

Utilization of Satellite Images in the Development and Promotion of Urban Areas (Case Study in the West Regions of the Country)

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Abstract

In the high resolution satellite images (HRSI), the high accuracy depends on accurate mathematical models for the satellite sensors. Because, there is not satellite orbit information for the most of the new HRSI, this issue is very important in geometric correction of satellite imageries. The pre-processing of satellite images consists of geometric and radiometric characteristics analysis. By performing these operations, it is possible to correct image distortion and improve the image quality and readability. The radiometric analysis refers to mainly the atmosphere effect and its corresponding to feature's reflection, while the geometric correction refers to the image geometry with respect to sensor system with the launch of various commercial high-resolution earth observation systems. However, during the generating of satellite imageries, the projection, the tilt angle, the scanner, the atmosphere condition, the earth curvature and etc., will cause the satellite images to have distortion. So, 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, different non-rigorous (generic) mathematical models investigate for geometric corrections over an IRS P6 (Resourcesat-I) Satellite imageries (exactly LISS IV sensor images) in Iran. The LISS IV sensor of the IRS-P6 (Resourcesat-I) satellite has the spatial resolution 5.8 m with a enhanced spectral resolution. These different geometric models for performing the geometric correction on the satellite imageries includes Rational function models, different orders of polynomials models, projective, affine (2D and 3D) and DLT (Direct Linear Transformation) model with the different numbers of GCP points. Therefore, these mathematical geometric models can be applied to determine the ground point coordinates in object space and so can be used to provide good sufficient insight about the rectified images. In fact non-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. With implementation of different transformation models on the test data in IRAN, we found the best transformation model in geometric corrections which have the minimum RMSE (Root Mean Square Error) rather than another transformation models.

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1. Introduction

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, Nimbus and IRS-P6. One of the main goals of these researches is to find an appropriate mathematical model with precise and accurate results.

In this paper, the different non-rigorous mathematical models in 2D and 3D have been used for geometric corrections of the LISS IV images from IRS-P6 (Resourcesat-I) satellite imageries. Different orders of polynomials, projective and affine model were used with the same numbers of GCP points. Figure 1 shows the steps of geometric correction in satellite imageries.

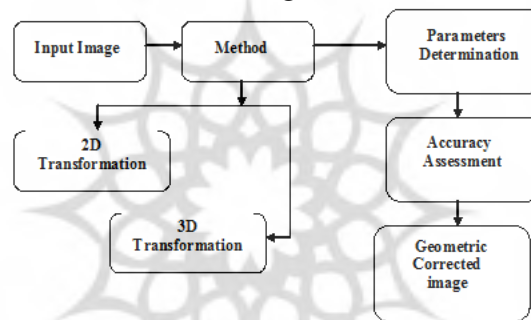


Figure 1. Steps of Geometric correction

In the next of the paper, mathematical models are discussed in section 2, experimental results and accuracy assessments are described in the last section.

2. Mathematical models

As we said previously, in this paper some of the 2D and 3D transformations used with the same numbers of GCP points. These models are generally available within most of remote sensing image processing systems. 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.

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

$$\begin{aligned}
 x &= \frac{P1(X,Y,Z)}{P2(X,Y,Z)} = \frac{\sum_{i=0}^{m1} \sum_{j=0}^{m2} \sum_{k=0}^{m3} a_{ijk} X^i Y^j Z^k}{\sum_{i=0}^{n1} \sum_{j=0}^{n2} \sum_{k=0}^{n3} b_{ijk} X^i Y^j Z^k} \\
 y &= \frac{P3(X,Y,Z)}{P4(X,Y,Z)} = \frac{\sum_{i=0}^{m1} \sum_{j=0}^{m2} \sum_{k=0}^{m3} c_{ijk} X^i Y^j Z^k}{\sum_{i=0}^{m1} \sum_{j=0}^{m2} \sum_{k=0}^{m3} d_{ijk} X^i Y^j Z^k}
 \end{aligned}
 \tag{1}$$

In this equation, P1, P2, P3, P4 are usually maximum degree polynomials equal to 3 which has 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 are expressed as below:

$$\begin{aligned}
 x &= a_0 + a_1 X + a_2 Y \\
 y &= b_0 + b_1 X + b_2 Y
 \end{aligned}$$

Equation (2)
Linear polynomial

$$x = a_0 + a_1X + a_2Y + a_3XY + a_4X^2 + a_5Y^2$$

$$y = b_0 + b_1X + b_2Y + b_3XY + b_4X^2 + b_5Y^2$$

Equation (3)
Quadratic polynomial

$$x = a_0 + a_1X + a_2Y + a_3XY + a_4X^2 + a_5Y^2 + a_6X^2Y + a_7XY^2 + a_8X^3 + a_9Y^3$$

$$y = b_0 + b_1X + b_2Y + b_3XY + b_4X^2 + b_5Y^2 + b_6X^2Y + b_7XY^2 + b_8X^3 + b_9Y^3$$

Equation (4)
Cubic polynomial

Also the three-dimensional general polynomial is expressed as below:

$$x = \sum_{i=0}^{m1} \sum_{j=0}^{m2} \sum_{k=0}^{m3} a_{ijk} X^i Y^j Z^k$$

$$y = \sum_{i=0}^{m1} \sum_{j=0}^{m2} \sum_{k=0}^{m3} b_{ijk} X^i Y^j Z^k$$

Equation (5)

In this equation, a and b are the model coefficients.

2.3 Projective and DLT models (Direct Linear Transformation model)

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. The relationship between the two spaces can be written the following formula:

$$x = \frac{L_0 + L_1X + L_2Y}{1 + L_6X + L_7Y}$$

$$y = \frac{L_3 + L_4X + L_5Y}{1 + L_6X + L_7Y}$$

Equation (6)

According to this equation, Eight-parameter transformation models (L_0 ---- L_7) are unknown parameters which those are model coefficients. Also as we pointed previously, (x, y) are the image coordinates and (X, Y) are the ground coordinates.

Also the DLT transformation model is shown in equation 7, where eleven parameter transformation models (L_1 ---- L_{11}) are unknown parameters which those are model coefficients.

$$x = \frac{L_1 X + L_2 Y + L_3 Z + L_4}{L_9 X + L_{10} Y + L_{11} Z + 1}$$
$$y = \frac{L_5 X + L_6 Y + L_7 Z + L_8}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

Equation (7)

2.4 Affine Models

The two affine condition equations are as follows:

IN 3D:

$$x = a_0 + a_1 X + a_2 Y + a_3 Z$$
$$y = b_0 + b_1 X + b_2 Y + b_3 Z$$

Equation (8)

And IN 2D:

$$x = aX + bY + e$$
$$y = cX + dY + f$$

Equation (9)

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

3. Experimental Results And Accuracy Assessments

The LISS-IV sensor image from IRS-P6 (Resourcesat-I) satellite from a region of ESFEHAN was used as a test field area. This image is located near the central part of ESFEHAN of IRAN. Figures 2 and 3 show the image with ground control and check points distribution respectively.

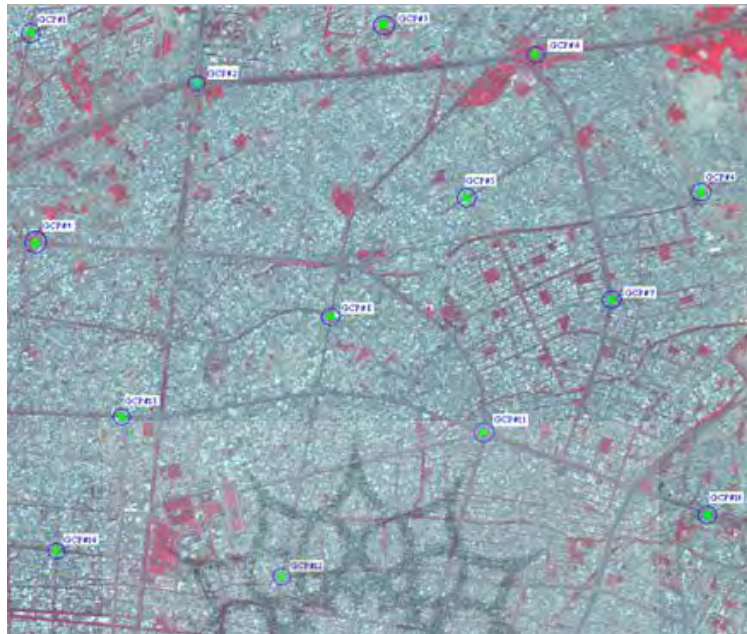


Figure 2. The test area with contribution of GCP points



Figure 3. The test area with contribution of check points

Also the main characteristics of the acquired images are presented in Table 1.

Table 1. Technical specification of the LISS IV sensor Image

Image type	LISS IV sensor image (MX mode)
Datum	WGS 84
Map Projection	UTM
Zone Number	39
Acquisition date	2008-02-25
File Format	Geo TIFF

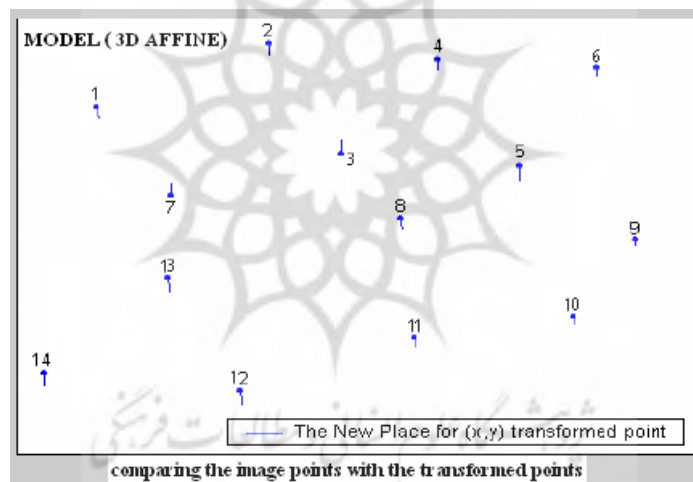
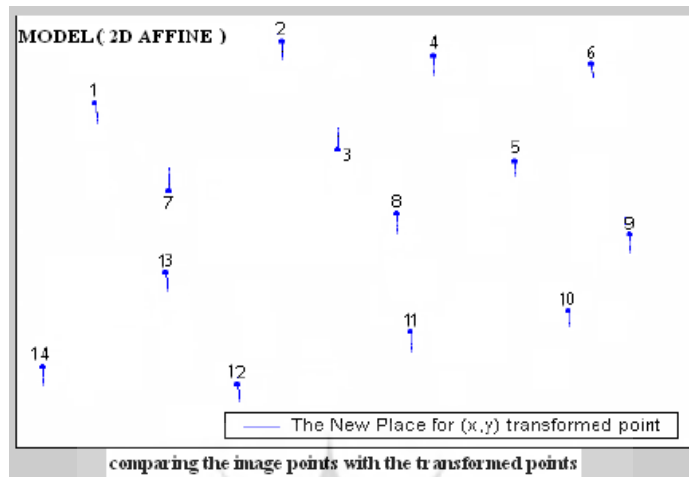
The check points and the ground control points (GCP points) in this research were derived from a digital 1/50000 scale of topographic map that produced by National Geographic Organization (N.G.O) of Iran. For Implementation of this Investigation, the unknown coefficients were determined with 14 Ground Control Points for each model. After with the determined coefficients, the corrected Image coordinates were calculated for 14 check points. The value of RMSE (Root Mean Square Error) was calculated and the obtain results are shown in Table 2.

Table 2. Results from the mathematical models

Geometric Model	NO. of GCP Points	NO. of CHECK Points	The value of RMSE
2D Affine	14	14	8.1895
3D Affine	14	14	3.4205
DLT	14	14	1.0154
2D projective	14	14	4.1241
Quadratic polynomial	14	14	7.2606
Cubic polynomial	14	14	6.3119

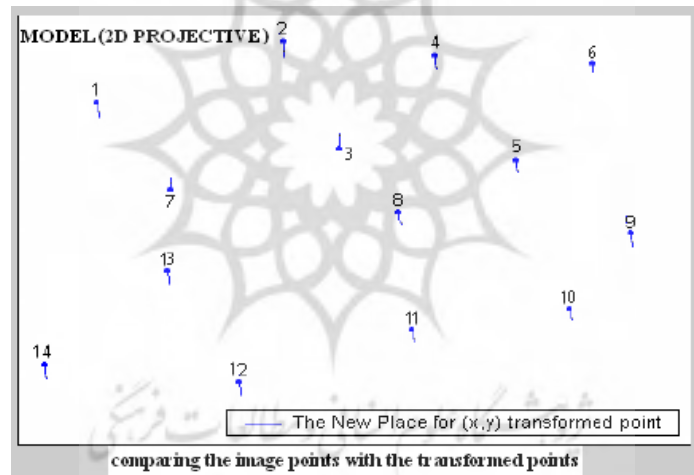
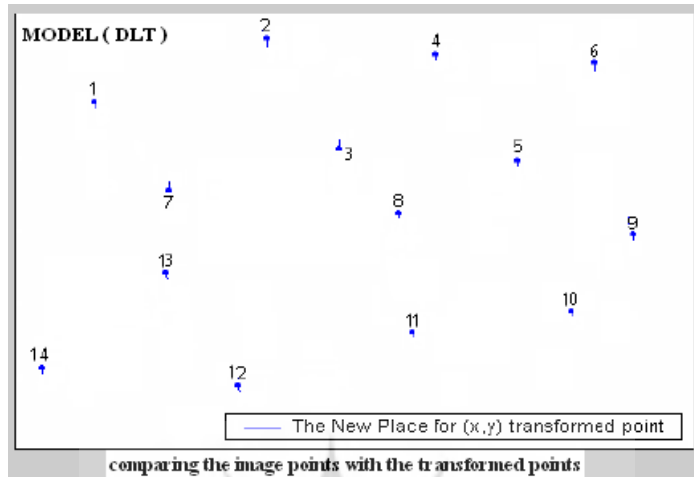
According to the value of RMSE errors the DLT and 3D affine models are better than the another model transformations.

Also the residual error vectors of each check point for different models are shown in figure 5 to 10.

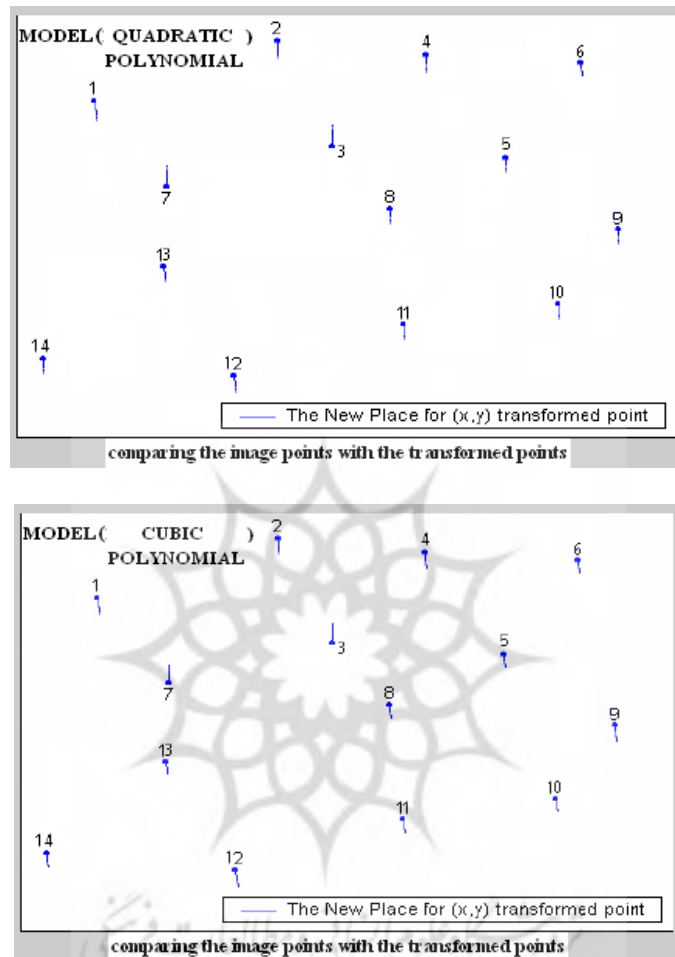


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4. Conclusion

In this paper, some of 3D and 2D transformation models were used with the same of ground control points. These models are generally available within most of remote sensing image processing systems. Among of the models, the DLT model was a best model for the test area. The accuracy of 1.01 m was being achieved with this model.

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