), Inpho MATCH-AT (v:5.3) software was used for block adjustment measurements.

C. The Second Test Application

In this application, the control points located on the field were underestimated on the measurements and calculations and photographs orientation are made with the help of direct GPS/IMU data. In this application, station point which the distance from the center of the study area ANRK ≈ 38km, CORS-TR was selected. GPS/IMU data were pre-processed by using the AERO office Software and as a result of this pre processing kinematic GPS data which is required for the GPS process is calculated [6]. Process results obtained on the day of flight with the coordinates of the GPS/IMU data, simulate flight was performed with postprocessing. Thus, coordinates of the mid-point the image are matched according to the photo number. Boresight corrections were found by postprocessing on file, and these data are used as the initial value at block adjustment. GPS/IMU data and tie point were obtained by using Ground Control Points on block corner automatically by Inpho MATCH-AT v:5.3 software. While adjustment, 5 Independent Control Point (check point) be calculated in the program and differences were determined with geodetic coordinates and errors are calculated.

D. The Third Test Application

In this application, the control points are located on the field data, GPS/IMU data, both photogrammetric triangulation measurement and by considering blocks in the stabilization process, have been resolved. For GPS/IMU solution, CORS-TR station points which the distance from the center of the study area ANRK ≈ 38km was selected.

III. Result

According to the first and second test set, photogrammetric triangulation measurement and block adjustment were performed. According to test sets, field studies, flights and office evaluation studies were compared in terms of time cost and accuracy.

MATCH-AT blocks adjustment process, a-priori mean square error as the Table I 'of a given size has been entered.

TABLE I
A Priori RMS

	a-priori standart deviations
Ground control (X) [mm]	12.3
Ground control (Y) [mm]	10.2
Ground control (Z) [mm]	13.4
Automatic image points [mm]	1.0
Image points of ground control and manual measurements [mm]	2.0
GPS X Y Z [m]	0.10
INS omega phi kappa [deg]	0.010; 0.010; 0.010

Furthermore, the solution parameters on adjustment in Table II in the mode of the adjustment process were performed.

TABLE II
Adjustment Solution Mode

	Solution mode
Selfcalibration	ON
Number of selfcalibration parameters	12
Write calibrated camera to project	ON
GPS-Mode	ON
Drift-Mode	ON
drift per strip	ON
drift for X,Y,Z	ON
enable shifts only	ON
INS-Mode	ON
INS-Boresight	ON
Earth's curvature correction	ON
Atmospheric correction	ON
Do not eliminate manual points	OFF

Test set 1 case, photos which constitute block was determined stereo by Z/I evaluation software, photogrammetric triangulation measurements have been carried out, GPS/IMU data without taking into account the 20 pieces of land plants coordinates of ground control points was performed using a block adjustment. Test set 2 case, constituting the block layout photos, considering GPS/IMU data on the Z / I evaluation software, were stereo evaluated, photogrammetric triangulation measurements have been carried out, without considering field 20 ground control point coordinates which is located on the block adjustment was performed.. For geo-referencing process 38km away from the CORS-TR point data is used.

Test set 3 in the case, taking into account constituting the block photos GPS / IMU data, reviewed Z / I the evaluation software stereo, photogrammetric triangulation measurements have been carried out, also, coordinates of 20 ground control points, which is located on the field in block adjustment are taken into consideration.

According to test pattern, the mean square error obtained at the end of the block adjustment was given Table III. Again, Table III also the cost of land studies, measuring and balancing costs photogrammetric triangulation, photogrammetric triangulation measuring and adjustment period were shown by calculated.

TABLE III
A POSTERIE RMS

	Test Set 1	Test Set 2	Test Set 3
RMS automatic points in photo [micron]	x 0.4 y 0.3	x 0.5 y 0.2	x 0.2 y 0.2
RMS control points in photo [micron]	x 1.4 y 1.3		x 0.9 y 1.0
RMS manual photo measurements with default standard deviation set [meter]	x 0.028 y 0.024 z 0.018		x 0.014 y 0.022 z 0.019
RMS INS observations [deg]		omega 0.005 phi 0.007 kappa 0.015	omega 0.003 phi 0.006 kappa 0.011
RMS GPS observations [meter]		x 0.081 y 0.095 z 0.062	x 0.091 y 0.053 z 0.042
mean standard deviations of rotations [deg/1000]	omega 0.8 phi 0.8 kappa 0.2	omega 0.6 phi 0.5 kappa 0.2	omega 0.6 phi 0.4 kappa 0.3
mean standard deviations of translations[meter]	x 0.033 y 0.024 z 0.044	x 0.023 y 0.018 z 0.034	x 0.013 y 0.034 z 0.028
Sigma naught [micron]	0.9	1.1	1.0
Time	8.3 hour	2.1 hour	2.2 hour
Cost	48 000. $	17 200. $	48 600. $

IV. CONCLUSION

Table III is examined; indirect geo-referencing (test set-1) and the direct geo-referencing (test set-2) calculated after adjustment there are no significant differences in terms of accuracy criteria. However, the accuracy of the test scheme-2 values are higher. When viewed in terms of time and cost, the test set-2 four times less than the advantage of time evaluation period and has cost 2.8 times less. than test set 1. This result seems to be a very important advantage. The combination of both of the test set-3 does not have a significant advantage in terms of accuracy. In contrast, increases the cost and time adversely. The accuracy of directly geo-referenced depends on:

- DGPS calibration,
- IMU calibration,
- Datum Tranformation parameters sensivity,
- Boresight calibration,
- Lever-arm calibration,
- GPS/IMU providing solutions quality and distance Ground Referance Point
- Camera calibration.

For this, in study, calibration which mentioned above, no doubt do sensitive and accurate geo-referencing directly, the accuracy will improve.

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