Geometric Correction in Ikonos Images – Case Study: Tehran, Iran

Jalal AMINI and Ali Reze Mohamadi HASHEMI, Iran

Key words: Remote Sensing, High-Resolution , Mathematical models

SUMMARY

In recent decades, Remote sensing data becomes one of the basic information required for mapping and different applications in geomatics. In the high resolution satellite images (HRSI), the high ccuracy depends on accurate mathematical models for the satellite sensor. Because, there is not satellite orbit information for the most of the new HRSI , empirical methods have been adopted. In this paper, different non-rigorous mathematical models investigate for geometric corrections over an Ikonos
geo-product image in Iran.

Geometric Correction in Ikonos Images – Case Study: Tehran, Iran

Jalal AMINI and Ali Reze Mohamadi HASHEMI, Iran

1. INTRODUCTION

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. 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 With the launch of various commercial high-resolution earth observation satellites, such as Indian Remote Sensing Satellite IRS-1C/1D, the Space Imaging IKONOS system, SPOT 5 and Digital Globe QUIKBIRD system, precise digital maps generated by satellite imagery are expected in the spatial information industry. For last decades, airborne photography is the primary technique employed in producing national map products due to its high accuracy and flexible schedule (Li, 1998). However, it cannot map areas where airplanes cannot reach and its mapping frequency is constrained by the limits of flight planning (Li, 2000). Now with the high-resolution satellites era, accuracy required by medium and small-scale maps are achievable, with the possibility to frequently map an area without the special flight planning and scheduling required using aerial photographs. Successful exploitation of the high accuracy potential of these systems depends on accurate mathematical models for the satellite sensor. In the last decade, many studies and researches performed with rigorous and non-rigorous mathematical models to rectify the satellite line scanner imagery such as SPOT, MOMS-02 and IRS-1C. One of the main goals of these researches is to find an appropriate mathematical model with precise and accurate results. The geometric accuracy of data products is terminated by the knowledge of precise imaging geometry, as well as the capability of the imaging model to use this information. The precise imaging geometry in its turn is stablished by knowledge of orbit, precise attitude, precise camera alignments with respect to the spacecraft and precise camera geometry (Srivastava and Alurkar, 1997). Rigorous mathematical models for geometric corrections of any images can be defined as the models, which can be precisely, present the relationship between the image space and the object space. Perspective geometry and projection performs the basis of the imaging model frame cameras as well as other sensors. For any point in the space, there is a unique projective point in the image plane, however , for any point in the plane there are infinite number of corresponding points in the space (Mikhail et al. 2001). Due to this fact, an additional constrain is needed to define the point in the 3D space. Collinearity equations are the rigorous model, which describe this projection relation between 2D image space and 3D object space.Unlike ordinary photogrammetric photography, high-resolution satellites are a line sensing imaging systems where every line is imaged at different time. That may help to understand the need of a special treatment of the sensor model (Makki, 1991). In general, the rigorous time dependent mathematical models are based on the collinearity equations, which relate image coordinates of a point to its corresponding ground coordinates. Published studies reported to date on IKONOS and other satellites focus in two main aspects ,the accuracy attainable in ortho-image generation and DTM extraction concerning 3D positioning from stereo spatial intersection using rigorous and non-rigorous sensor orientation models. Due to some limitations, most of the new High Resolution Satellite Imagery (HRSI) vendors hide the satellite orbit information and calibration data from the customers community such as for IKONOS and QUICKBIRD imagery. This means that other alternative models should be used to solve practically this problem and calculate the imagery parameters. Therefore, these empirical approaches can be applied to determine the ground point coordinates in either 2D or 3D.

In this paper, the different non-rigorous mathematical models in 2D and 3D have been used for geometric corrections of Ikonos image. Different orders of polynomials, projective and affine model were used with different numbers of GCPs. Figure 1 shows the steps of geometric correction in satellite images.

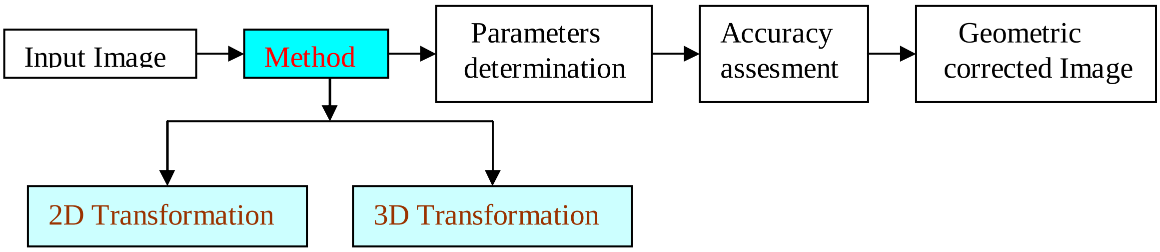


Figure 1. Steps of geometric correction

In the rest of the paper,mathematical models are discused in section 2, exprimental results and accuracy assesment are discribed in the last section.

2. MATHEMATICAL MODELS

During the satellite imaging process, the projection, the tilt angle, the scanner, the atmosphere condition, the earth curvature and the undulation etc., will cause the satellite image distorted. It is necessary to correction these distortions before one can really use it as a precise measurement in the large scale operations. In this paper, as previously stated, the orbital parameters were unknown. The mathematical model used to compensate the distortion correction is the so-called rubber shifting method. It neglects all the sources of distortions but deal with the present ones with the help of control points. This also makes the correction procedure easier in the circumstance of insufficient parameters. In this paper, some of 3D and 2D transformation used with different 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. The following sub sections discuss the models characteristics.

2.1. Rational Function Model

The rational function is the most commonly used non-parametric model, which is implemented in almost all software packages for the processing of satellite images. This type of approach is used by image salesmen to allow the final user to obtain added value products, such as orthoprojection without the necessity of having a model of the sensor, but by only attaching the coefficients of the relation between the image coordinates and the ground coordinates.

The rational function model allows a relationship to be determined between the image coordinates (x,y) and the 3D coordinates of the object (X,Yand Z) through polynomial relations, as shown in equation (1)

$$x=P1(X,Y,Z)/P2(X,Y,Z)$$

$$x = \sum_{i=0}^{m_1} \sum_{j=0}^{m_2} \sum_{k=0}^{m_3} a_{ijk} X^i Y^j Z^k / \sum_{i=0}^{n} \sum_{j=0}^{n_2} \sum_{k=0}^{n_3} b_{ijk} X^i Y^j Z^k \qquad (1)$$

$$y=P3(X,Y,Z)/P4(X,Y,Z)$$

$$y = \sum_{i=0}^{m_1} \sum_{j=0}^{m_2} \sum_{k=0}^{m_3} c_{ijk} X^i Y^j Z^k / \sum_{i=0}^{n} \sum_{j=0}^{n_2} \sum_{k=0}^{n_3} d_{ijk} X^i Y^j Z^k$$

where P_1,P_2,P_3, P_4 are usually maximum degree polynomials equal to 3,corresponding to 20 coefficients.

2.2 Polynomial Models

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. A 1st-order transformation is a linear transformation, which can change location , scale, skew, and rotation. In most cases, first order polynomial used to project raw imagery to a object for data covering small areas .

Transformations of the 2nd-order or higher are nonlinear transformations that can be used to convert Lat/Long data to object or correct nonlinear distortions such as Earth curvature, camera lens distortion. The following equations are used to express the general form of the polynomial models in 2D and 3D cases :

Two-dimensional general polynomials

- Linear polynomial

$$x=a_0+a_1X+a_2Y \qquad (2)$$
$$y=b_0+b_1X+b_2Y$$

- Quadratic polynomial

$$x=a_0+a_1X+a_2Y+a_3XY+a_4X^2+a_5Y^2 \qquad (3)$$
$$y=b_0+b_1X+b_2Y+b_3XY+b_4X^2+b_5Y^2$$

- Cubic polynomial

$$x=a_0+a_1X+a_2Y+a_3XY+a_4X^2+a_5Y^2+a_6 X^2Y+a_7X Y^2+a_8X^3+a_9Y^3$$
$$y=b_0+b_1X+b_2Y+b_3XY+b_4X^2+b_5Y^2+b_6 X^2Y+b_7X Y^2+b_8X^3+b_9Y \quad (4)$$

Three-dimensional general polynomials

$$x=\sum_{i=0}^{m_1}\sum_{j=0}^{m_2}\sum_{k=0}^{m_3} a_{ijk} X^i Y^j Z^k \quad (5)$$
$$y=\sum_{i=0}^{m_1}\sum_{j=0}^{m_2}\sum_{k=0}^{m_3} b_{ijk} X^i Y^j Z^k$$

where (a,b) are the model coefficients, (X,Y) are model parameters .

2.3 Projective Model

Projective model express the relationship between two space based on perspective projection concepts. The basic elements of the perspective projection consist of the point of the perspective center, bundle of arrays through this point and two different planes cut the bundle of arrays and do not contain perspective center. These two space can be defined in our work as image space and the ground space.The relationship between the two spaces can be written the following formula :

Eight-parameter transformation model :

$$x=\frac{L_0 + L_1X + L_2Y}{1 + L_6X + L_7Y} \quad (6)$$
$$y=\frac{L_3 + L_4X + L_5Y}{1 + L_6X + L_7Y}$$

where L is the model coefficient, (x, y) are the image coordinates and (X ,Y) are the terrain coordinates .

And for DLT model :

$$x=\frac{L_1X + L_2Y + L_3Z + L_4}{L_9X + L_{10}Y + L_{11}Z + 1} \quad (7)$$
$$y=\frac{L_5X + L_6Y + L_7Z + L_8}{L_9X + L_{10}Y + L_{11}Z + 1}$$

2.4 Affine Models

Adoption of an affine model as opposed to perspective projection model for satellite line-scanner imagery has been previously considered for both SPOT and MOMS-02 imagery and results showed that the affine model is quite robust and stable for image orientation and triangulation. The noteworthy point is that using the affine model can save at least thirty percent on image prices by ordering stereo images without the need for the rational functions. Each observation of a GCP will give rise to a set of two affine condition equations derived from the relationship between the image coordinates and the GCP coordinates in the geocentric system.The two affine condition equations are as follows :

In 3D

$$x = a_0+a_1X+ a_2Y+ a_3Z \quad (8)$$
$$y = b_0+b_1X+ b_2Y+ b_3Z$$

In 2D

$$x=aX+bY+e \quad (9)$$
$$y=cX+dY+f$$

where (x, y) are the image coordinates and (X, Y, Z) are the ground coordinates.

3. EXPERIMENTAL RESULTS AND ACCURACY ASSESSMENTS

An IKONOS satellite image from a region of Tehran is used as a test field area.This image is located near the central part of Tehran. Figure 2a,2b respectivly show the image with ground control and check points distribution. Table 1 presents the main characteristics of the acquired images.

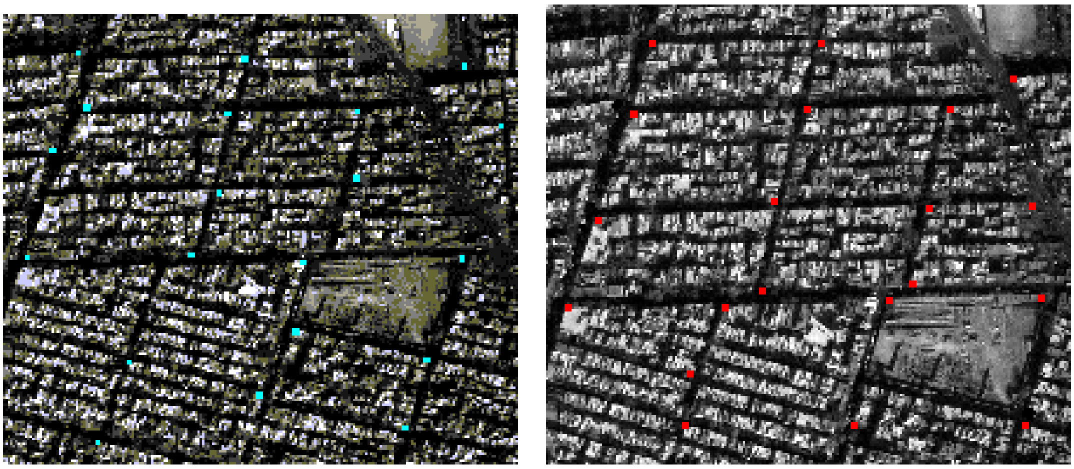

(a) (b)

Figure 2. The test area with a) GCP and b) check points distribution

Table 1. Technical specification of the Ikonos Image

Image type	Pan , Mono
Datum	WGS 84
Map Projection	UTM
Zone Number	39
Acquisition date	2001-05-25
File Format	Geo TIFF

The check points and the ground control points (GCPs) in this research were derived from a digital 1/500 topographic map that produced by National Catrographic Center (NCC) of Iran. It provides approximately 50cm planimetric accuracy and 50cm vertical accuracy. In Compare with the ground resolution of the IKONOS image, this digital map provides sufficient control data.Figure 3 shows the topographic map.

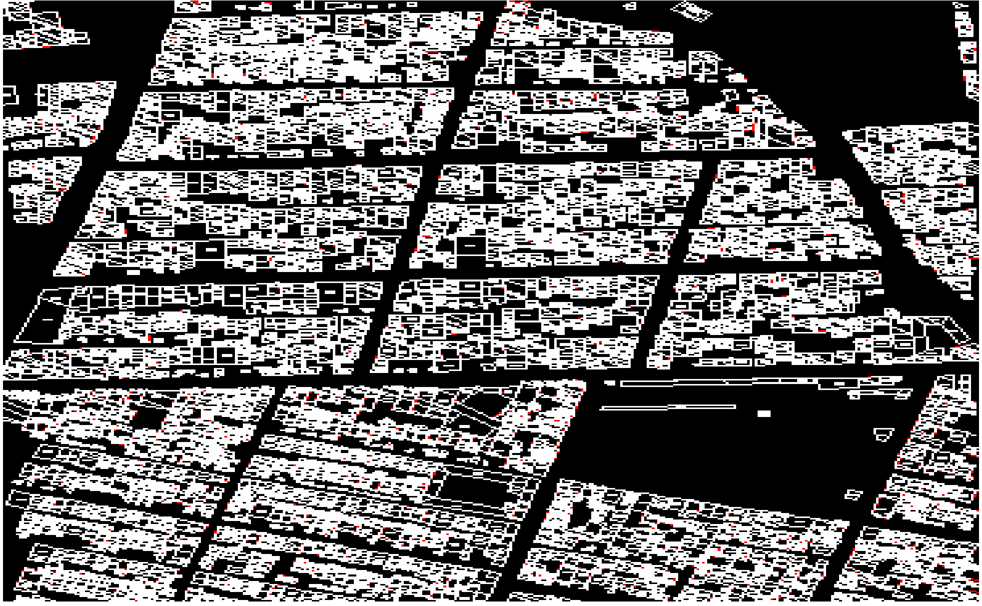


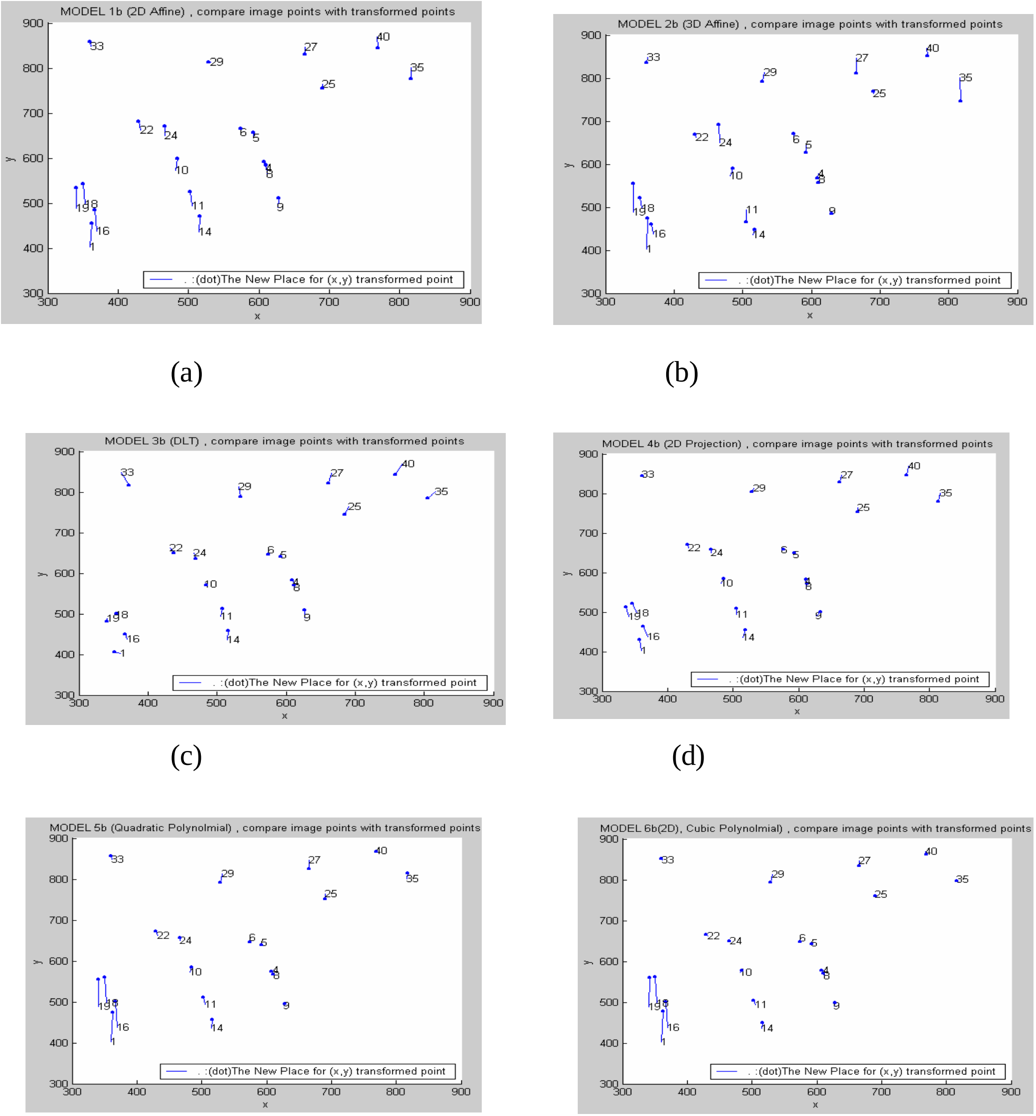
Figure 3. The topographic map

For Investigation of the results from the mathematical models in section 2,firstly the unknown coefficients were determined with 20 control points for each model.then with this determined coefficients,the corrected Image coordinates were calculated for 20 check points.RMS errors were calculated for each model base on the two types of coordinates for check points.Table 2 shows results for each model.

Table 2. Results from the mathematical models

Model	**No GCP**	**NO C.P**	**RMS error**
2D Affine	20	20	13.79014
3D Affine	20	20	1.889675
DLT	20	20	1.188267
2D Projective	20	20	13.20788
Quadratic polynomial	20	20	7.314452
Cubic polynomial	20	20	5.583822

Figure 4 shows the vector error plot of each check point for different models. As shown in figure, the vector plot od DLT model is better these the other models.



(a) (b)

(c) (d)

(e) (f)

Figure 4. Vector plot of errors for differnet models (a) 2D Affine Transformation model (b) 3D Affine Transformation mode. (c) DLT Transformation model. (d) 2D Projective Transformation model. (e) Quadratic polynomial Transformation model. (f) Cubic polynomial Transformation model

4. CONCLUSION

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. 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.
In this paper, some of 3D and 2D transformation models were used with different numbers of ground control points. These models are generally available within most of remote sensing image processing systems. Amonge of the maodels, the DLT model was a best model for the test earia. The accuracy of 1.1 m was be achived with this model.

ACKNOWLEDGEMENTS

The autors would like to thanks from University of Tehran for support this project and Remote Sensing Center (RSC) and Cadaster Organization for the Ikonos image and the map.

REFERENCES

Dowman,I., and Tao C.V.,2002.An update on the use of rational functions for Photogrammetric restitution,Highlights ISPRS,vol.7,No.3,pp.22-29.

Fraser,C.S.,Baltsavias, E.,Gruen, A.,2002.Processing of Ikonos imagery for submetre 3D positioning and building extraction,ISPRS Journal of photogrammetry & Remote Sensing 56 (2002) 177-194.

Fraser ,C., Hanley, H.,Yamakawa, T.2001.sub-Metre Geopositioning with Ikonos Geo imagery , ISPRS Joint Workshop on High Resolution Mapping from Space , Hanover,Germany ,2001.

Fritz,L.,1995.Recent Developments for Optical Earth Observation in the United states, Photogrammetric Week,pp75-84,Stuttgart ,1995.

Hanley,H.B. and Fraser,C.S.,2001.Geopositioning accuracy of Ikonos imagery : indications from 2D transformations,photogrammetric Record ,17(98) : 317-329.

Hattori,S.,one ,T., Fraser, C.S. and Hasegawa,H.,2000. Orientation of high-resolution satellite images based on affine Projection,International Archires of photogrammetry & Remote Sensing, Amsterdam,33(B3):59-366(on CD ROM).

Li, R., Zhou, G., Yang, S., Tuell, G., Schmidt, N. J. and Flower, C , 2000, Astudy of the potential attainable geometric accuracy of IKONOS satellite images, IAPRS, 33(B4), 587-595.

Mikhail, E.M., Bethel, J.S. and McGlone, J.C., 20001, Itroduction to modern photogrammetry, John Wiley&sons, New York.

CONTACTS

Jalal Amini, Ali Reze Mohamadi Hashemi
Department of Geomatics Engineering
Faculty of Engineering, University of Tehran
Tehran
IRAN
Tel: +92218008841
Email: jamini@ut.ac.ir