ACCURACY ASSESSMENT OF PROJECTIVE TRANSFORMATION BASED HYBRID APPROACH FOR AUTOMATIC SATELLITE IMAGE REGISTRATION

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ABSTRACT

This paper presents the accuracy assessment of remote sensing satellite images for image registration. Image registration is an essential part of image processing for areas like remote sensing, medical and computer vision. The accuracy assessment is the essential step of remote sensing image analysis for the investigation and other applications. Image registration is the alignment of two or more images taken from different sources like different viewpoints, time and sensors. In this paper, a hybrid approach given to an image registration process that includes Speeded Up Robust Feature (SURF) detector for feature extraction and feature description, Random sample consensus (RANSAC) algorithm for outlier rejection i.e. to reject the false matching and the projective transformation function to register the slave image. Accuracy of the image registration process is considered on two parameter i.e. correlation coefficient and Root Mean Square Error (RMSE) of the Control Points. This work proposes the accuracy assessment of projective transformation for automatic satellite image registration.

Keywords: Image registration, Projective transformation, SURF Algorithm, RANSAC Algorithm

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1. INTRODUCTION
Image registration is the process for determination of exact spatial transform between two or more images. The application of image registration required in various fields like military investigation, medical imaging science, satellite image processing etc. This registration process can carried out both manually or automatically. Also, automatic image registration can performed by registering images in feature based methods or intensity-based methods. Hence, for feature based image registration, many methods have used like Harris corner detection, SURF (Speeded Up Robust Feature) (Liu et al. 2014; Gupta et al.), SIFT (Scale invariant Feature Transform), RANSAC (Random Sample Consensus) etc. (Bennour and Tighiouart, 2012). The mathematical model for RANSAC algorithm is different according to various requirements. Previous researchers adopt affine transformation based image registration process, which is just a special case of projective transformation method. In affine transformation model, only we have to deal with the transformation of a triangle. However, in projection method, transformation of a system of four point i.e. quadrangle is dealt. In projective transformation method, parallelism not preserved, whereas it preserved in affine transformation model. Length between points and angle between lines not preserved in both the system. To measure the accuracy of image registration based on quadrangle, we adopted projective transformation based image registration in this paper and along with this, SURF detector used for feature detection and description of feature. RANSAC algorithm used to decline the false matching using projective transformation model and the transformation matrix formed using projective transformation model.

2. THEORETICAL BACKGROUND
The methods adopted to make this hybrid approach are SURF detector, RANSAC algorithm and projective transformation function.

2.1. Projective Transformation
Plane-to-Plane mapping functions are known as Projective transformation based on plane-to-plane projection. A 3*3 matrix is used for the projective transformation in a homogeneous co-ordinate system for any projection plane (Calderon and Romero, 2007; Xia and Liu, 2006; Zokai and Wolberg, 2005). If the projective transformation is not affine, then it is not dependent on any plane and the distance of the planes from the projection line is infinity (Mustafa et al., 2014; Matungka and Zheng, 2009). A projection of a plane to another plane is shown in the fig. 1.

Figure. 1. Plane to plane projection [15]

The new location of the transformed pixel i.e. x1, y1 calculated from the original location of the pixel before transformation i.e. x, y as described below equation (Jianchao et al., 2001; Gleicher, 1997).
Accuracy Assessment of Projective Transformation Based Hybrid Approach for Automatic Satellite Image Registration

\[ x_1 = \frac{h_1 x + h_2 y + h_3}{h_7 x + h_8 y + 1} \]

\[ y_1 = \frac{h_4 x + h_5 y + h_6}{h_7 x + h_8 y + 1} \]

To form the transformation matrix we use these \( h_1, h_2, h_3, h_4, h_5, h_6, h_7, h_8 \) projection parameters. The transformation matrix of projective transformation is shown below.

\[
\begin{bmatrix}
  x_1 \\
y_1 \\
1
\end{bmatrix}
= \begin{bmatrix}
h_1 & h_2 & h_3 \\
h_4 & h_5 & h_6 \\
h_7 & h_8 & 1
\end{bmatrix}
\begin{bmatrix}
x \\
y \\
1
\end{bmatrix}
\]

2.2. SURF Algorithm

For feature detection and feature description purposes, SURF algorithm is used which is quite useful for 3-D image construction and for detection of objects (Mustafa et al., 2014; Gupta et al., 2014). The basic algorithm is quite similar to SIFT algorithm but SURF algorithm is more efficient than SIFT in time consumption parameter.

The blob detector used by SURF is Laplacian of the Gaussian (LoG) based. The image function \( i(x, y) \) in terms of pixel value is convolved by Gaussian kernel and the equation is given below (Pandya et al., 2013; Bouchicha and Besbes, 2013; Mahesh and Subramanyam, 2012).

\[ h(x, y, l) = \frac{1}{2\pi l^2} e^{-\frac{x^2+y^2}{2l^2}} \]

Where \( l \) = certain scale

Below equation describes the Scale Space representation.

\[ Z(x, y, l) = h(x, y, l) \ast f(x, y) \]

The determinant of the Hessian Matrix is calculated from the below shown matrix.

\[ H_M = \begin{bmatrix}
Z_{xx} & Z_{xy} \\
Z_{xy} & Z_{yy}
\end{bmatrix} \]

Where \( H_M \) is the Hessian Matrix.

And the final index of blob detector is calculated as

\[ (x_1, y_1, l) = \arg\max_{local} (x, y, l) (\det(H_M)(x, y, l)) \]

2.3. RANSAC Algorithm

Random Sample Consensus (RANSAC) algorithm defines the remaining outliers from the outliers detected first. A consensus set is defined among these points on the basis of a mathematical model which is projective transformation function in this case. By calculation of the probability of all detected points to fit in that model, the consensus set optimized by much iteration (Bennour and Tighiouart, 2012). The total no. of iterations can calculated by below equation (Wong and Clausi, 2009).

\[ I = \frac{\log(1-p)}{\log\left(1 - \left(\frac{\#\text{inlier}}{T}\right)^m\right)} \]

Where \( p \) = desired probability, \( \#\text{inlier} \) = no. points fitted into current consensus set, \( T \) = total no. of points, \( m \) = minimum no. of points to be fitted.
3. METHODOLOGY
The proposed methodology is a hybrid approach using SURF feature detector, RANSAC algorithm and projective transformation function. The entire method is divided into sub-part and the flow chart shown in fig. 2.

3.1. Collection of GCP Points
Control Points (CPs) are collected from the master image. CPs are normally chosen as the building corner and intersection of roads. Some spectacular objects which are easily identified in satellite image are also chosen as CPs. These points are taken from the source image itself.

3.2. Projective Transformation Estimation
Projective transformation matrix is calculated from the inliers generated from the projective transformation based inliers calculation using RANSAC algorithm. The new location of the slave image pixels are calculated using equation no. 1. The transformation matrix is for projective transformation is according to equation no. 2. After, that using this projective transformation matrix, the slave image is registered.

3.3. Image Resampling
After the image is registered, three different kinds of image resampling techniques applied to generate the final registered image. The resampling methods are “Nearest Neighbour”, “Bilinear Interpolation” and “Cubic Convolution”.

3.4. Accuracy Assessment
In this proposed methodology, correlation coefficient and RMSE (Root Mean Square Error) of the distance between the respective CPs in both the images are considered to check the accuracy of the image registration. Correlation coefficient is calculated directly from the image pixel values by the below equation.

$$C = \frac{\sum_x \sum_y (A_{xy} - \bar{A})(B_{xy} - \bar{B})}{\sqrt{(\sum_x \sum_y (A_{xy} - \bar{A})^2)(\sum_x \sum_y (B_{xy} - \bar{B})^2)}}$$

Where, \(\bar{A}\) = mean of pixel value of first image
\(\bar{B}\) = mean of pixel value of second image.
RMSE is calculated for each experiment using the below equation.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (x_i - y_i)^2}{n}}$$

Then these values of correlation coefficient and RMSE for each experiment noted down for comparison.
4. RESULTS AND DISCUSSION

The investigated results are achieved through different experiments using proposed methodology with the help of MATLAB R2015a, ARCGIS 10.2, and ERDAS IMAGINE 2014 software.

4.1. CPs Collection

All the CPs are taken from master image of CartoSat-1. The Area of Interest (AOI) is MANIT, Bhopal campus. The co-ordinates and the point description of the CPs are given in Table 1.

Table 1. Details of GCPs description

<table>
<thead>
<tr>
<th>Point Name</th>
<th>Northing (in m.)</th>
<th>Easting (in m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP1</td>
<td>2569037.70473</td>
<td>746462.94653</td>
</tr>
<tr>
<td>CP2</td>
<td>2569100.1441</td>
<td>746987.703209</td>
</tr>
<tr>
<td>CP3</td>
<td>2568610.50983</td>
<td>747517.615517</td>
</tr>
<tr>
<td>CP4</td>
<td>2568235.6911</td>
<td>747030.223643</td>
</tr>
<tr>
<td>CP5</td>
<td>2569002.6531</td>
<td>747472.57276</td>
</tr>
</tbody>
</table>
These points are then plotted in a Google earth image of MANIT, Bhopal campus to show the exact location of the points. This is done by creating a KML file by exporting these coordinates to ArcGIS 10.2 software. Then by this KML file, all the points are plotted to Google earth software. For better visual interpretation, some adjustment is done in the software. The result of this is shown in fig. 3.

**Figure 3.** Location of CPs in MANIT, Bhopal campus

### 4.2. Test Images for Experiments
Both reference and slave images are collected from CartoSat-1 image of Bhopal Area. The resolution of this image is 2.5m. Our AOI is MANIT, Bhopal Campus. The slave image is manually distorted to create the test images and both reference and slave images are shown in fig. 4.

![Figure 4. Initial (a) Reference Image, (b) Slave Image](image)

### 4.3. SURF Feature Detector
The detected points and matched point pairs in both reference and slave image using SURF feature detectors are shown in fig. 5.
4.4. Projective Transformation

Inliers are calculated from the detected points on the basis of projective transformation model based RANSAC algorithm. These inliers are shown in fig. 6.

The projective transformation matrix is estimated using these inliers. The slave image is registered using this transformation matrix. The output images are shown in fig. 7, the reference image and registered image using projective transformation function and different results from different resampling techniques.
Figure 7. Image registration using projective transformation and image resampling (a) Nearest Neighbour Image Resampling, (b) Bilinear Interpolation Image Resampling, (c) Cubic Convolution Image Resampling

The total number of detected points by SURF feature detector, the total number of points in inliers by RANSAC algorithm after eliminating the false matching by different parameter model, correlation coefficient for each registration process for all the satellite images are shown in Table 2.

Table 2. Comparison of the number of point detection for CartoSat-1 satellite image

<table>
<thead>
<tr>
<th>Satellite images</th>
<th>No. of points detected by SURF</th>
<th>No. of inliers by RANSAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>CartoSat-1</td>
<td>51</td>
<td>42</td>
</tr>
</tbody>
</table>
4.5. Accuracy Assessment

After co-ordinate mapping of the slave image in accordance to the master image and the registration parameters, RMSE is calculated for the shifting of CPs in slave image in comparison to the reference image of each satellite image, it can be seen in the Table 3.

<table>
<thead>
<tr>
<th>Resampling Method</th>
<th>RMSE for Projection based Image registration (in m.)</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easting</td>
<td>Northing</td>
</tr>
<tr>
<td>Nearest Neighbour</td>
<td>1.792497621</td>
<td>4.319615775</td>
</tr>
<tr>
<td>Bilinear Interpolation</td>
<td>1.292383238</td>
<td>3.192355028</td>
</tr>
<tr>
<td>Cubic Convolution</td>
<td>1.533533922</td>
<td>2.643006666</td>
</tr>
</tbody>
</table>

From the above results, obtained from proposed methodology, it is observed that this hybrid simulation gives highest accuracy around 0.97 correlation coefficient and the RMSE is also quite low, varying from 1-4 m approximately. As the resolution of CartoSat-1 image is 2.5m, this result is quite accurate.

5. CONCLUSION

In this work, a new approach to the registration of remotely sensed images is proposed and tested on satellite image on different scenes. From the above observations of results obtained from the simulations carried out, it concluded that this hybrid approach using projective transformation function gives highest accuracy in comparison to classical methods of similarity measure. In the experiments, registration accuracy with 0.97 correlation coefficient and the RMSE from 1-4 m. Accuracy assessment using co-ordinates of CPs collected is far more efficient in RMSE calculation. This approach can apply to multi-modal image registration as well and will compare to other registration techniques. In future work, the hybrid approach to image registration problem can be enhanced using different types of algorithms like genetic optimization of registration parameters, Principal Component analysis, Image entropy calculation, wavelet based image registration techniques.

REFERENCES


