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ASSESSMENT OF GEOMETRIC CORRECTION OF HIGH RESOLUTION SATTELITE IMAGERY USING DIFFERENT APPROACHES

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ملخص البحث:

تعد الصور الفضائية ذات القدرة التحليلية العالية مصدر هام للبيانات الجغرافية. العديد من طرق التصحيح الهندسي قد تم إستخدامة في هذا البحث. تم أختيار منطقة لإجراء التجارب عليها بإستخدام تصوير فضائي ذو قدرة تحليلة عالية وتصوير جوي رقمي للمنطقة ذاتها. تم أنتاج صورة جوية مقومة ومصصححة وإجرأء عملية مطابقة لها بالتصوير الفضائي لإستنتاج نقاط مرجعية أوتوماتيكيا. أستخدمت طريقتين لإجراء التصحيح الهندسي للتصوير الفضائي. الطريقة الأولي تعتمد علي المعاملات الموفرة بواسطة شركة التصوير ولا تعتمد علي المعلومات الأرضية. الطريقة الثانية تعتمد علي المعلومات الأرضية ولا تعتمد علي المعلومات التي يتم توفيرها بواسطة الشركة وتم إستخدام النقاط المستنتجة من تطابق الصور كأساس للضبط بدلا من نقاط الثوابت المرجعية الأرضية. أدي إستخدام أسلوب التصحيح الهندسي بأستخدام المعلومات الأرضية ثلاثية الأبعاد للنقاط المرجعية المستنتجة وبعد تصحيح الأرتفاعات بأستخدام نموذج لسطح الأرض ذو قدرة تحليلية عالية مستنتج من التصوير الجوي إلي تحسين دقة التصحيح الهندسي للتصوير الفضائي وتقليل قيمة الإنحراف المعياري للخطأ إلي 1.223 م في إتجاه (س) و 0.949 في إتجاه (ص).

Abstract

High resolution satellite images (HRSI) has become a very important data source of geographic information. This paper presents a different approaches of high resolution satellite imagery geometric correction. In order to compare different approaches, a satellite imagery matching with digital geometrically corrected ortho-photo using the automatic ground control extraction (AGE) technique. Matched points are ortho-corrected then, two different operational techniques are used in the process of geometric correction. Terrain-independent and terrain-dependent approaches were used in predicting ground coordinates of a set of previously observed ground check points. The study led to an improvement of the accuracy when dense DEM with 3D terrain-dependent model was used by reducing the error to 1.223 m in X and 0.949 in Y.

Keywords: Geometric Correction, Ortho-rectification, High Resolution Satellite Imagery, RFM

1_Introduction

Geometric correction of satellite data is one of the basic operation needed for remote sensing applications. Detailed sensor technical information of location and platform during data acquisition are not usually delivered to be implemented with the rigorous model. One of the most Non-parametric models used in geometric correction of the satellite data is the 3D rational function model (RFM) [Grodecki and Dial [1], Dowman and Tao [2]; Fraser et al. [3]; Tao et al. [4]; Toutin, [5]]. It is considered the commonly used algorithm in almost all commercial software packages of ortho-rectification of satellite image data [Dawmen and Tao [6]]. Geometric correction coefficient are extracted using automatically generated GCP's from image matching between satellite images and aerial images [Gianentto et al. [7]]. Ortho-rectification process with high accuracy is required, the ancillary data (GCPs, DEM) must be of high quality [Lingua and Borgogno, 2003 [8]; Chmiel et al., 2004 [9]]. With GCPs measured by differential global positioning system (DGPS), the most expected error comes from image pointing. Different approaches will be used to enhance the final geometric accuracy of the ortho-rectified satellite image, and the final geometric correction will be assessed.

2 Image Geometric Correction Models

Non-parametric models are used in geometric correction of satellite imagery due to the lack of information about the sensor required for the rigorous model. Various models have been used to solve geometric correction of satellite data mathematically; 2D polynomial functions, 3D polynomial functions, affine model, 3D rational functions. Various models can be classified into two main classes (a) terrain-dependent 3D rational functions without vendor image support data, (b) terrain-independent or refined 3D rational functions with vendor image support data.

2.1 3D Rational Functions Terrain-dependent Without Image Support Data

The most non-parametric methods used in satellite images geometric correction commercial solution is the rational polynomial camera (RPC) Manuel, A., et al [10], or the rational function model (RFM) that defines the projection parameters between satellite image coordinates (u ,v) and ground coordinates (X, Y, Z) as in eq(1).

$$u = \frac{p_a(X,Y,Z)}{p_b(X,Y,Z)} \ , \ v = \frac{p_c(X,Y,Z)}{p_d(X,Y,Z)} \quad (1)$$

The number of coefficients ($pa\ldots\ldots d$,) is dependent on polynomials' degree which in most cases is the third order and polynomial equations are expressed as in eq(2).

Pa $(X, Y, Z) = a_0 + a_1X + a_2Y + a_3Z + a_4x^2 + a_5xy + a_6yz \ldots \ \ldots . + a_{18}yz^2 + a_{19}z^3 \ldots .$ (2.1)

Pb $(X, Y, Z) = b0 + b1X + b2Y + b3Z + b4x2 + b5xy + \ \ldots . + b18yz2 + b19z3 \ldots .$ (2.2)

Pc $(X, Y, Z) = c0 + c1X + c2Y + c3Z + c4x2 + c5xy + \ldots . + c18yz2 + c19z3 \ldots .$ (2.3)

$\mathrm{Pd}(X, Y, Z) = \mathrm{d0} + \mathrm{d1X} + \mathrm{d2Y} + \mathrm{d3Z} + \mathrm{d4x2} + \mathrm{d5xy} + \ldots + \mathrm{d18yz2} + d19z3 \ldots$ (2.4)

The detection of transformation parameters (ai, bi, ci, di) can be achieved through an iterative least square adjustment process of the linearized form of the polynomial equations (1). Dealing with a large GCP number, in equation (2), the Tikhonov algorithm [11] is mostly applied.

2.2 3D Rational Functions Terrain-independent Without Image Support Data

In case of the availability of physical sensor model from commercial satellite data vendors, a grid nodes determined coordinates can be used to solve the rational polynomial coefficients (RPCs) using the physical sensor model [Tao and Hu, 2001 [12]]. Usually, third-order RPCs for the forward form are distributed by image vendor in very high-resolution sensors. According to the terrain-independency of this method, this method can be implemented without ground control points. The accuracy obtained is not good. Study results showed QuickBird image geometric correction (RMSE1D) between 2.4 m and 13.8 m with this method [Cheng et al., 2003 [13]]. There is a possibility to refine geometric correction RPCs in this method by adding a few GCPs and, this can be done directly or indirectly [Hu et al., 2004 [14]]. Direct refining process modifies RPCs delivered by the satellite image vendor while, indirect refining process adds complementary parameters in image or ground space, without modifying the originally delivered RPCs.

3. Application and Case study

An area covered by a QuickBird satellite data was examined for about 132 square kilometers for an area of Fayed and Abu-Sultan on the Suez gulf The two geometric correction methods described in the previous section is tested and the results is reported in the following section.

3-1 Dataset preparation

The experimental work took place in the area of Fayed and Abo-Sultan on the west coast of Suez gulf, where the following data were collected:

1) 45 ground GPS stations distributed over the area of interest to be divided into 39 control points and independent 9 checkpoints. –The control and the checkpoints were collected with RMS of 0.037 meters, 0.040 and 0.052 meters in X, Y and Z respectively.
2) Aerial imagery covering an area 12.5 X 14 km data captured using Leica Ads80 camera with ground resolution 25 cm for Fayed and Abu-Sultan area (Fig :1).
3) A bundle block adjustment of the captured Ads80 imagery was done using 36 gcp's and checked against 9 independent observed check points distributed as in (Fig : 1) with RMS of 0.261, 0.313 and 0.556 meter in X,Y and Z respectively (Table:1).
4) A 0.5 meter ground resolution orthophoto was produced from the Ads80 imagery.
5) A 0.5 meter ground resolution dense digital terrain model DDTM covering the area of aerial photography.
6) The same area of the aerial imagery data was captured using QuickBird sensor of 0.62 meter ground resolution.

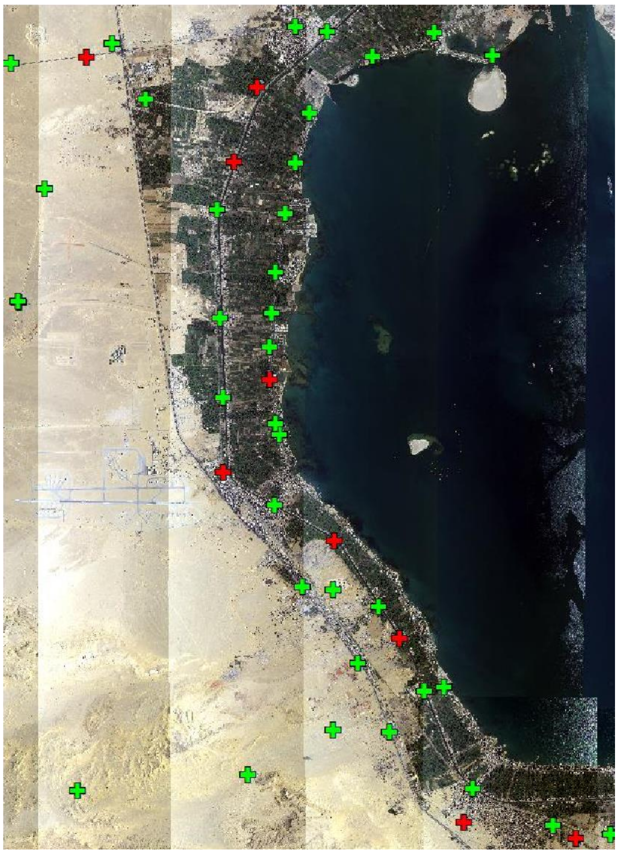

Figure 1. Ortho-Photo of The Study Area Showing Distribution of (36) Ground Control Points and (9) Check Points .

Table 1. Block Adjustment Check Points Errors and Root Mean Square Errors.

PointID	Err_X Meters	Err_Y Meters	Err_Z Meters
14	0.013	-0.086	-0.634
16	-0.752	-0.160	-0.951
18	-0.034	0.012	-0.807
20	0.153	-0.618	0.623
22	-0.347	-0.180	-0.200
32	-0.392	0.270	-0.548
34	-0.330	-0.741	-0.326
36	-0.460	-0.471	-1.179
39	-0.358	-0.544	-1.342
Mean	-0.279	-0.280	-0.596
RMS	0.261	0.313	0.556

3-2 Methodology and Applications

Although, geometric correction of satellite data using RFM model has an acceptable planimetric accuracy, it is affected by the number and distribution of GCP's [15]. In this research two methods have been implemented to compute sensor orientation parameters. The first method was Terrain-dependent 3D Rational Functions without Vendor Image Support Data, the first order rational polynomial function (RFM-1) was tested in this work. RFM-1 requires at least 7 known ground control points [10]. The second method used was Terrain-independent 3D Rational Functions with Vendor Image Support Data through the ERDAS IMAGINE 2016 in which indirect method is implemented based on the block adjustment developed by Grodecki and Dial [10] for image space.

$$\Delta x = x' - x = a_0 + a_1 x + a_2 y$$
$$\Delta y = y' - y = b_0 + b_1 y + b_2 y \quad (3)$$

Where a0, a1, a2, b0, b1, and b2 are the adjustment parameters of an image, and x' and y' express the discrepancies between the measured line and sample coordinates for the new GCPs in the image space (x, y) and the projected coordinates for the same GCPs (x, y).

ThAGE was used to identify matched control points from the satellite data with the preset aerial ortho-photo of the area of interest and extracting elevation of the control points from the DDTM as well, resulting in full control points. to be used as an input of the geometric correction using the former different rational function models. The two models were implemented to achieve final geometric correction using the same set of ground control points. The process took place on a 0.62m ground resolution QuickBird satellite scene according to the applied workflow in (fig: 2). The aerial orthophoto was used in the (AGE) with a criteria of correlation acceptance (L> 90%) resulting in an automatic detection of 572 photo control point and a DDTM to add elevation data of the chosen points. The results of two methods of geometric correction have been checked against the same 9 independent checkpoints that were used to check the aerial block adjustment, and the results have been reported.

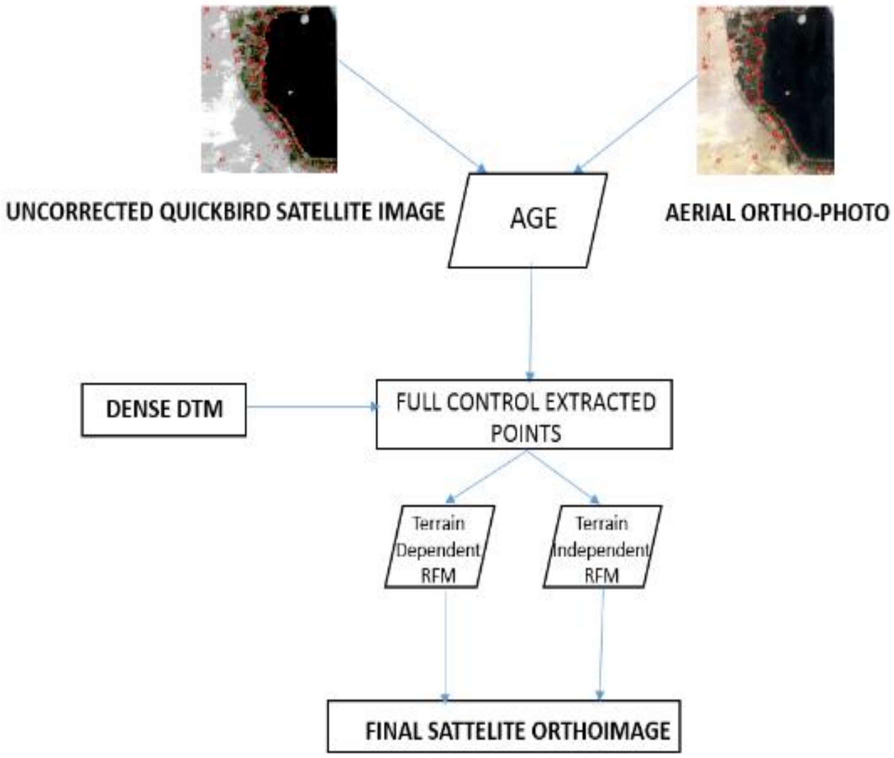

Figure2. Workflow of The Geometric Correction Procedure of The QuickBird Satellite Data of The Area of Fayed and Abu-Soltan

4. Satellite Data Ortho-rectification

Ortho-rectification has been processed by two different procedures. First one was terrain-dependent 3d rational function without vendor image support, using ground control points deduced from the AGE process through a developed software by the authors. The Second procedure was terrain-independent 3d rational function with vendor image support using a commercial off the-shelf software. Implementing the RFM model in ERDAS IMAGINE 2011.

. The two methods were tested using chosen fixed 9 checkpoints.

5. Analysis and Results

Geometric correction achieved of the QuickBird satellite data of the test area using different RFM methods were analyzed. Former research discussed number and distribution of control points using conventional and non-conventional methods stated that best geometric correction of a single QuickBird scene using different models occurred when using more than 18 will-distributed GCPs [10]. In this reksearch the number of GCP's extracted by the (AGE) process reached 572 points using the aerial ortho-photo as a source of ground coordinates for the uncorrected satellite data. The terrain-independent with image vendor support was implimented through ERDAS IMAGINE 2016. Results have been checked against 9 check points giving a total RMSE of 2.212. The extracted (AGE) points have been used in the terrain-dependent RFM process developed module designed by the authors. Resulting in an improvement of the total RMSE measured from the 9 check points reaching 1.55 meters (2.5 pixels). (Table 2).

Table 2. Accuracy Assessment of Check Points Errors Using Terrain-Dependent and Terrain-Independent Methods.

Point ID	Terrain-Independent RFM		Terrain-Dependent RFM	
	Err_*x*	Err_*y*	Err_*x*	Err_*y*
14	1.678	-0.061	-0.497	1.272
16	-0.733	0.251	-1.047	-2.296
18	-0.928	2.150	-2.854	-0.221
20	-0.348	0.865	1.607	0.632
22	0.981	0.139	-1.325	0.197
32	0.705	0.442	1.402	1.235
34	-1.998	-0.155	2.397	3.072
36	-1.600	-1.607	-2.286	0.359
39	1.125	0.890	1.007	-0.087
Mean	-0.124	0.324	-0.177	0.462
RMS	1.223	0.949	1.7481	1.356

6. Conclusion

The assessment of two conventional techniques terrain-independent technique with image vendor support versus terrain-dependent without image vendor support technique developed by the authors has been carried out in this research. Satellite ortho-image was developed by a sequence of steps beginning with GCP's extraction using automatic GCP's extraction (AGE) process. Using (RFM) terrain-independent with image vendor support model gives total RMSE of 2.212 meters (3.5 pixels) which was not relatively good, the processing of random GCP's using (RFM) terrain-dependent without image vendor support model developed by the authors leads to a better geometric correction, leading to an improvement of accuracy form 3.5 pixels to 2.5 pixels.

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