The Effect of the Number of Control Points on the Adjusted Satellite Images

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Abstract– **Traditional survey methods become tedious and time consuming and hens very cost with large scale mapping surveys. In recent years remote sensing imagery was adopted to reduce the cost and facilitate the survey works. These images require some control points to match with the ground coordinates. This research work is oriented to study the effect of the number of control points on the adjusted satellite image. Quick bird image was tested utilizing number of control points. These points were selected on the image first and then observed on the ground using GPS receiver. Some control points was used to adjust the image, where the others were used as check points. Satellite image was repeatedly adjusted and then accuracy was estimated. The effect of the number of control points on the adjusted image was examined by increasing the number of control points in georefrencing model and estimating the accuracy in each case. Three geo-referencing models were taken into account in this research .These models were first order polynomial, affine and projective model. First order polynomial and affine models require at least 3 control points to adjust a satellite image, where, 4 control points are required when using projective model. Results showed that the accuracy of the adjusted satellite image was improved with increasing the number of control points. And the projective model yield better accuracy using four control points compared with other tested models. Moreover, six control points were sufficiently enough to adjusted satellite image using first order polynomial model. Also results showed that affine model always provides lower accuracy compared with other tested models.**

Keywords– GPS, GCPs, RMSE, Georeferancing, Polynomial, Affine and Projective Transformations Models

I. INTRODUCTION

In the past, mapping works was considered to be hard and tedious, that is because of the old methods and conventional equipments that have been used such as, chain, campus, plane table, optical level and theodolite. Such survey tools required a number of persons to be in the job, and time consuming to achieve the desired accuracy, rather than the accommodation and the team camp facilities required.

Modern instrument such as total station and Global Positioning System (GPS) may speed the time of data collection and reduce the cost to some extend. But, still land survey equipments are slow and cost effective for mapping large areas. Therefore, photogrammetry could be a practical substitute for mapping large areas.

Photogrammetric techniques based on covering the area by successive overlapping photographs in a parallel flight strips. Then maps could be produced utilizing photographs rather than collecting data directly from the field. Thus reducing the time and minimizing the cost

Recently, satellite remote sensing becomes an attractive tool of collecting mapping data, because it provides number of advantages. These advantages may include large data coverage, accessibility, continuity and homogeneity of data. More over it provides a low cost means of data collection. These advantages of remote sensing over the other mapping data collection techniques make it an attractive tool in different fields. Today, remote sensing affords a practical means of frequent and accurate monitoring of the earth's resources on literally a global basis. It is aiding in assessing the impact of human activities on air, water and land. Data obtained from remote sensors have provided information necessary for making sound decisions and formulating policy in a host of resource-development and land use applications.

II. REMOTE SENSING PRINCIPLES

Remote sensing can be defined as the acquisition of data and derivative information about objects or materials (targets) located at the earth's surface or in its atmosphere by using sensors mounted on platforms located at a distance from the targets to make measurements (usually multispectral) of interactions between the targets and electromagnetic radiation. Accordingly, remote sensing consists of two operations; data collection and data analysis. Data collection may affected by the source of energy used, atmospheric windows, the nature of interaction of electromagnetic energy with earth surface features (matters) and the type of the sensor used.

On the other hand, data analysis in all applications, produce useful information to the users for decision-making. In spite of the different applications of remote sensing it all uses the parameters of photo-interpretation (colour, shape, size, shade, texture, pattern, location and land use) in addition of using the reference information such as maps, reports or statistical information etc. or even visiting the field to produce useful information about physical, chemical or biological state of objects. These information has to be presented in a suitable form for decision, making.

III. GLOBAL POSITIONING SYSTEM (GPS)

The global positioning system (GPS) was developed by the US Department of Defense (DoD) as a navigation system. The first satellite to support the development and testing of the system was placed in orbit in 1978 and fully operated in

December 1993. Today, it becomes an important tool of collecting data required to adjust remote sensing satellite images. This system is basically consists of three main components; (i) Space segment; (ii) Control segment; and (iii) User segment.

A. The Space Segment

Consists of 24 satellites, operating in 6 orbital planes spaced at 60˚ interval around the equator. Four additional satellites are held in reserve as spares. The satellites travel in near-circular orbits that have a mean altitude of 20,200km above the earth and an orbital period of 12 sidereal hours. Precise atomic clocks are used in the GPS satellites to control the timing of the signal they transmit.

B. The Control Segment

Consists of five monitoring ground stations at which the signals from the satellites are monitored and their orbits tracked. The tracking information is relayed to the master control station in Colorado Springs. The master control station uses this data to make precise near future predictions of the satellite orbits, and their clock correction parameters.

C. The User Segment

Consists of two categories receivers that are classified by their access to two services that the system provides; The Standard Positioning Service (SPS): Provided on the L1 broadcast frequency at no cost to the user. The Precise Positioning Service (PPS): is broadcast on both L1 and L2 and is only available to receivers having valid cryptographic keys.

D. The GPS Signals

The GPS satellites continually broadcast a unique signal on two carrier frequencies on a number of different frequencies. But instead of having only one message on one frequency, a number of different messages can be carried on one frequency at the same time.

The carriers, which are transmitted in the L band of microwave radio frequencies, are identified as the L_1 signal with frequency of 1575.42MHz and the L_2 signal at frequency of 1227.60MHz. The L_1 band has frequency of $154\times f_0$, and L_2 band has a frequency of $120\times f_0$.

In order for receiver to determine the ground position of the station they occupy. It was necessary to devise a system for accurate measurement of signal travel time from satellite to receiver. This was accomplished with modulating the carrier with *Pseudo Random noise* (PRN) code.

Each satellite transmits two different PRN codes. These are: (i) *Coarse/Acquisition code or (C/A) code* has a frequency of 1.023MHz and a wavelength of 300m. It is accessible to all users, (ii) *Precise code or P code* has a frequency of 10.23MHz and a wavelength of 30m can only be read with receivers that have the proper cryptographic keys. The L_1 signal is modulated with P-code and C/A code, while L_2 is modulated only with P-code.

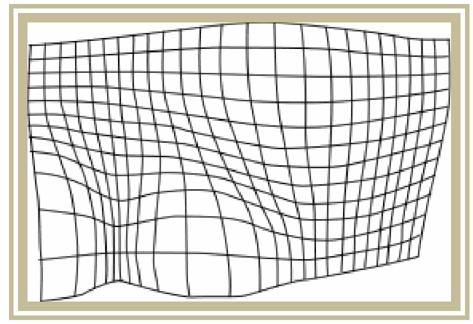

Fig. 1: Image distortion

Navigation message is carried by both L_1 and L_2 frequencies and basically carry information about satellite position and its working status (healthy).

E. Fundamentals of GPS Positioning

GPS receiver compute distances to four satellites and fixes a position by trilatration. Two fundamental methods are employed by the GPS receivers to determine distances to satellites: code range and carrier phase-shift measurements.

IV. IMAGE ADJUSTMENT

The geometry of images acquired by sensors on board satellites is significantly geometrically distorted due to number of parameters, such as earth curvature and rotation, change in platform speed, height and orientation etc. thus the image obtained may be distorted as shown in Fig. 1.

In order to geometrically rectify satellite image, and bring it to a reference space coordinate system, it is normally required to use number of Ground Control Points (GCPs) - points of a known coordinates- that must have been well distributed throughout the image. These GCPs are selected on the image first. Then their coordinates are observed using global positioning system (GPS).

A mathematical model is required in order to define the relationship between image coordinates and ground coordinates systems, thus, transforming image coordinate system to ground coordinate system.

Non-linear Polynomial Transformations are often applied to adjust satellite images. It takes into account the nonlinear distortions. It can have an infinite number of terms as in the following equation:

$$X = x + a_1x + a_2y + a_3xy + a_4x^2 + a_5y^2 + \dots$$
$$Y = y + b_1x + b_2y + b_3xy + b_4x^2 + b_5y^2 + \dots$$

Where, X, Y and x, y are ground and image coordinates respectively. a_1, b_1, a_2, b_2, $\dots b_5$ are the transformation parameters.

The minimum number of control points required to solve polynomial model are three with first order solution.

Linear affine transformation model allowing the transformation from image coordinates to object space coordinates through six parameters describe the transformation, expressed in the following equation:

$$X = a_1 x + a_2 y + a_3$$
$$Y = b_1 x + b_2 y + b_3$$

The projective transformation describes the relationship between the two coordinate systems (planes). It is the basic fractional model which can relate the image space and the object space. It integrates only the planimetric coordinates as the 2D polynomial model. The projective transformation is also called eight parameter transformations because the totals of unknowns of the model are eight as shown in the equation below.

$$X = \frac{a_1 x + a_2 y + a_3}{b_1 x + b_2 y + 1}$$
$$Y = \frac{a_4 x + a_5 y + a_6}{b_1 x + b_2 y + 1}$$

Where, the parameters as described before:

V. MEASUREMENTS AND RESULTS

This work is oriented to test the effect of the number of the control points on the adjustment satellite image. A quick bird satellite image Fig(2) of 0.6m special resolution covering an area of north Omdurman-Sudan at 2006 was used in this research work.

The 22 ground points were selected on the image. Their coordinates were observed using geodetic GPS receiver. 10 points out of 22 was used as control where the rest of 12 points was used as check points as shown in Table 1.

A satellite image was first adjusted using first order polynomial transformation model utilizing three control points. Then the positional accuracy of the image was estimated by measuring the image coordinates of the 12 check pints and computing the Root Mean Square Error (*RMSE*) between the measured and ground coordinates in easting (*E*) and northing (*N*).

$$RMSE = \frac{\sqrt{(x' - x)^2}}{n}$$

Where, x' and x are measured and actual value and n is the number of pints

The linear error was computed as:

$$LinearError = \sqrt{(RMSE(E))^2 + (RMSE(N))^2}$$

Tests were continued by increasing the number of control points to 4, 5, up to 10 points and estimating the accuracy by the check points in each case. Table (2) below illustrates results obtained in each case when using polynomial model.

Fig. 3 shows graphically the (RMSE) against the number of control points used with first order polynomial model.

The test was repeated again using two dimensional affine coordinate transformation models. Results obtained as shown in Table 3.

Graphical, the effect of the number of control points on the adjusted image using affine transformation model, can be illustrated in Fig. 4.

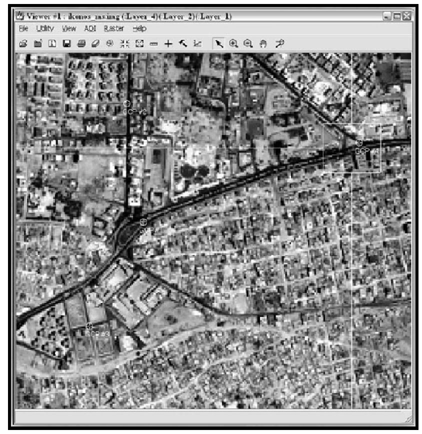

Fig. 2: Satellite image

Table: 1 Control and check point

No.	Northing	Easting
1	1731812.697	445008.287
2	1732413.269	446021.518
3	1730970.767	445867.244
4	1729695.483	445962.689
5	1729630.650	444620.229
6	1730882.034	444290.074
7	1730901.975	443090.851
8	1729655.360	443057.765
9	1729756.106	441759.126
10	1731122.716	441891.378
11	1732352.571	441809.737
12	1732323.238	443032.710
13	1732396.591	443917.227
14	1733323.328	444806.579
15	1733500.300	445912.219
16	1734701.255	445947.030
17	1734711.685	445059.396
18	1734693.930	444138.903
19	1734671.463	443049.354
20	1734680.846	441894.482
21	1733406.768	441816.039
22	1733341.694	443057.760

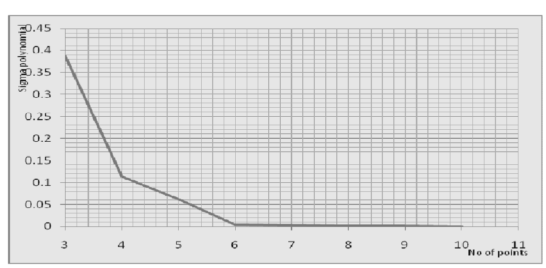

Fig. 3: Number of control points against linear RMSE using polynomial model

Table 2: Polynomial model

No. of Points Used	RMSE		Linear RMSE
3	E	0.145017	0.387063
	N	0.358871	
4	E	0.054969	0.113288
	N	0.099058	
5	E	0.042260	0.062048
	N	0.045432	
6	E	0.002833	0.003801
	N	0.002534	
7	E	0.002295	0.002729
	N	0.001477	
8	E	0.001298	0.001538
	N	0.000824	
9	E	0.000617	0.001073
	N	0.000878	
10	E	0.000598	0.000790
	N	0.000516	

Table 3: Affine model

No. of Points Used	RMSE		Linear RMSE
3	E	0.641449	0.735256
	N	0.359367	
4	E	0.102333	0.128090
	N	0.077039	
5	E	0.081253	0.099360
	N	0.057187	
6	E	0.077194	0.090590
	N	0.047408	
7	E	0.080807	0.088802
	N	0.036826	
8	E	0.024214	0.041073
	N	0.033176	
9	E	0.010123	0.029355
	N	0.027554	
10	E	0.003258	0.007543
	N	0.006804	

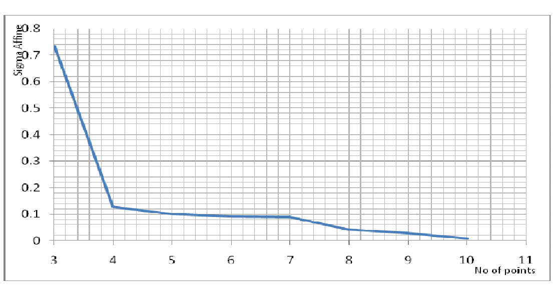

Fig. 4: Number of control points against linear mean square error using affine model

Table 4: Projective model

No. of points	RMSE		Linear RMSE
3	E	-	-
	N	-	
4	E	0.010967	0.013992
	N	0.008690	
5	E	0.010099	0.013165
	N	0.008445	
6	E	0.008726	0.011943
	N	0.008154	
7	E	0.008583	0.011373
	N	0.007461	
8	E	0.005573	0.007849
	N	0.005527	
9	E	0.003128	0.005012
	N	0.003915	
10	E	0.001925	0.002472
	N	0.001551	

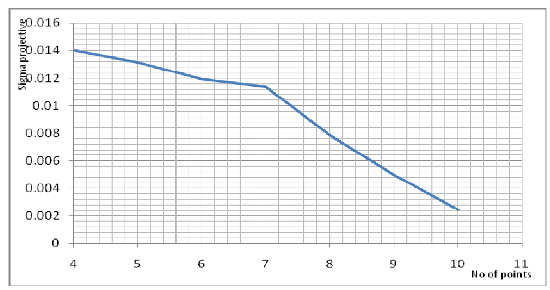

Fig. 5: Linear RMSE against the number of control points when using projective model

Finally the test was carried out using projective transformation model. Results were computed as listed in table (4) below.

Fig. 5 shows graphically the linear RMSE against the number of control points, when using projective model.

VI. CONCLUUSIONS

By referring to the tests carried out and results obtained above, it can be concluded with the following:

i. The accuracy of the adjusted satellite image generally improved with increasing the number of control points.
ii. Although minimum of three control points can be used with first order polynomial to adjust satellite image, six control points were sufficiently enough to get a better accuracy. More than six control points do not effectively improve accuracy.
iii. Projective model yield better accuracy compared with other tested models.
iv. Affine model always produce a lower accuracy compared with the other tested models.

v. The three tested models provide accuracy better than 0.01m when using seven control points. On the other hand more than seven control points did not significantly improve the accuracy.

vi. Moreover, three control points with polynomial and affine model and four with projective moel (i.e. the minimum number of control points) produced accuracy which was better than special resolution of the tested image (0.6m) from which it can be said that these accuracies obtained were computational accuracy and with such resolution the minimum number of control points are sufficiently enough to do the job.

VII. RECOMMENDATIONS

This research work concentrate on studying the effect of the number of control points on adjusted satellite image taking three mathematical models and does not cover all related parameters affecting the accuracy of the adjusted satellite image. Therefore, the following recommendations are suggest for further works:

i. More georefrencing models can be examined,

ii. Different satellite images with different special resolutions such as Spot, Landsat and Ikonos can be tested.

iii. Statistical models other than the root mean square error can be used to estimate the accuracy.

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