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Study on Geometric Correction Algorithms for SAR Images

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Abstract **- Geometric correction is an important step in the Synthetic Aperture Radar (SAR) image processing. A SAR image has to be geocoded before it is usable for further processing or information extraction. There are three major processes involved in a typical geometric correction: error modeling, ground control point selection and image transformation. In this paper, a study on four geometric correction methods namely global polynomial model, 2D direct linear transformation model, hybrid model and genetic algorithm with global polynomial model will be presented. By choosing appropriate ground control points, these geometric correction methods are applied onto an actual UAV SAR data for performance evaluation using root mean square error technique.**

Index Terms **– SAR, Remote Sensing, Geometric Correction.**

I. INTRODUCTION

SAR also known as synthetic aperture radar is an advanced form of side looking airborne radar which utilizes the flight path of the platform to simulate an extremely large antenna or aperture electronically. SAR image is generated from the echo signals received by radar from the earth surface. However the SAR images generated through signal processing usually contains errors or distortions. The errors or distortion may cause the changes of scale over the image, irregularities in the angular relationship among the image element, displacement of object in an image and occlusion of one image element by another. The correction of the errors and removal of distortion present in the data is termed pre-processing because; quite logically such operations are carried out before the data are used for particular purpose. [1] Pre-processing consist of geometric correction and radiometric correction. Geometric correction of remote sensing images is an important process before image processing in order to ensure the information extracted from the image to be accurate and true.

II. BASIC GEOMETRIC CORRECTION

Geometric correction is the process of reposition of pixels from the uncorrected image location to the reference grid through geometric operations. There are few steps of geometric correction:

1) Determine the geometric correction method. Different types of geometric correction have different number of coefficients and different amount of ground control points require.
2) Determine the coordinate transform model. Use the ground control points selected to determine the coefficient and generate the coordinate transform model.
3) Resample the input SAR image and obtain the image after removing the geometric distortion.

III. GEOMETRIC CORRECTION METHOD

There are few types of geometric correction method will be discuss in this paper

A. Global Polynomial Model [2]

The equations that have been used to construct the global polynomial model are:

$$= \sum_{i=0}^{N}\sum_{j=0}^{N-i} a_{ij}\ {}_{ref}{}^{i}\, y_{ref}{}^{j} \quad (1)$$

$$y = \sum_{i}^{N}\sum_{j}^{N-i} b_{ij}\ {}_{ref}{}^{i} y_{ref}{}^{j} \quad (2)$$

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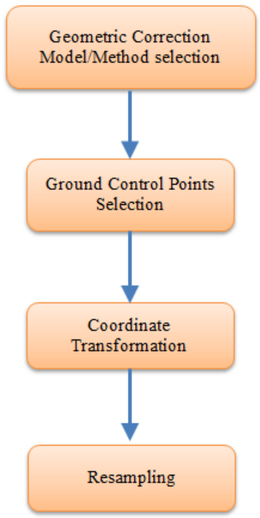

Fig.1 Flow cart of the geometric correction

where *x*,*y* represent the ground control points from the SAR image, x_{ref}, y_{ref} represent the ground control points from the reference image, N denoted the order of the polynomial. The most frequencies used are the affine model and quadratic model. The equations are as below:

1) Affine Model:

$$= a_{00} + a_{10}\ _{ref} + a_{01}y_{ref} + a_{11}\ _{ref}y_{ref} \quad (3)$$

$$y = b_{00} + b_{10}\ _{ref} + b_{01}y_{ref} + b_{11}\ _{ref}y_{ref} \quad (4)$$

2) Quadratic model

$$= a_{00} + a_{10}\ _{ref} + a_{01}y_{ref} + a_{11}\ _{ref}y_{ref} + a_{20}\ _{ref}{}^{2} + a_{02}y_{ref}{}^{2} \quad (5)$$

$$y = b_{00} + b_{10}\ _{ref} + b_{01}y_{ref} + b_{11}\ _{ref}y_{ref} + b_{20}\ _{ref}{}^{2} + b_{02}y_{ref}{}^{2} \quad (6)$$

Each $a_{ij}, b_{ij}$of the coefficients represents different geometric operation.

B. 2D Direct Linear Transformation Model [2]

The equations that have been used to construct the 2D Direct Linear Transformation Model are:

$$u = \frac{L_1x+L_2y+L_3}{L_7x+L_8y+1} \quad (7)$$

$$v = \frac{L_4x+L_5y+L_6}{L_7x+L_8y+1} \quad (8)$$

$L_i$are the coefficients for the 2D direct linear transform model. This model assumes the difference of height of the area in the image to be zero.

C. Rational function Model [3]

The equations that have been used to construct the rational model are:

$$u = \frac{\sum_{i=0}^{n}\sum_{j=0}^{m} a_{ij}x^iy^j}{\sum_{i=0}^{n}\sum_{j=0}^{m} b_{ij}x^iy^j} \quad (9)$$

$$v = \frac{\sum_{i=0}^{n}\sum_{j=0}^{m} c_{ij}x^iy^j}{\sum_{i=0}^{n}\sum_{j=0}^{m} d_{ij}x^iy^j} \quad (10)$$

$a_{ij}, b_{ij}, c_{ij}, d_{ij}$are the coefficients of the rational function model.

D. Genetic Algorithm with Global polynomial Model [4]

The equations uses for this method to construct the coordinate transform model are the same as the global polynomial model. It included only include the fitness test after the coordinate transformation model to evaluate the compatibility of the ground control points to be used to derive the geometric transformation coefficients.

IV. GEOMETRIC CORRECTION METHOD TESTING

The geometric correction methods were tested using an image from the google earth software as the reference image and a SAR image was selected from our own C-band SAR sensor as the

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image with geometric distortion. The area of the image was located at Mersing Johor, Malaysia.

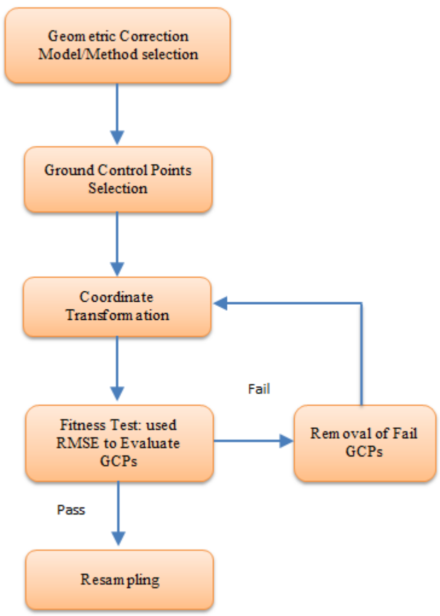

Fig.2 Process flow of the Genetic Algorithm with Global polynomial Model

Fig.3 Reference Image used for the Geometric Correction

A. Ground Control Characteristic

Ground control points (GCPs) are the location on the surface of the Earth that can be identified on an image.[5] By pairing the coordinates from the reference image and the SAR Image, geometric transformation coefficient can be derived. The GCPs selected should have the following characteristics:

- High contrast in all image of interest
- Small feature size
- Unchanging over time
- All are at the same elevation

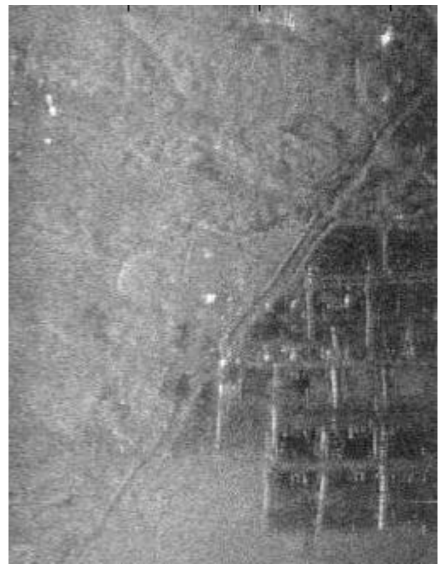

Fig.4 SAR Image used for the geometric correction.

15 points of GCPs are selected from both the reference image and SAR image for geometric transformation coefficient derivation. The sample of the corrected SAR image is shown in Figure 5.

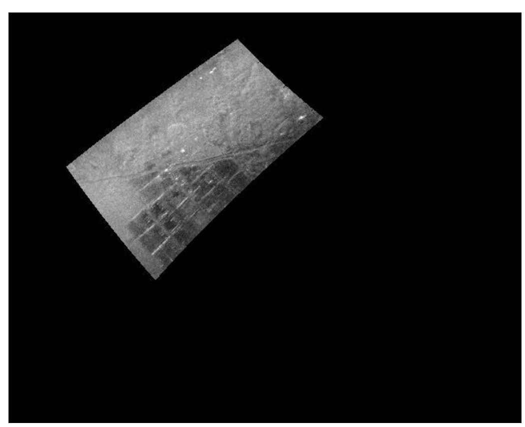

Fig.5 SAR Image after Genetic Algorithm with Global polynomial Model coordinates transformation.

B. Root Mean Square Error Evaluation [6]

The fitness of the GCPs to form the coordinate transform model is evaluated using the Root Mean Square Error, RMSE. The equations are as below:

$$_{rmse} = \sqrt[2]{\frac{1}{n}\sum(\quad - \quad_0)^2} \qquad (11)$$

$$y_{rmse} = \sqrt[2]{\frac{1}{n}\sum(y - y_0)^2} \qquad (12)$$

$$Total_{rmse} = \sqrt[2]{(\quad_{rmse}{}^2 + y_{rmse}{}^2)} \qquad (13)$$

$_0, y_0$ represent the reference coordinate of a GCPs while *x, y* represent the *x, y* coordinate output of the coordinate transform model and *n* represent the number of GCPs used.

V. RESULT

A. Global Polynomial Model

Table 1: Calculated RMSE of the x and y coordinate after affine model coordinate transformation.

Coordinate	RMSE
x	1.7884
y	1.6731
Total	2.4490

Table 2: Calculated RMSE of the x and y coordinate after quadratic polynomial model coordinate transformation.

Coordinate	RMSE
x	1.5217
y	1.6731
Total	2.2616

B. 2D Direct Linear Transformation Model

Table 3: Calculated RMSE of the x and y coordinate after 2D Direct Linear Transformation Model coordinate transformation.

Coordinate	RMSE
x	2.2402
y	1.8815
Total	2.9225

C. Rational Model

Table 4: Calculated RMSE of the x and y coordinate after Rational Model coordinate transformation.

Coordinate	RMSE
x	13.2101
y	3.2500
Total	13.6040

D. Genetic Algorithm with Global polynomial Model

Table 5: Calculated RMSE of the x and y coordinate after Genetic Algorithm with Global polynomial Model coordinate transformation.

Coordinate	RMSE
x	0.5175
y	0.6097
Total	0.7997

VI. CONCLUSION

The result shows that the genetic algorithm with global polynomial have the best result, 0.7997 among all of the geometric correction method discuss while rational function model have the worst result, 13.6040. The result shows that the selection type of geometric correction method and selection of the ground control points are very important in order to get a more accurate geometric corrected SAR image. The quality of the image is also very important as it will affect the GCPs selection.

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