THE EVALUATION OF EXTERIOR ORIENTATION PARAMETERS FROM GLOBAL POSITIONING SYSTEM AND INERTIAL MEASUREMENT UNIT IN THE TEST FIELD

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ABSTRACT : With direct geo-reference approach through using Geographic Positioning System integrated with Inertial Measurement Unit(GPS/IMU), map production earns a number of benefits such as cost reduction in field survey, less time consumption in mapping process and ability to map in difficult terrains. The objective of this study is to compare processing of Orthophoto product, 1: 25,000 scale, between using exterior orientation parameters obtained from GPS/IMU and applying Photogrammetric approach, then to assess the horizontal accuracy of those products in term of map scale. By using NSSDA standard test method, together with ASPRS standard, upon 46 check points specified on the approved survey test field, it is found that the root means square error of horizontal position calculated as 0.9960 meter, which further evaluated in the aspect of accuracy within 1:4,000 map scale or better.

INTRODUCTION

Geospatial data is considered as fundamental part of geographic information system also know as GIS. In particular, Orthophoto, widely used in GIS applications, which is produced from digital Photogrammetry.
With this approach, through using Geographic Positioning System together with Inertial Measurement Unit (GPS/IMU), Exterior Orientation(EO) parameters directly obtained during aerial photography collection are to be used in Direct Georeference(DG). As a result, ground control point, used in Aerial Triangulation process, can be cut down.

The objective of this study is to evaluate horizontal accuracy of 1: 25,000 Orthophoto, produced from direct geo-referencing Photogrammetry, which is to be used in producing large scale maps. Furthermore, for accuracy evaluation, this study applies US standard of measure used in geospatial data and root mean square error(RMSE) indicating accuracy in term of map scale from ISPRS standard.

In this study, aerial photography campaign are conducted by using Zeiss RMK TOP camera equipped with GPS/IMU, flight attitude parameters are thus recorded together with each exposure. Located at Chulachomklao Royal Military Academy, Nakonnayok province, study area used in this research (Promtong,2008) was approved as a survey test field covering with scattering known points on the ground.

METHOD

This study is to compare Exterior Orientation parameters between Direct Georeference and those Exterior Orientation parameters obtained from aerial triangulation in the process of producing 1:25,000 Orthophoto (Wolf, 2002). Then evaluation of horizontal accuracy of the Orhtophoto, using selected 20 ground control points (GCPs), is to perform on the study area. Aerial photos, used in this study, were taken with Zeiss RMK TOP camera with 150 mm. focal length. Using 60 % forward overlap and 30 % side overlap, 15aerial photos covering study area were acquired in generating orthophoto as seen in figure1, also study area on corresponding map in figure2.

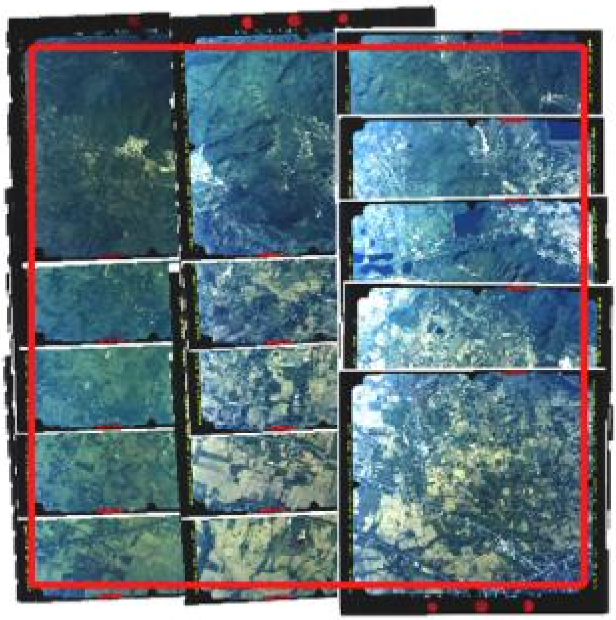

Figure 1 Aerial photos covering study area

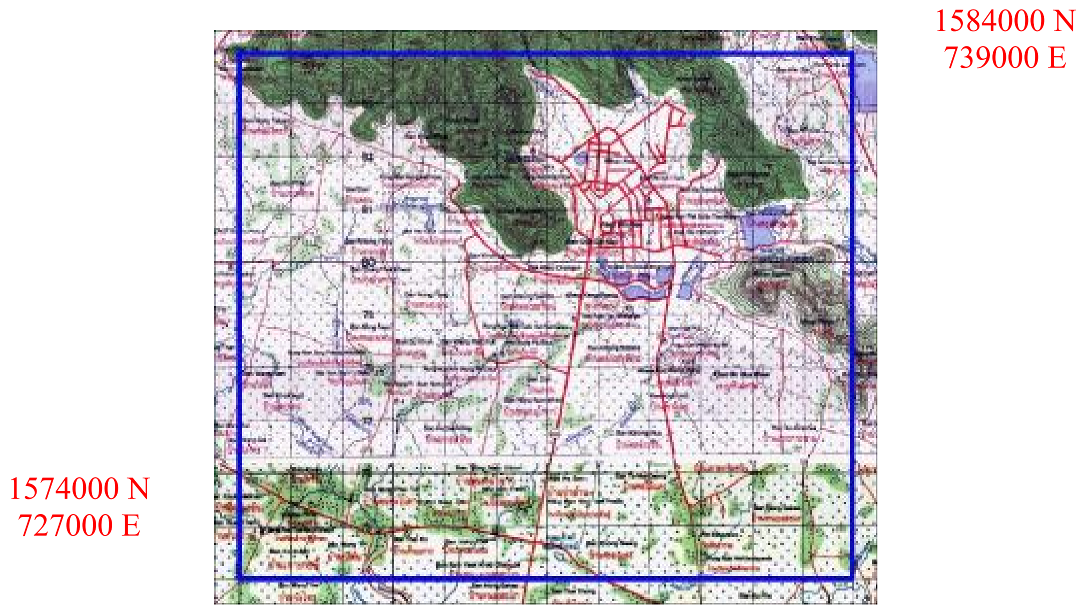

Figure 2 Map shows study area

Located on study area with clearly visibility on the aerial photos, there are 20 GCPs to be used in this study. In addition, check points were chosen according to FGDC 1998 standard such that at least 20 check points were required and they should spread out evenly around 10 points in each quadrant of the study area. Besides, each check point in each quadrant also located at least 1.71 km., around one tenth of diagonal length of study area, which is 13.27 km. as referred to figure 3.

Figure 3 Ground control points and check points on the study area

In the process of producing orthophotos, Digital Terrain Model (DTM) was created from height data collected from stereo model in photogrammetry process. Final product, orthophoto, can then be accomplished through using DTM together with Relative Orientation parameters in photogrammetry instrument. Other issue, in this study, datum and coordinating system of GCPs and check points are: WGS84, WGS84 together with UTM zone47 for horizontal coordinate, and orthometric height for vertical coordinate. Horizontal coordinate values of check points in the study area obtain through using GPS measurement, and vertical coordinate is collected by using Ellipsoidal height of those check points then converted to orthometric height, with Geoid separation average -28.786 meter. Process flow of two comparison approaches : Direct Georeference and Photogrammetry, is illustrated in figure 4.

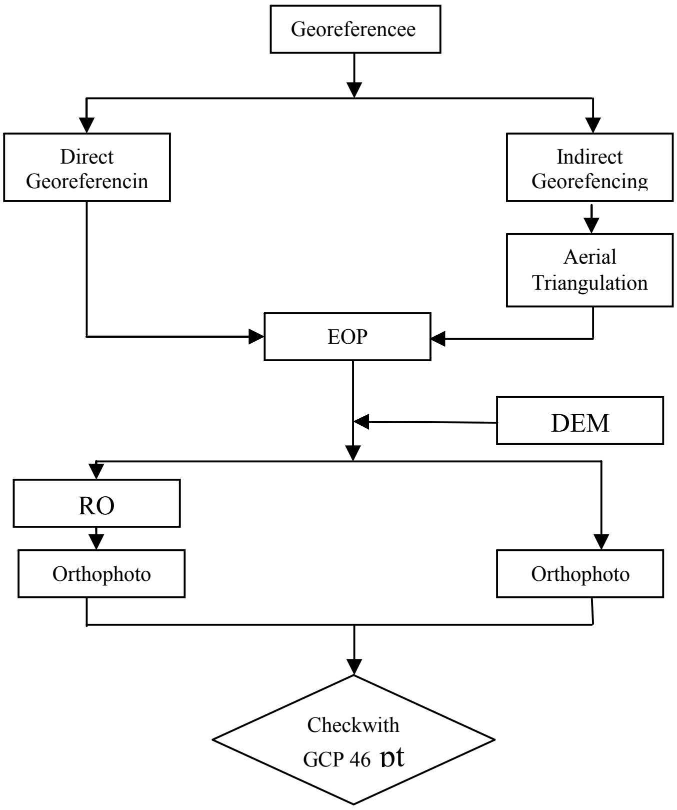

Figure 4 Process flow of Direct Georeference and Photogrammetry used in this study

EVALUATION OF POSITIONAL COORDINATE ACCURACY

Applying National Standard for Spatial Data Accuracy (NSSDA), position accuracy evaluation of this study calculates RMSE values from those check points and then proceeds further in accuracy result in term of map scale. Furthermore, the discrepancy of position against corresponding ground position, and the accuracy results from calculation described in confidential level, this used method claims accuracy at confidential level of 95 %.
Usually, positional accuracy test will conduct against references whose accuracy degree is more superior. In this study, coordinates of those check points are measured in the field by using GPS receiver, then comparing them against coordinates of corresponding points upon orthophoto product. With this principle, this study conducts coordinate test of selected 46 check points, scattering over study area, which results in spreading of errors all over the target area.

TEST STANDARDS

This study includes following well known criteria as follows :

1.NSSDA from Federal Geographic Data Committee(FGDC) which provides horizontal accuracy by computing RMSE value using following equations (Federal Geographic Data Committee, Geospatial Positioning Accuracy Standards,1998) :

$$RMSE_x = \text{sqrt}\,[\Sigma\,(X_{data\,i} - X_{check\,i})^2 / n] \qquad (1)$$

$$RMSEy = \text{sqrt}\,[\Sigma\,(Ydata\ i - Ycheck\ i)2 / n] \qquad (2)$$

where $RMSE_x$ is Root Mean Square Error of x axis and
$RMSE_y$ is Root Mean Square Error of y axis.

$X_{data\,i}$, $Y_{data\,i}$ are coordinate of point i in the test product
$X_{check\,i}$, $Y_{check\,I}$ are coordinate of reference point i, obtained from field measurement
n is number of test points

Horizintal error of point i is calculated as follows:

$$\text{sqrt}\,[(X_{data\,i} - X_{check\,i})^2 + (Y_{data\,i} - Y_{check\,i})^2] \qquad (3)$$

$RMSE_r$ of horizontal error can be calculated as follows:

$$RMSE_r = \text{sqrt}\,[\Sigma\,((X_{data\,i} - X_{check\,i})^2 + (Y_{data\,i} - Y_{check\,i})^2)\,/n] \qquad (4)$$

$$RMSE_r = \text{sqrt}\,[\,RMSE_x^{\,2} + RMSE_y^{\,2}\,] \qquad (5)$$

Positional accuracy according to NSSDA standard can be obtained as follows:

$$accuracy_r = 1.7308 * RMSE_r \qquad (6)$$

2.American Society of Photogrammetry and Remote Sensing(ASPRS) ‘s standard. This standard, under supervision of ASPRS specification and standard committee, specifies accuracy standard for 1: 20,000 map and larger scale used for engineering task. Using RMSE value to assess map accuracy into classes: class1, 2 and 3, ASPRS standard defines maps under class2 should possess RMSE value more than 2 times that of class1, and maps under class3 should have RMSE value more than 3 times that of class1.ASPRS standard, for planimetric feature coordinate accuracy requirement, evaluates horizontal coordinates along x and y axis according to calculated RMSE value from those well defined points of target map as illustrated in table1.

Table1 Horizontal accuracy standard from ASPRS

ASPRS Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y) for Well-Defined Points

Target Map Scale	ASPRS Limiting RMSE in X or Y (Meters)		
Ratio m/m	**Class 1**	**Class 2**	**Class 3**
1:500	0.125	0.25	0.375
1:1,000	0.25	0.50	0.75
1:2,000	0.50	1.00	1.5
1:2,500	0.63	1.25	1.9
1:3,000	0.75	1.5	2.25
1:4,000	1.0	2.0	3.0
1:5,000	1.25	2.5	3.75
1:8,000	2.0	4.0	6.0
1:9,000	2.25	4.5	6.75
1:10,000	2.5	5.0	7.5
1:16,000	4.0	8.0	12.0
1:20,000	5.0	10.0	15.0

From table1, it can be stated, for instance, class1 map should have RMSE of horizontal coordinate within 1 meter, which corresponds to map accuracy equivalent to 1:4,000 map scale.

IMPLEMENTATION

Using study area at CRMA, Nakonnayok province, covering around 120 square kilometer, this research collects EO parameters of each aerial photo, using GPS/IMU during taking aerial photo. These EO parameters are compared with those measured from Photogrammetry process using 20 GCPs upon the same target area. In this step, orthophotos with 1:25,000 map scale, as final product, are generated by those two approaches: direct georeference and Photogrammetry. Then, further step is to proceed for accuracy evaluation by measuring coordinates of selected 46 check points scattering properly, according to NSSDA specification, in the study area as seen in figure 5. The results of x,y coordinates of those check points are forwarded to evaluate on geospatial data accuracy using NSSDA standard of FGDC. Furthermore, RMSE of horizontal coordinates of those check points are proceeded for accuracy checking with ASPRS standard in order to find out classification of map accuracy and corresponding map scale.

Figure 5 Display of coordinate reading from one of those check points

RESULTS

Results from conducting accuracy evaluation of EO parameters from GPS/IMU or direct geo-reference from this study can be concluded as follows:

1.From calculation of 46 check points selected according to NSSDA standard, RMSE of horizontal coordinates(RMSExy) is 0.996 meter, which is equivalent to horizontal accuracy of 1.724 meter(NSSDA) with 95% confidential level, as seen more detail in table 2.

2.As the result of horizontal coordinate accuracy RMSExy 0.996 meter of orthophoto product from direct geo-reference, the accuracy of this product is classified as Class1, according to ASPRS standard. With this standard, the result of horizontal accuracy can be defined in map scale of 1:3,984. In other words, the orthophoto, as product of this study, can be used to generate large scale map of 1:3,984 or smaller map scale products.

Table 2 Result of horizontal coordinate evaluation of orthophotos using NSSDA standard

Point number	Point description	Easting (independent)	Northing (independent)	Easting (test)	Northing (test)	diff in x	(diff in x)^2	diff in y	(diff in y)^2
1	1049EHV	[illegible]	[illegible]	[illegible]	[illegible]	-1.229	1.510	1.195	1.428025
2	1049EHV	731306.751	1575710.506	731305.685	1575711.039	-1.066	1.201	0.5330	0.401829
3	1050AHV	728063.127	1578096.213	728063.481	1578096.036	0.656	0.430	0.177	0.031329
4	1050DHV	731297.256	1570077.573	731296.987	1570077.643	0.871	0.759	0.33	0.1089
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.117	1.234	0.363	0.131769
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1.193	1.423	-0.1625	[illegible]
7	1052AHV	728656.831	1582710.827	728655.742	1582752.29	-1.189	1.414	-0.607	0.368449
8	1052BHV	730314.559	1582461.228	730315.783	1582460.387	1.224	1.498	0.641	0.410881
9	2170DHV	734078.466	1573047.095	734079.363	1573040.412	0.903	0.811	0.817	0.667489
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.111	1.234	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.447	0.199	-0.105	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.221	0.049	-0.3249	0.10556
13	2177BHV	734702.431	1583007.897	734700.688	1583006.739	-1.743	3.038	-0.958	0.917764
14	2100DHV	730706.846	1580123.581	730706.259	1580122.935	0.647	0.419	0.646	0.417316
15	[illegible]	730425.136	1580402.39	730424.484	1580402.419	0.652	0.425	0.0292	0.000853
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.782	0.612	0.6377	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.044	0.002	0.577	0.332929
19	9001	726781.701	1581510.754	726781.102	1581510.679	-0.599	0.359	-0.0857	0.007344
20	9002	727420.981	1579478.390	727420.45	1579479.424	0.531	0.282	0.0312	0.000973
21	9003	721033.215	1571035.411	721033.045	1571034.875	0.17	0.029	0.5421	0.293872
22	9004	721022.639	1575044.885	721021.952	1575045.029	0.717	0.514	0.1439	0.020707
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.111	0.012	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.241	0.058	-0.5397	[illegible]
25	9008	730436.794	1580109.432	730437.975	1580108.817	1.182	1.397	-0.5852	0.342459
26	9009	729257.485	1578574.715	729258.143	1578574.725	0.658	0.433	0.0106	0.000112
27	9010	730476.359	1577408.270	730476.804	1577407.825	0.446	0.199	0.4519	0.204214
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.343	0.118	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0.000	-0.815	[illegible]
31	9015	734735.375	1582153.524	734735.151	1582152.332	-0.224	0.050	-1.1915	1.419672
32	9016	730602.361	1580576.110	730602.402	1580575.788	0.041	0.002	0.3277	0.107387
33	9017	729676.085	1580021.131	729675.094	1580020.428	0.991	0.982	0.7033	0.494631
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.392	0.154	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1.525	2.326	-0.1365	0.018632
36	9020	702936.409	1570809.002	702936.157	1570810.164	0.252	0.064	0.3618	0.130899
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.036	1.073	[illegible]	[illegible]
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.321	0.103	1.2538	[illegible]
39	9023	738668.203	1583165.603	738667.625	1583164.155	-0.588	0.341	-1.4478	2.096125
40	9024	730155.588	1581994.553	730154.602	1581993.550	0.986	0.972	0.9937	0.98744
41	9025	737092.472	1580607.262	737091.644	1580606.640	0.620	0.384	0.6137	0.376628
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.298	0.089	[illegible]	[illegible]
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.08	0.006	[illegible]	[illegible]
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.61	0.372	[illegible]	[illegible]
45	9031	737277.574	1573695.216	737276.831	1573695.856	-0.74	0.548	0.6404	0.410112
46	9032	733124.28	1581182.045	733124.141	1581182.601	0.139	0.019	0.245	0.060025

sum	27.108	sum	18.52166
average	0.589	average	0.402645
RMSE x	0.768	RMSE y	0.634543
		RMSE xy	0.995963
		NSSDA	1.723813

CONCLUSION

The result of this study proves that horizontal accuracy of map product through applying direct geo-reference, 1: 25,000 orthophoto, can be classified into map scale as1:3,984, to be exact. Consequently, direct geo-reference via using GPS/IMU provides sufficient accuracy to produce large scale map products. Moreover, other valuable benefits obtained are as follows: shorten mapping process, reduce field survey expense, and extend mapping coverage in both vast and inaccessible area.

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