Accuracy Assessment of 2D and 3D Geometric Correction Models for Different Topography in Iraq

Dr. Abdul Razzak T. Ziboon
Building and Construction Engineering Department, University of Technology/ Baghdad
Email: razzak1956@yahoo.com
Israa H. Mohammed
Building and Construction Engineering Department, University of Technology/Baghdad

Received on: 1/11/2011 & Accepted on: 4/4/2013

ABSTRACT

In recent decades, Remote sensing data becomes one of the basic information required for mapping and different applications in geomatics. In this research, different mathematical models in 2D and 3D cases are investigated and comprised in order to assess the accuracy of these models under different conditions of terrain topography. Three high resolution satellite QuickBird images of three different study areas, with respect to their topography have been used in this work. In this research, the 2D mathematical models which were used, 1st, 2nd order polynomial, and projective transformation model while, the 3D mathematical models used were, 1st, 2nd order 3D polynomial, and direct linear transformation model. All these methods are applied for each study area and evaluated through the Matlab environment facilities.

Keywords: Quickbird Images, Polynomial Model, Projective Transformation Model, Direct Linear Transformation Model.

تقييم دقة نماذج التصحيح الهندسي ثنائية وثلاثية الأبعاد لتضاريس مختلفة في العراق

الخلاصة

في السنوات العشرة الأخيرة أصبحت بيانات التحسس النائي واحدة من أهم المعلومات الأساسية المطلوبة لعملية التخطيط والتطبيقات المختلفة في الهندسة الجيوماتيكية. في هذا البحث، تم التحقق والمقارنة لنماذج رياضية مختلفة ثنائية وثلاثية الأبعاد من اجل تقييم دقة هذه النماذج في حالات مختلفة من وعورة التضاريس. استخدمت في هذا العمل ثلاث صور فضائية عالية الدقة من نوع (QuickBird) لثلاث مناطق دراسة مختلفة نسبة إلى وعورة تضاريسها. إن النماذج الرياضية

https://doi.org/10.30684/etj.31.11A5
2412-0758/University of Technology-Iraq, Baghdad, Iraq

الثنائية الأبعاد المستخدمة في هذا البحث كانت: (متعددة الحدود من الدرجة الأولى والثانية ونموذج التحويل الاسقاطي). أما النماذج الرياضية ثلاثية الأبعاد المستخدمة في البحث كانت: (متعددة الحدود ثلاثية الأبعاد من الدرجة الأولى والثانية ونموذج التحويل الخطي المباشر). طبقت هذه النماذج الرياضية لكل منطقة من مناطق الدراسة. وقد تم تقييم النماذج الرياضية من خلال برنامج (Matlab).

INTRODUCTION

Remotly sensing image data of the earth's surface acquired either aricraft or spacecraft platforms is inherently subject to geometric distortions.These distortions may be due to several factors. Therefore, It is usually necessary to preprocess remotely sensed data and remove geometric distortions. Image preprocessing operations normally precede all other image manipulation and analysis, such as enhancement or classification. The preprocessing of remotely sensed image consists of geometric and radiometric characteristics analysis. by realizing these features, it is possible to correct image distortion and improve the image quality and readability, [1]. Radiometric analysis refers to mainly the atmosphere effect and its corresponding terrain feature's reflection, while geometric analysis refers to the image geometry with respect to sensor system. This paper covers the processes of geometrically correcting an image so that the geometric representation of the imagery will be as close as possible to the real world. Geometrically corrected imagery can be used to extract accurate distance, area, and direction information, [2].

GEOMETRIC CORRECTION MODELS

A simple geometric model usually involves mathematical functions, which are easier to understand and do not require the knowledge of image sensor physics, [3]. In this respect, simple geometric models require mathematical functions to relate the image space and object space. The mathematical function parameters are solved with the help of the GCPs collected throughout the image by using the least squares adjustment process. Once the mathematical function parameters are determined, the correct positions of each pixel in the image can be estimated by these functions, [4]. In this paper, some of 2D and 3D transformation used with numbers of ground control points. These models are generally available within most of remote sensing image processing systems. These models can be used to provide sufficient insight about the ground elevation effects on the metric integrity of the rectified images, [5].

The mathematical models used in this paper are:

- 2D Polynomial Model.
- Projective Transformation.
- 3D Polynomial Model.
- Direct linear transformation model.

The following sub sections discuss the models characteristics.

Two Dimensions Polynomial model

Polynomial models usually can be used in the transformation between image coordinates and object coordinates. The needed transformation can be expressed in different orders of the polynomials based on the distortion of the image, the number of GCPs and terrain type, [5]. Because 2D polynomial functions do not take into account the elevations of the GCPs these models can be efficiently used when the imaged area is relatively flat, namely where the image is not influenced by the topographic effects. The following equations are used to express the general form of the polynomial models, [6]:

- 1st order polynomial.

$$x = \mathrm{a_o} + \mathrm{a_1 X} + \mathrm{a_2 Y} \quad \text{... (1)}$$

$$y = b_o + b_1 X + b_2 Y \quad \text{... (2)}$$

- 2nd order polynomial.

$$x = a_0 + a_1 X + a_2 Y + a_3 XY + a_4 X^2 + a_5 Y^2 \quad \text{... (3)}$$

$$y = b_0 + b_1 X + b_2 Y + b_3 XY + b_4 X^2 + b_5 Y^2 \quad \text{... (4)}$$

Where (x, y) are coordinates of the GCP in the original input image while (X, Y) represent corresponding coordinates of the GCP on the ground or map and (a, b) are polynomial coefficients to be determined by the least square adjustment.

Projective transformation

Projective model express the relationship between two spaces based on perspective projection concepts. These two spaces can be defined in our work as image space and the ground space, [7]. The two-dimensional projective coordinate transformation is also known as the eight-parameter transformation. In their final form, the two-dimensional projective coordinate transformation equations are, [8]:

$$x = \frac{a_1 + a_2 X + a_3 Y}{a_7 X + a_8 Y + 1} \quad \cdots (5)$$

$$y = \frac{a_4 + a_5 X + a_6 Y}{a_7 X + a_8 Y + 1} \quad \cdots (6)$$

Where (a1, a2, a3, a4, a5, a6, a7, and a8) are the eight unknown parameters of the functions, (x, y) are the image coordinates and (X, Y) are the ground coordinates.

Three Dimensions Polynomial model

The 3D polynomial functions are an extension of the 2D polynomial function by adding Z-terms related to the third dimension of the terrain, [3]. However, because they are similar to the 2D order polynomial functions, the problems of the 2D order polynomial functions are also valid for these functions except for the topography. They still require accurate, numerous and evenly distributed GCPs. The order of the 3D polynomial model, generally between one and three, [9]. The following equations are used to express the general form of the polynomial models in 3D case, [6]:

- 1st order (3D) polynomial.
-

$$x = a_o + a_1 X + a_2 Y + a_3 Z \quad \text{... (7)}$$

$$y = b_o + b_1X + b_2Y + b_3Z \quad ...(8)$$

- 2nd order (3D) polynomial.

$$x = a_o + a_1X + a_2Y + a_3Z + a_4XY + a_5XZ + a_6YZ + a_7X^2 + a_8Y^2 + a_9Z^2 \quad ...(9)$$

$$y = b_o + b_1X + b_2Y + b_3Z + b_4XY + b_5XZ + b_6YZ + b_7X^2 + b_8Y^2 + b_9Z^2 \quad ...(10)$$

Where (x, y) are the image coordinates, (X, Y) are the ground coordinates and (a, b) are the polynomial coefficients to be determined by the least square adjustment, [6].

Direct Linear Transformation (DLT)

Direct Linear Transformation (DLT) model initially used by Abdel-Aziz and Karara in 1971 for non metric cameras in close range photogrammetry and Novak in 1997 for geometric correction of satellite images, [10]. The DLT model is the transformation between the image pixel coordinate system and the object space coordinate system as a linear function. It has been widely used in close-range photogrammetry and can also be used for the satellite image geometric correction. Actually, the DLT model is often used to derive the approximate initial values of unknown parameters for the collinearity equations, [9, 11]. The model can be expressed as, [3]:

$$x = \frac{L_1X + L_2Y + L_3Z + L_4}{L_9X + L_{10}Y + L_{11}Z + 1} \quad \cdots(11)$$

$$y = \frac{L_5X + L_6Y + L_7Z + L_8}{L_9X + L_{10}Y + L_{11}Z + 1} \quad \cdots(12)$$

Where (x, y) are coordinates of a point in image space and (X,Y, Z) are coordinates of same point in ground space and (L1, …, L11) are transformation parameters between two dimensional image space and the three dimensional object space to be determined by least square adjustment with minimum of (6) GCPs, [3].

STUDY AREAS

Flat area

The first study area is chosen in Baghdad city in the middle of Iraq. The area has an elevation range of between (32-47 m), and can be considered as flat area. The distribution of ground control points and check points have been shown in the Figures (1) and (2) respectively.

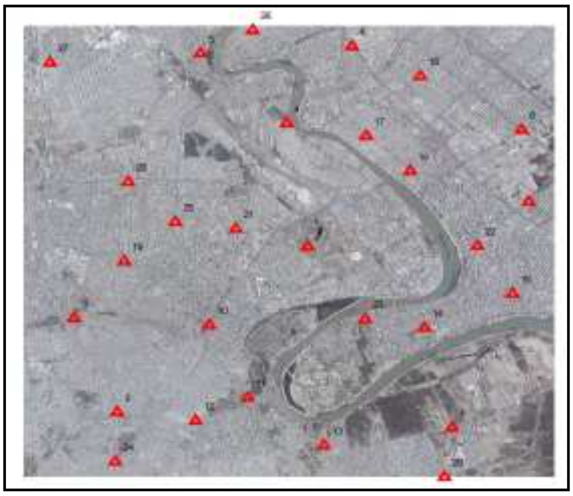

Figure (1) the first study area with GCPs distribution.

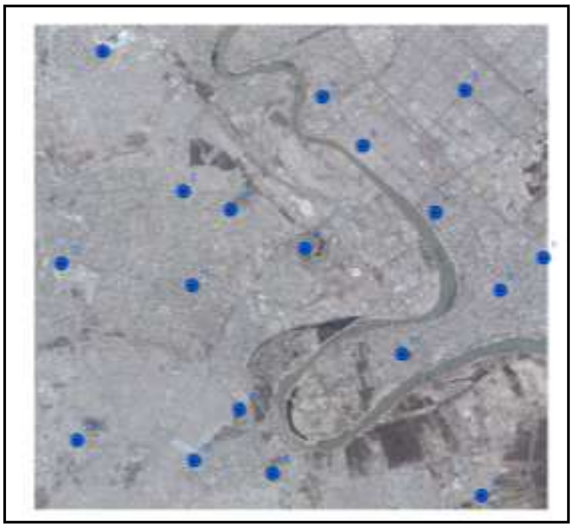

Figure (2) the first study area with CPs distribution.

Hilly area

The second study area is chosen in the center of Irbil city at the north of Iraq. This area has an elevation range of between (377-528 m), and can be considered as hilly area. The distribution of ground control points and check points have been shown in the Figures (3) and (4) respectively.

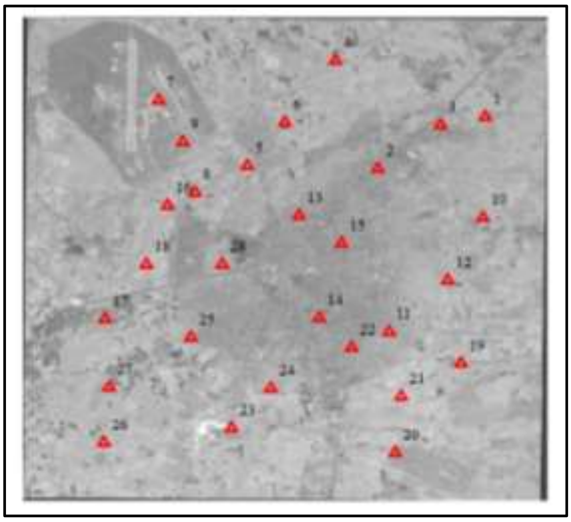

Figure (3) the second study area with GCPs distribution.

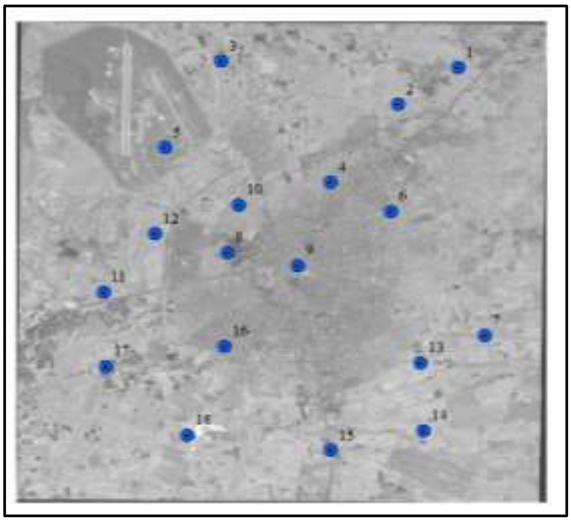

Figure (4) the second study area with GCPs distribution.

Mountain area

The third study area is chosen in Soran, Irbil city at the north of Iraq. The area has an elevation range of between (1450-3150 m), and can be considered as mountain area. The distribution of ground control points and check points have been shown in the Figures (5) and (6) respectively.

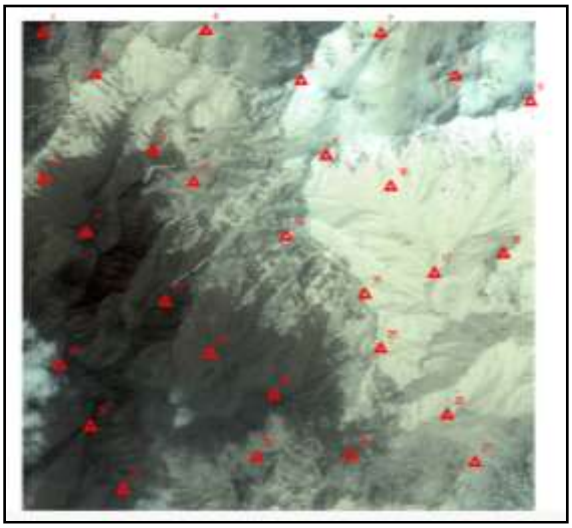

Figure (5) the third study area with GCPs distribution.

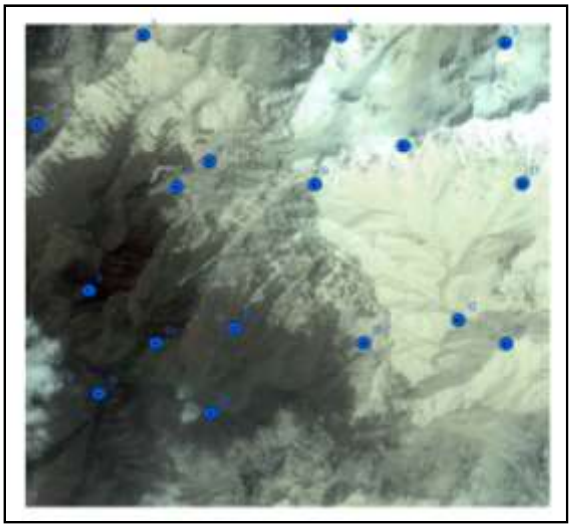

Figure (6) the third study area with GCPs distribution.

RESULTS AND DISCUSSION

In this paper, different geometric correction mathematical models are applied using three high resolution satellite Quick Bird images (panchromatic 0.6 m in spatial resolution) of three different study areas, with respect to their topography (flat area, hilly area and mountain area) in Iraq. All the geometric models which are used, utilized the ground control points GCPs in order to establish the mathematical relationship between image and corresponding ground coordinates. A total number of (46) GCPs were selected, well distributed over each of the three study areas, (28) points were used as control points and the rest of them were considered as check points. The ground coordinates of all GCPs were collected through the DGPS, type (Leica GPS SR20). The selection of GCPs targets is accurate as more as possible. The (TRMSE) for GCPs and check points have been calculated for all models in order to find the best model. All these models are evaluated through the Matlab environment facilities, [12].

The geodetic parameters used in DGPS coordinates characteristics and the images information can be given in Table (1), this information was used in all methods.

Table (1) The Used Geodetic Parameters and Images Information.

Parameter	QuickBird (1)	QuickBird (2)	QuickBird (3)
Image type	panchromatic	panchromatic	panchromatic
Spatial Resolution	0.6m	0.6m	0.6m
Map Projection	UTM	UTM	UTM
Datum	WGS 84	WGS 84	WGS 84
Zone Number	38	38	38
Acquisition Date	2008	2008	2008
Measurement Method	DGPS	DGPS	DGPS

The summary of results and TRMSE conclusion using the six models for the three study areas can be illustrated in Table (2).

The results of this table show that the 2^{nd} Order 2D Polynomial and 2^{nd} Order 3D Polynomial models are the best models in the flat area while the 2^{nd} Order 3D Polynomial and DLT models are the best models in the hilly and mountain areas because the best accuracy is achieved with these models. Also In the flat area the accuracy of 2D models is nearly similar to the accuracy of 3D models while in the hilly and mountain areas the accuracy of 3D models is better than the accuracy of 2D models because 3D models take into account the effect of relief displacement that occur in the hilly and mountain areas by including the elevation of GCPs (Z) in its function. In the results of 2^{nd} Order 3D Polynomial and DLT models there is a substantial stability of the error in the flat, hilly, and mountain areas. On the contrary, in 2D Polynomial and Projection Transformation models, there is a linear increase of TRMSE is found, passing from a flat area to more rugged terrains, reaching a maximum value of about (0.8 pixel) for GCPs with a polynomial of first order in the mountain area.

Table (2) The Summary of Results for The Three Study Areas.

Model	TRMSE (pixel) Flat Area		TRMSE (pixel) Hilly Area		TRMSE (pixel) Mountain Area	
	Control	**Check**	**Control**	**Check**	**Control**	**Check**
1^{st} Order 2D Polynomial	0.6042	0.6494	0.6914	0.7528	0.8003	0.8508
2^{nd} Order 2D Polynomial	0.5433	0.6153	0.6436	0.7025	0.7113	0.7875
Projective Transformation	0.5878	0.6337	0.6787	0.7206	0.7867	0.8467
1^{st} Order 3D	0.5903	0.6393	0.6441	0.7097	0.7239	0.7769

Polynomial						
2^{nd} Order 3D Polynomial	0.5176	0.6085	0.5520	0.6282	0.5250	0.5976
Direct Linear Transformation	0.5760	0.6281	0.5999	0.6427	0.5973	0.6406

CONCLUSIONS

1- The results of flat area indicate that the 2^{nd} order 2D polynomial and 2^{nd} order 3D polynomial models are the best models, while in the hilly and mountain areas the 2^{nd} order 3D polynomial and DLT are the best models because the best accuracy is achieved with these models.

2- In the flat area the accuracy of 2D models is nearly similar to the accuracy of 3D models while in the hilly and mountain areas the accuracy of 3D models is better than the accuracy of 2D models because 3D models take into account the effect of relief displacement that occurs in the hilly and mountain areas by including the elevation of GCPs (Z) in its function.

3- In the results of 2^{nd} order 3D polynomial and DLT models there is a substantial stability of the error in the flat, hilly, and mountain areas. On the contrary, in 2D polynomial and projection transformation models, there is a linear increase of TRMSE is found, passing from a flat area to more rugged terrains, reaching a maximum value of about (0.8 pixel) with a polynomial of first order in the mountain area.

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