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PLANIMETRIC ACCURACY OF ORTHORECTIFIED QUICKBIRD IMAGERY USING NON-PARAMETRIC SENSOR MODELS

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Abstract: *Now the resolution of VHR satellite images, such as QuickBird images is sufficient to generate digital orthoimages. Orthorectification is the process of geometrically correcting imagery for significant geometric inaccuracies which can be caused by topography, camera geometry, and sensor related errors. The output of orthorectification is a planimetrically true image. There are two approaches for orientation of images: physical model and non–parametric models. Physical models describe the physical acquisition geometry and are based on colinearity equations and complanarity equations. Non-parametric sensor models describe the relationship between the image and the ground coordinates based on the RPC (Rational Polynomial Coefficients), digital elevation model (DEM) and three-dimension ground control points (3D-GCPs). The orthorectification methods applied in this study are the following: (1) using the RPC supplied with data only; (2) using the RPC supplied with data + 2GCPs; and (3) using built RPC from 3D GCPs.*

The test field is a flat area covered with single QuickBird, 0.599m resolution, panchromatic standard ortho-ready Level-2A date 2005-09-06. Mean Off Nadir Viewing Angle = 8.6; and Cloud Cover = 0.029. The required height information, ground control points (GCPs) and check points (CPs) used in this study are obtained from digital surface model (DSM) and ground survey.

The objective of this research is to study non-parametric sensor models for orthorectification of QuickBird imagery to produce orthoimages for the selected study area. In the framework of the investigation, accuracy evaluation of the planimetric position of the obtained satellite orthoimages is made.

Aims:

1. Using remote sensing data and digital image processing techniques to produce orthoimages with suitable scale.
2. The results of this study could be useful for future production of orthoimages in similar study area.

Introduction

Orthorectification is the process of geometrically correcting imagery for significant geometric inaccuracies which can be caused by topography, camera geometry, and sensor related errors. The output of orthorectification is a planimetrically true image. The goals of orthorectification images require very high positional accuracy or uniform scale throughout the image. For example, after orthorectification it becomes appropriate to measure or precisely locate features in the image, to collect information for a GIS, or to combine the image with other accurately rectified images for sophisticated analysis.

In the case of this paper, the input images are very high-resolution satellite images QuickBird provided with RPC (Rational Polynomial Coefficients) sensor models. Original RPCs provided with very high-resolution satellite image products are known to contain significant biases, which can be corrected if GCP data of the image area is available (Grodecki and Dial, 2001; Fraser et al., 2006).

Objectives of the Research Work:

1. To study produced orthoimages from QuickBird 0.599 m resolution, panchromatic standard ortho-ready Level-2A.

2. To assess the quantitative assessment of produced orthoimages, through calculation of statistics of the check points.

Data Sets and Test Site:

The test area is located in Egypt. The test area is covered by QuickBird, 0.599m resolution, panchromatic standard ortho-ready Level-2A date 2005-09-06. The mean off nadir viewing angle = 8.6 degree, and % cloud cover = 2.9%. The total area=33 km^2. The Characteristics of QuickBird images are :

Sensor Name: QuickBird
Focal Length (mm) = 8836.2
Image Pixel Size x,y (mm) (0.013745, 0.013745)
Mean In Track View Angle = -8.6
Mean Cross Track View Angle = -1.0
DEM Correction = "Base Elevation"; terrain Hae = 21.08;
Image Descriptor = "ORStandard2A";
bandId = "P";
Product Level = "LV2A";
Product Type = "Standard";
bits Per Pixel = 16;
scanDirection = "Forward";
Cat Id = "1010010004807F00";
First Line Time = 2005-09-06T08:55:51.056546Z;
Mean Sun Az = 147.4;
Mean Sun El = 62.1;
Mean Sat Az = 194.6;
Mean Sat El = 80.5;
Mean Off Nadir View Angle = 8.6;
Cloud Cover = 0.029;
Earliest Acq Time = 2005-09-06T08:56:10.888743Z;
Latest Acq Time = 2005-09-06T08:56:10.888743Z;

Ground Control Points GCPs and Check Points CPs

Ground Control Points (GCPs) and Check Points (CPs) are necessary to orthorectify the satellite images and to control the orthoimages accuracy, 12 GCPs were collected by using GPS and the coordinates of 26 CPs extracted from large scale maps 1/2500. A well distributed points over the territory of Kafr Az-zyat were done.

Digital Surface Model DSM

One input for orthorectification of QuickBird images is the elevation model. The traditional way to correct image geometry is by using a bare ground model (DTM: digital terrain model). The result of this kind of rectification is acceptable for small scale application; however, large scale images suffer from the fact that 3D objects have a lean. 3D objects are not represented geometrically correct because their height is not taken into account. In case of buildings, displacement of footprints and roofs is extremely unpleasant when e.g. merging such image data with other geographically correct information.

A 3D digital surface model DSM were generated from map scale 1/2500 produced from stereo aerial photos covered the study area by generated the contour lines of these maps with contour interval 1m and interpolation with a grid-cell of 0.80 meters.
The generated model used consists of both bare land or digital terrain model (DTM) and digital building (DBM).

Used Map Projection And Datum

Projection: map Projection Name = "UTM"; map Zone = 36 ;Reference Ellipsoid:WGS-84; semi Major Axis = 6378137.0000; inverse Flattening = 298.257223563;

1 Projection: ETM Datum: Halmart 1906
\Map converted from UTM Datum WGS-84 reference system to ETM Datum: Halmart 1906, by using Envi software and the seven transformation parameters.

Methodology

As mentioned before, according to the technical features of QuickBird products, the best choice when dealing with an accurate orthorectification is to start from the Basic or Standard OrthoReady products. In this study three different approaches can be used to orthorectify the QuickBird images.

Inputs for generation orthoimages include satellite images, GCPs and/or map and DEM.The generation of orthoimages is accomplished in three steps, viz. generation of digital elevation model (DEM) using and GCPs, geometric correction and grid generation in a given map projection using ground to image mapping, and re-sampling to generate a gray- level image in a required output (map) resolution. The RPC (Rational Polynomial Coefficients or rapid positioning coordinates) sensor model can now be used to orthorectify data from QuickBird sensors within ENVI 4.0. The RPC orthorectification process combines several sets of input data to place each pixel in the correct ground location. In addition to the image to be rectified, the RPC coefficients and some sort of elevation information are required. Furthermore, the offset between mean sea level and the gravitational equipotential surface known as the *geoid* is required so the elevation can be correctly interpreted. Finally, if the source image does not have approximate geo-location information available, the rough location of the image on the earth's surface must be computed to provide a location base needed for the RPC transformation.

Methods of orthorectification which applied in this study were.
(1) using the RPC supplied with the data only.
(2) using the RPC supplied with the data + 2GCPs
In this case, the RPCs supplied with the data was used followed by transformation using 2 GCPs.
(3) using build RPCs from 3d GCPs only.
In this case, another option was used to build RPCs for any generic pushbroom sensor, scanned aerial photograph, or digital aerial photograph. Build RPCs function can be done from ground 3d-control points (GCPs) or from known exterior orientation parameters (XS, YS, ZS, Omega, Phi, and Kappa). Then, use the Generic RPC to orthorectify the image. In our case we build RPCs function based 3d ground control points (GCPs) using ENVI software. ENVI software implements a build up Rational Function Model for orthorectification QuickBird images.

In the present research the accuracy test includes calculations of the discrepancies of X, Y coordinates for a total group of (26) test points check points CPs located on the orthorectified image covering the whole test area. These point's X, Y coordinates are compared with the corresponding ones derived from the existing map 1/2500 which are considered as a reference in this research. In all the tests the same number of CPs was used for each of the four studied orthorecticiation approaches.

The Digital elevation model used was accurate. This means that the transformation from image pixels to projected coordinates was obtained based on accurate GCPs in x, y and z.

In any case, when applying the transformation to the whole image, the position of each pixel in the final rectified imagery is dependent on the accuracy of elevation data.

Results and Analysis

The first result is related to the first method: using the rational polynomial functions RPCs supplied with the data (no additional GCPs) and the DTM to generate orthorectified panchromatic image.

The results in terms of RMSE, maximum and minimum residuals errors in x and y direction on 26 CPs have been summarized in table 1. When applying RPCs supplied with the data (no additional GCPs), The RMS error and in check points CPs X and Y directions are 1.178m and 0.524m .The total RMSt is 1.392m. The max. and min. residuals in x direction are 9.227m and 4.378m, in y direction are 4.712m and 2.384m

Table 1. RMS error maximum and minimum residuals in check points CPs X and Y directions and the total RMSt using the RPCs supplied with the data

No. of GCPs	No of CPs	Dx (m)	Dy (m)	RMS (m)	RMSt (m)
0	26	Max 5.227 Min 2.378	Max. 4.712 Min. 2.384	x 3.956 y 3.956	4.875

The second sets of results Table 2 are related to the application of the rational polynomial functions provided with the image data followed by transformation using only two GCPs and the DTM to generate orthorectified panchromatic image.

When applying RPCs supplied with the data +2 GCPs, the RMS error and in check points CPs X and Y directions are 0.959m and 0.742m .The total RMSt is 1.499m. The max. and min. residuals in x direction are 3.657m and -0.432m, in y direction are 2.337m and -1.411m

Table 2. RMS error maximum and minimum residuals in check points CPs X and Y directions and the total RMSt using RPCs supplied with the data+ 2 GCPs.

No. of GCPs	No of CPs	Dx (m)	Dy (m)	RMS (m)	RMSt (m)
2	26	Max. 3.657 Min. -0.432	Max. 2.337 Min. -1.411	x 0.959 y 1.152	1.499

The Third sets of results Tables 3 are related to the application of build rational polynomial functions from user 3d GCPs to generate orthorectified image.

When collecting around 12 GCPs and working with a first order build RPCs from user 3d GCPs only. The RMS error and in check points CPs X and Y directions are 1.161m and 1.663m.The total RMSt is 2.028m. The max. and min. residuals in x direction are 2.271m and 2.731m, in y direction are 5.435m and -2.341m

Table 3. RMS error maximum and minimum residuals in check points CPs X and Y directions and the total RMSt using Build RPCs for any generic pushbroom sensor

No. of GCPs	No of CPs	Dx (m)	Dy (m)	RMS (m)	RMSt (m)
12	26	Max. 2.271 Min. -2.731	Max. 5.435 Min. -2.341	X 1.161 Y 1.663	2.028

Conclusions

Regarding the assessment of obtained results, the following conclusions can be outlined for flat terrains area:

1. Generation of orthoimages with high accuracy can be done effectively from Ortho Ready Standard panchromatic product using non-parametric models that does not require the data of imaging sensor and orbit elements.The user can also order smaller Ortho Ready Standard panchromatic scenes which are cheaper instead of full scenes.
2. The RPC (Rational Polynomial Coefficients) non-parametric model are used for orthorectifying QuickBird imagery of flat terrain with accuracies 4,875m, 1.499m and 2.028m according to the three methods of orthorectification. These accuracies of the orthorectification meet theoretically the requirements for orthoimages scale 1:10000, 1:3000 and 1:5000 or smaller.

Recommendations:

1. Re-calculating the results for images that covers hilly terrain.
2. Re-calculating the results using physical model (the rigorous**)**.

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