Automatic Image Registration Through-Principal Axes Registration

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ABSTRACT
Image registration aims to find one to one correspondence between points that are presented in images which are needed to be registered. Also Image registration is the process of spatially aligning two or more images of same location taken at different timings or from different view-points by transforming into one coordinate system. In this paper, a new automatic satellite image registration is proposed based on principal axes registration method. The proposed algorithm uses Scale-invariant feature transform (SIFT) to detect point features from high resolution satellite images and then for removing mismatches (outliers) it uses Random sample consensus (RANSAC) algorithm. Finally, principal axes registration method used to register two images which share common visual information and that are assumed to be differing from each other. The principal axes registration algorithm is based on affine transformation to register two images which are transformed by translation, rotation and scaling. For validation The Root Mean Square Error (RMSE) is used for similarity measure. Experiment results shows that the proposed algorithm can register high resolution satellite images (Cartosat-1, Landsat, Resourcesat-1) which are captured at different timings. The proposed algorithm has been implemented in MATLAB.

Keywords
Image Registration, SIFT, RANSAC, Principal axes registration, affine transformation.

1. INTRODUCTION
Image registration is the process of transforming the different sets of data into one co-ordinate system which are captured at different timings or from different view-points. Registration is necessary in order to be able to compare or integrate the data obtained from different measurements and it is an essential step in most image processing tasks [1]. It is widely used in remote sensing, weather forecasting and medical imaging. It is a branch of computer vision that deals with the geometric alignment of a set of images. The set may consist of two or more digital images taken of a single scene at different times, from different sensors, or from different viewpoints. The main goal of registration is to establish geometric correspondence between the images so that they may be transformed, compared, and analyzed in a common reference frame. However, it could not design a universal registration system to solve all kinds of tasks depending on the different type of image and various types of degradations. When images are taken from different timings at same viewing angle, there exist geometrical transformation such as rotation, translation and scale between two images [4,6] and various methods have been developed and surveys have been published regarding the same.

2. IMAGE REGISTRATION
Registration methods can be divided into the following classes: Algorithms that use image pixel values directly, e.g., correlation methods; Algorithms that use the frequency domain, e.g., fast Fourier transform-based methods; Algorithms that use low-level features such as edges and corners, e.g., feature-based methods [16]. Algorithms that use high-level features such as identified (parts of) objects, or relations between features, e.g., graph-theoretic methods In the above methods some algorithms work on rigid bodies [10,14] and some work on non-rigid bodies, in order to register two images.
In this paper used computational technique suitable for registration of sets of images which are translated and rotated with respect to one another. The technique is based on the classical theory of rigid bodies, employing as its basis the principal axes transformation [1]. The advantages of the technique are simplicity and speed of computation. The procedure is completely automatic and relies on both pan-chromatic and multi-spectral satellite images.

In general, the procedure for image registration from two views can be summarized as follows.

Feature selection in one of the scenes of two images: Selected features should correspond to an interesting phenomenon in the scene and/or the object space [12, 13].

Identification of the conjugate feature in the other scene: This problem is known as the matching/correspondence problem within the photogrammetric and computer vision communities.

Mathematical model: Matched Points from the two images are given as input to the mathematical model to perform affine transformations between two images [15].

Image re-sampling Technique: It is a mathematical technique used to create a new version of the image in order to determine accurate position [3].

The previous image matching algorithms like Harris is not invariant to scale and rotation. For better image matching, SIFT algorithm was developed which is invariant to scale and rotation and this algorithm was used for both image matching and object recognition techniques. The main idea of SIFT is to transform image content into local feature coordinates that are invariant to translation, rotation and scale and other image parameters. Also in order to select more number of feature points applied image enhancement technique as in [2].

RANSAC algorithm is a mathematical model which is used for the better optimization of feature points. A basic assumption is that the data consists of "inliers", i.e., data whose distribution can be explained by some set of model parameters, though may be subject to noise, and "outliers" which are data that do not fit the model. So, with the outliers in our model there will be increase of final prediction error. Furthermore, RANSAC trains the model only with inliers ignoring outliers [5].

3. PROPOSED METHOD

In this section discussed the proposed registration algorithm and this algorithm enables finding, for each point in the first image, the corresponding point in the second image. The first image will be referred as the reference image and the second image will be referred as the sensed image. The reference image is kept unchanged and the sensed image is transformed to take the geometry and spatial coordinates of the reference image [15]. If the images represent different views of a 3-D scene, or if the scene represents a dynamic environment, it may not be possible to find correspondence between all points in the images. Image registration aims to find correspondence between points that are present in both images. The detailed flow chart of algorithm is shown in fig 1.

Principal axes of image registration:

If the images are segmented to contain the same scene parts, and coordinates of pixels belonging to the reference image are: [1]

$$\{\boldsymbol{Pi}=(\boldsymbol{xi},\boldsymbol{yi}):\boldsymbol{i}=\mathbf{1},\ldots\ldots\boldsymbol{m}\} \text{ [3.1]}$$

The coordinates of pixels belonging to the sensed image are:

$$\{\boldsymbol{Pj}=(\boldsymbol{xj},\boldsymbol{yj}):\boldsymbol{j}=\mathbf{1},\ldots\ldots\boldsymbol{n}\} \text{ [3.2]}$$

The co-ordinates of centroid of reference image will be:

$$\boldsymbol{xbar}=\mathbf{1}/\boldsymbol{m}\sum_{i=1}^{m} xi \text{ [3.3]}$$

$$\boldsymbol{ybar}=\mathbf{1}/\boldsymbol{m}\sum_{i=1}^{m} yi \text{ [3.4]}$$

The co-ordinates of centroid of sensed image will be:

$$\boldsymbol{Xbar}=\mathbf{1}/\mathrm{n}\sum_{j=1}^{n} Xj \text{ [3.5]}$$

$$\boldsymbol{Ybar}=\mathbf{1}/\mathrm{n}\sum_{j=1}^{n} Yj \text{ [3.6]}$$

If the centroid of two images corresponding to the same scene point, By moving the co-ordinate system origin in each image to its centroid, co-ordinates of points in both images will be measured with respect to the same co-ordinate system.

The transformation requires replacing $\boldsymbol{Pi}$ with $\boldsymbol{T1Pi}$ and replacing $\boldsymbol{Pj}$ with $\boldsymbol{T2Pj}$, where

$$T1 = \begin{bmatrix} 1 & 0 & -xbar \\ 0 & 1 & -ybar \\ 0 & 0 & 1 \end{bmatrix} \text{ [3.7]}$$

$$T2 = \begin{bmatrix} 1 & 0 & -Xbar \\ 0 & 1 & -Ybar \\ 0 & 0 & 1 \end{bmatrix} \text{ [3.8]}$$

$$Pi = \begin{bmatrix} xi \\ yi \\ 1 \end{bmatrix} \text{ [3.9]}$$

$$Pj = \begin{bmatrix} Xj \\ Yj \\ 1 \end{bmatrix} \text{ [3.10]}$$

Once the coordinate systems of the images are moved to their centroid, the rotational difference between them can be determined by finding the axis of minimum inertia of each image and calculating the angle between them. Using points in the reference image, the angle between the major axis of the points and x-axis is [8]:

$$\propto = 0.5 \tan -1 \{2 \textstyle\sum_{i=1}^{m}(xi - xbar)(yi - ybar)/\sum_{i=1}^{m}(xi - xbar)^2 - \sum_{i=1}^{m}(yi - ybar)^2\} \text{ [3.11]}$$

The angle between the major axis of points in the sensed image and the X-axis

$$\boldsymbol{\beta} = 0.5\tan -1\{2\textstyle\sum_{j=1}^{m}(Xj - Xbar)(Yj - Ybar)/\sum_{j=1}^{n}(Xj - Xbar)^2(Yj - Ybar)^2\} \text{ [3.12]}$$

Selected α and β the rotational difference between the images will be

$$\boldsymbol{\theta}=\boldsymbol{\alpha}-\boldsymbol{\beta} \text{ [3.13]}$$

The problem of determining the major axis of a set of points can be solved from a different point of view. Consider finding the direction along which the largest spread among the points is observed in the image. The direction of maximum spread can be determined by finding the covariance matrix of the points and calculating the eigenvectors and Eigen values of the matrix [9]. Then, the eigenvector corresponding to the larger Eigen value defines the major axis of the points. The other eigenvector, which is normal to the major axis, is known as the minor axis. Major and minor axes of a set of points are known as the principal axes of the set of points.

The covariance matrix of the sensed image is

$$C = 1/n \begin{bmatrix} \sum_{j=1}^{n}(\mathrm{xi} - \mathrm{xbar})^2 & \sum_{j=1}^{n}(xi - xbar)(yi - ybar) \\ \sum_{j=1}^{n}(xi - Xbar)(yi - Ybar) & \sum_{j=i}^{n}(\mathrm{yi} - \mathrm{ybar})^2 \end{bmatrix}$$

[3.14]

The covariance matrix of the reference image is

$$C = 1/m \begin{bmatrix} \sum_{j=1}^{n}(\mathrm{Xj} - \mathrm{Xbar})^2 & \sum_{j=1}^{n}(Xj - Xbar)(Yj - Ybar) \\ \sum_{j=1}^{n}(Xj - Xbar)(Yj - Ybar) & \sum_{j=i}^{n}(\mathrm{Yj} - \mathrm{Ybar})^2 \end{bmatrix}$$

[3.15]

Denoting Eigen vector associated with the larger Eigen value of ‘c’ by

$$\boldsymbol{v} = [v1 \quad v2 \quad v3]^t \text{ [3.16]}$$

Denoting Eigen vector associated with the larger Eigen value of ‘C’ by

$$\mathrm{V} = [V1 \quad V2 \quad V3]^t \text{ [3.17]}$$

The angle v makes with x-axis can be computed from

$$\propto = \mathbf{tan}{-}\mathbf{1}\ (\boldsymbol{v2}/\boldsymbol{v1}) \text{ [3.18]}$$

The angle vector V makes with X-axis can be computed from

$$\boldsymbol{\beta} = \mathbf{tan}{-}\mathbf{1}\ (\boldsymbol{v2}/\boldsymbol{v1}) \text{ [3.19]}$$

Therefore, if the x-axis and X-axis have the same direction the sensed image will be rotated with respect to the reference image by

$$\boldsymbol{\theta} = \boldsymbol{\beta} - \boldsymbol{\alpha} \text{ [3.20]}$$

$$R = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \text{[3.21]}$$

If the reference and sensed images have only translational and rotational differences, the transformation that maps point p in the reference image to the corresponding point P in the second image will be

$$T_2^{-1}RT1 \text{ [3.22]}$$

$$p = T_2^{-1}RT1p \text{ [3.23]}$$

$$T_2^{-1} = \begin{bmatrix} 1 & 0 & xbar \\ 0 & 1 & ybar \\ 0 & 0 & 1 \end{bmatrix} \text{[3.24]}$$

If the sensed image, in addition to being translated and rotated, it is also scaled with respect to reference image by a factor of s. The larger Eigen values of c will be scaled with respect to larger Eigen value of c by $s2$

Therefore Eigen values of c and C are λ1 and λ2. The sensed image will be scaled with respect to reference image by $s = \sqrt{\lambda 1/\lambda 2}$

$$\text{Therefore,} \quad S = \begin{bmatrix} S & 0 & 1 \\ 0 & S & 1 \\ 0 & 0 & 1 \end{bmatrix} \text{[3.25]}$$

The transformation used to resample the sensed image to the geometry of the reference image will be

$$T_2^{-1}SRT1 \text{ [3.26]}$$

$$P = T_2^{-1}SRT1P \text{ [3.27]}$$

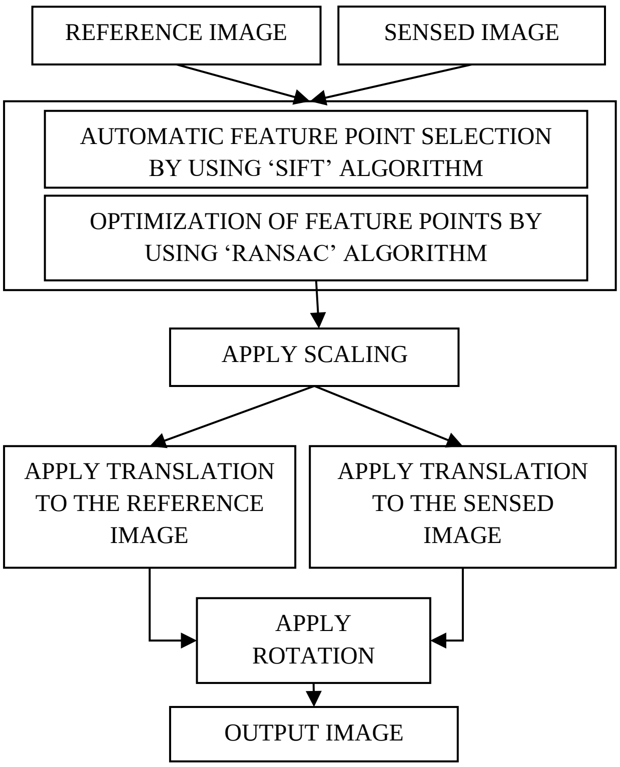

Fig 1: Block diagram of the algorithm

4. IMPLEMENTATION

Implementation describes about how the proposed algorithm is implemented. It shows how the inputs are taken from the datasets and then finding translational and rotational differences [7] between them, and they can be registered by rigid transformations. The implementation of registration process is done in MATLAB. Performance analysis can be done at each stage and the results at each stage are evaluated. The present study has reviewed the previous research work on the use of remote sensing data and a methodology for aligning two images using different datasets covering in northern parts of India. The proposed method was developed based on the knowledgebase collected from the data sets of CARTOSAT-1, LANDSAT and RESOURCESAT.

4.1 TEST DATA

The satellite image which is shown in figure (1) captured on 3rd Feb 2012 and figure (2) on 21st Feb 2013. It has been taken from Resourcesat-1 of LISS-3 sensor which has a resolution 23.5 meters and covers a swath of 142kms. These images have different translation, Rotation and scale. Figure (5) shows the registered image which is overlapped on the reference image (Translation = (610, 811), Rotation = 6.953°, Scale = 0.9996). Area: Banshi Khairi, Madhya Pradesh, India

Fig 2: Reference Image   Fig3: Sensed Image

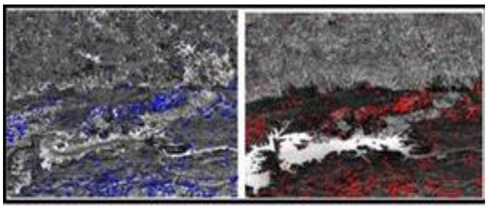

Fig 4: Automatic Feature Points Selection (SIFT)

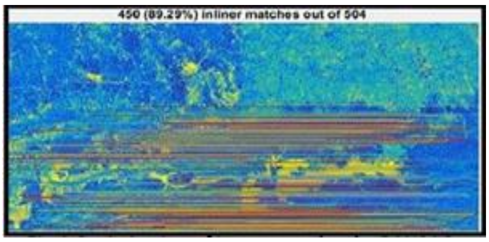

Fig 5: Optimization of image matches by using RANSAC

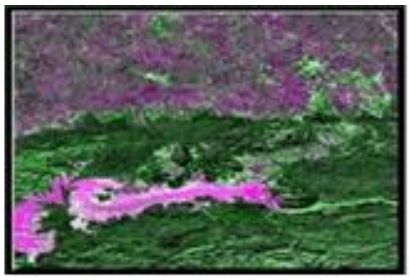

Fig 6: Registered Image

4.2 TEST DATA

The satellite image which is shown in figure (6) captured on 9th May 1981 and figure (7) on 9th JUN 2013. It has been taken from Landsat-1 which has a resolution 60 meters and covers a swath of 185kms. Figure (10) shows registered image which is overlapped on the reference image (Obtained, Translation = (467,185), Rotation = 6.6695°, Scale =0.9969). Area: Incheon, South Korea (1981-2013) 32 years

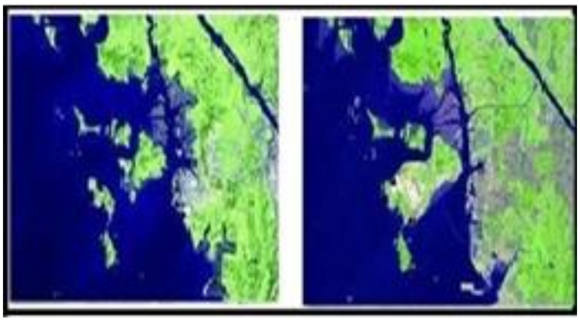

Fig 7: Reference Image   Fig8: Sensed Image

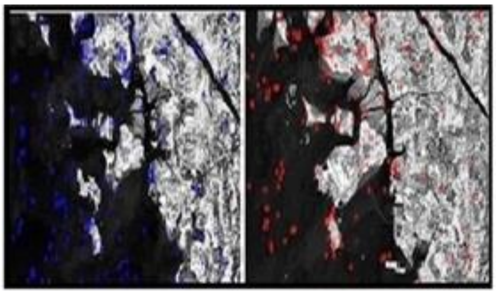

Fig 9: Automatic Feature Points Selection (SIFT)

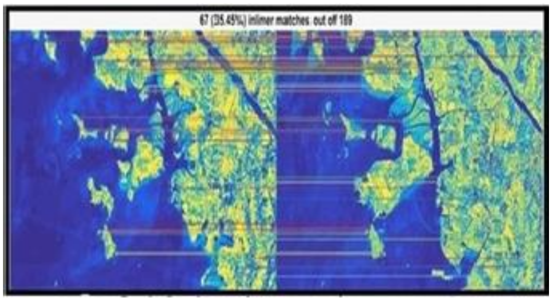

Fig 10: Optimization of image matches by using RANSAC

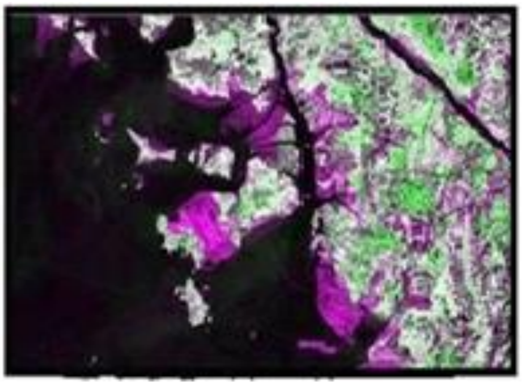

Fig 11: Registered Image

4.3 TEST DATA

The satellite image which is shown in figure (11) captured on 7th Nov 2008and figure (12) on 16th Dec 2013. It has been taken from Resourcesat-1 of AWiFs sensorwhich has a resolution 56 meters and covers a swath of 740kms. Figure (15) shows the registered image which is overlapped on the reference image (Obtained, Translation = (10225, 1357), Rotation =0.0031°, Scale = 1.0002) Area: Karnataka, India

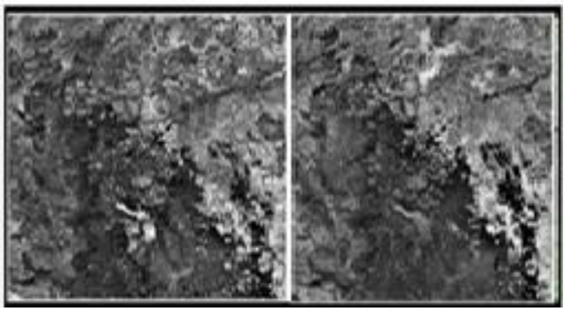

Fig 12: Reference Image   Fig13: Sensed Image

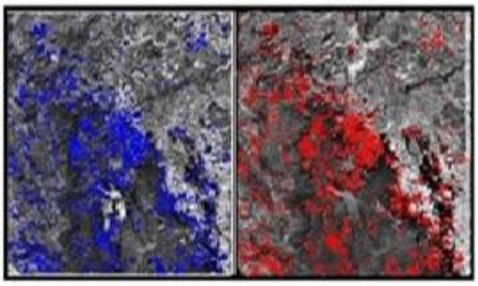

Fig 14: Automatic Feature Points Selection (SIFT)

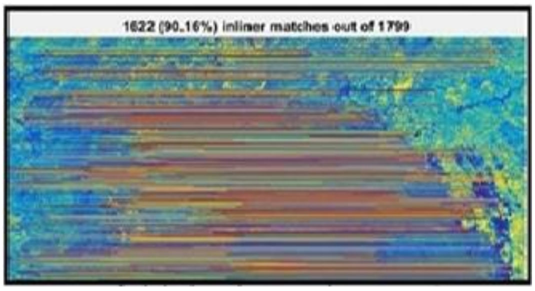

Fig 15: Optimization of image matches by using RANSAC

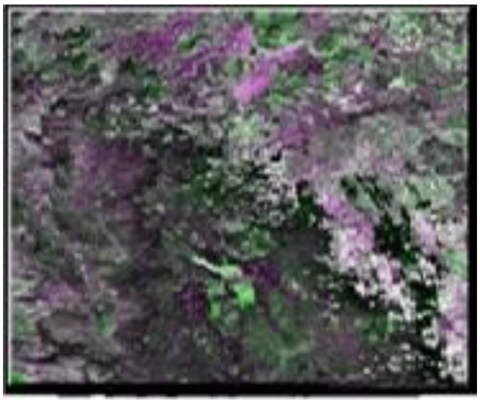

Fig 16: Registered Image

4.4 TEST DATA

The satellite image which is shown in figure (16) captured on 17th April 2015 and figure (17) on 29th April 2015 has been taken from cartosat-1 sensor which has a resolution 2.5 meters and covers a swath of 30kms. Figure (20) shows the registered image which is overlapped on the reference image (Obtained, Translation = (34151, 18039), Rotation =1.6099°, Scale =1.0000). Area: Mumbai, Maharashtra, India

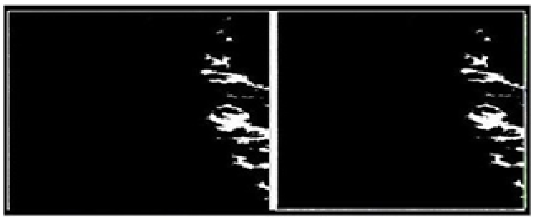

Fig 17: Reference Image **Fig 18: Sensed Image**

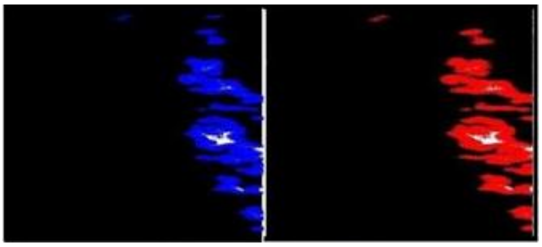

Fig 19: Automatic Feature Points Selection (SIFT)

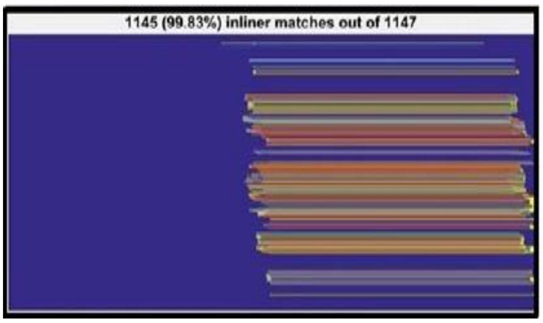

Fig 20: Optimization of image matches by using RANSAC

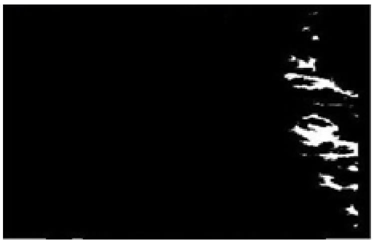

Fig 21: Registered Image

4.5 Performance Evaluation

To calculate the performance of proposed registration algorithm, the Root Mean Square Error(RMSE in pixels) was calculated [11]

$$\text{RMSE}=1/k\sqrt{\sum_{i=1}^{k}(P_{R(x,y)} - Q_{s(x,y)})^2}$$

Where,

K = Number of Corresponding points

$P_{R\,(x,\,y)}$ = Coordinates of corresponding points in the reference image

$Q_{S\,(x,\,y)}$ = Coordinates of corresponding points in the sensed image

The above test data shows registered images of different data sets and there Root Mean Square error (RMSE) in number of pixels is shown in Table1. The control points which are used in RMSE were used in image transformation parameters. The RMSE for different test datasets shows the best accuracy in automatic image registration. The results show that the proposed automated algorithm has the best performance than the manual image registration, with an improvement in registration accuracy.

Table 1: RMSE values for the proposed method

S.NO	SATELLITE	SENSOR	RMSE
1	CARTOSAT-1		0.0377
2	RESOURCESAT-1	LISS-3	1.6626
3	RESOURCESAT-1	AWiFS	3.4206
4	LANDSAT	LANDSAT-8	1.3340

5. CONCLUSION

This paper contains an overview of automatic image registration and proposes principal axis of image registration which can be used for high resolution satellite images. This method can be used to align images that have non-linear geometric differences (like highly undulated regions) and this algorithm is uses non-rigid registration method can be used to refine the registration so that the images will align locally as well as globally. The proposed method has been tested on different high resolution satellite data sets and also test results show that the proposed method is more accurate and effective for satellite imagery registration.

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