Automatic Geometric Registration of Satellite Images for Correcting Rotation Distortion

Vidyullata Sawant Devmane, Udhav. V. Bhosle and R.H. Khade

Abstract-- **Processing of satellite imagery takes major share of entire image processing activities because of many important applications such as natural resource management, crop estimation, rescue planning and monitoring. Aligning of satellite images to Earth coordinate system is major issue in Earth observation applications. In this paper, a new algorithm for satellite image registration is developed which is based on the matching of groups of three segments. As gray levels or textures cannot be used for the registration of images from separate spectral bands, an segment based method has been developed. Edges are detected first then corners and the corners are connected to get group three line segments to form triangles. A set of candidate transformations is determined by matching triangles from the source and destination images. The algorithm is able to register images where rotation distortion is present. The effectiveness of the algorithm has been verified on a distorted image.**

***Key Words*-- Automatic Geometrical Registration, Satellite Image Registration**.

I. Introduction

IMAGE registration is the process of overlaying two or more images of the same scene taken at different times, from different viewpoints, and/or by different sensors. It geometrically aligns two images the reference and sensed images. The present differences between images are introduced due to different imaging conditions. Image registration is a crucial step in all image analysis tasks in which the final information is gained from the combination of various data sources like in image fusion, change detection, and multichannel image restoration. Typically, registration is required in remote sensing in multispectral classification, image mosaicing ,weather forecasting, creating super-resolution images, integrating information into geographic information systems(GIS), in medicine(combining computer topography (CT)) and NMR data to obtain more complete information about the patient, monitoring tumor growth, information about the patient, monitoring tumor growth, treatment verification, in cartography (map updating), and in computer vision (target localization, automatic quality control). During the last decades, image acquisition devices have undergone rapid development and growing amount and diversity of obtained images invoked the research on automatic image registration. Commercial software, such as ErDas, utilizes control points or sensor's information to implement image registration. However, information on the control points or sensor's information may not be readily available or accurate enough.The registration based on such information is therefore limited and may even be inaccurate. Another disadvantage of using control points for image registration is that too much manual work is involved. It is indeed a tedious work for user to input so many correspondences on both of the images via an interactive way. Thus, the functionality of automatic satellite image registration is much required.

Visual/IR sensors operate at different frequency bands and their images have different gray level characteristics. The multisensor image registration is useful for tasks such as target recognition because information derived from different sensors is complementary and can be used jointly to improve detection and tracking performance. Features presented in the Visual images are often not the same as those in the IR Images automatic registration of Visual and IR imagery is very difficult. Segment based method is more robust approach than point based methods, as segments fitted to edges are less sensitive to those factors are easily manageable as vectors. The feature based methods can provide good platform for automatic image registration and automatic image registration has been explicitly requested for long time, but it is just an ideal solution in the past. In literature survey in section 2 various aspects of image registration and different feature based approaches will be discussed , section 3 gives outline of the new registration method, section 4 gives idea of extraction of possible transformation of the new technique. In the section 5 some experimental result are summarized and section 6 give overall conclusion.

II. Literature Survey

The majority of the registration methods consists of the following four steps feature detection, feature matching, transformation model estimation, image resampling and transformation.

A. *Feature Detection*

The features are objects either manually selected by an expert or automatically chosen by program. During an automation of

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registration step the approach is based on the extraction of salient structures–features in the images. Significant regions (forests, lakes, fields), lines (region boundaries, coastlines, roads, rivers) or points (region corners, line intersections, points on curves with high curvature) are understood as features. They should be distinct, spread all over the image and efficiently detectable in both images. They are expected to be stable in time to stay at fixed positions during the whole experiment. The comparability of feature sets in the source and destination images is assured by the invariance and accuracy of the feature detector and by the overlap criterion.

B. Feature Matching

The detected features in the source and destination images can be matched by means of the image intensity values in their close neighborhoods, the feature spatial distribution, or the feature symbolic description. The two major categories area-based and feature-based methods are further classified into subcategories according to the basic ideas of the matching methods.

1)Area-Based method :

Area-based methods, sometimes called correlation-like methods or template matching, merge the feature detection step with the matching part. These methods deal with the images without attempting to detect salient objects

a)Correlation-Like Methods:

The classical representative of the area-based methods is the normalized CC .This measure of similarity is computed for window pairs from the sensed and reference images and its maximum is searched. The window pairs for which the maximum is achieved are set as the corresponding ones . If the sub pixel accuracy of the registration is demanded, the interpolation of the CC measure values needs to be used. Although the CC based registration can exactly align mutually translated images only, it can also be successfully applied when slight rotation and scaling.

b)Fourier Methods(FT) :

If an acceleration of the computational speed is needed or if the images were acquired under varying conditions or they are corrupted by frequency-dependent noise, then Fourier methods are preferred rather than the correlation like methods. They exploit the Fourier representation of the images in the frequency domain. The phase correlation method is based on the Fourier Shift Theorem.

C)Mutual Information Methods:

The mutual information (MI) methods have appeared recently and represent the leading technique in multimodal registration. Registration of multimodal images is the difficult task, but often necessary to solve, in medical imaging. The MI, originating from the information theory, is a measure of statistical dependency between two data sets and it is particularly suitable for registration of images from different modalities. In equation (1) MI between two random variables ‘X’ and ‘Y’ is

$$MI(X,Y)=H(Y)-H(Y/X)=H(X)+H(Y)-H(X,Y) \qquad (1)$$

The method is based on the maximization of MI the authors described the application of MI for the registration by magnetic resonance images as well as for the 3D object model matching to the real scene. MI was maximized using the gradient descent optimization method.

2. Feature-Based Methods:

Two sets of features in the reference and sensed images represented by the CPs (points themselves, end points or centers of line features, centers of gravity of regions, etc.) have been detected. The aim is to find the pair wise correspondence between them using their spatial relations or various descriptors of features.

a) Automatic Visual/IR image registration:

The complete registration method is given in [7], first we have to perform contour extraction, then point feature extraction, point feature matching ,consistency checking and image transformation linear and nonlinear both, perspective and polynomial transformations are applied.

b) Automated image registration by combination of feature based and area based matching:

“Reference.[3]” explains Wavelet based feature extraction technique and relaxation based image matching techniques are used together. Satellites like IKONOS & Quick Bird are closer to the earth compared to the others so the terrain relief affects in their images, strongly especially in mountainous areas, the kind of distortion can be rectified by this way.

c) Semi-automatic registration of multi source satellite imagery with varying geometric resolutions:

Linear features can be represented either by an analytical function like straight lines, conic sections or parametric functions or free form shape as mentioned in the [1] straight line segments have been chosen as the registration primitives.

d) Registration based on Wavelet Transform:

Among feature extraction methods shape extraction is most robust and the most effective for remote sensing data under various conditions. The shape information of the regions in the images is analyzed by the wavelets transformation. Affine transformation is applied for the registration and its parameters are also determined by the minimum of the MSE as given in the [4]. The wavelet method is remarkably stable than FT, irrespective of various shapes of the regions.

e) Accuracy enhancement by spectral matching method in image-to-image co-registration:

"Reference [5]" uses algorithm, which maximizes local correlation in each spectral band at each co-registration point. In this paper spectral refinement of pixel to pixel matching is done. Here there is use of the Perspective Transformation Model.

f) Automatic image registration between image and object spaces:

The new approach of image registration is nicely given in the [6] which mainly relied on edges and corners. The procedure is, first tie point positioning then ,the polynomial transformation is used ,automatic increasing tie points based on edges, accuracy improvement by corners and resampling according the transformation model, here the relation between image space and object space will be established.

Feature-based matching methods are typically applied when the local structural information is more significant than the information carried by the image intensities. They allow to register images of completely different nature (like aerial photograph and map) and can handle complex image distortions. The common drawback of the feature-based methods is that the respective features might be hard to detect and/or unstable in time.

C. Transform Model Estimation

The type and parameters of the so-called mapping functions, aligning the source image with the destination image, are estimated. The parameters of the mapping functions are computed by means of the established feature correspondence.

D. Image Resampling and Transformation

The sensed image is transformed by means of the mapping functions. Image values in non-integer coordinates are computed by the appropriate interpolation technique.

III.Outline Of The Segment-Based Registration Method

In this registration method triangle segments by grouping three line segments are extracted from source and destination images and possible matching between the triangles are determined. Every triangle match has associated transformation parameters.

The main steps of the registration procedure are as the following

1)Extract edges from source and destination images by Cranny's edge extractor algorithm.

2)Detect corners using Fast Corner Detection algorithm from both source and destination images.

3)Connect corners into straight line segments. Connected line segments will used in formation of triangles.

4)Each triangle segment from source and destination images by grouping three line segments have been considered for matching and exhaustive search have performed.

5)Triangles with vary small area or with very acute angles are discarded, because of their high sensitivity to segment noise.

6)For each triangle of the source image, the transformation yielding a match with every triangle of the destination image is computed and stored. A set of limits for the transformation parameters for rotation is established and all transformations out of the ranges are discarded. This will be helpful to reduce the computation time.

7)The transformation obtained is applied to the source image segments and rotation distortion is corrected.

IV. Extraction Of Possible Transformation

Triangle matching is used to determine possible transformations. Every three line segments form a triangle, one example is shown in "Fig. (1)".

A group of three segments connected to three corners forms triangle. The congruence relation among the triangles has considered for triangle matching is, if two triangles are congruent then they should have same perimeter. Particular region in the source and destination images are considered to avoid more computations. When three line segments are grouped together they are labeled clockwise order for the triangle matching. Respective angle test has done that is by 'AAA' test triangle matching is shown done as in "Fig. 2"

Each angle of refernece is compaired with distorted image angle as given below.

{<A , <B , <C} → { <D ,<E ,<F }
{ <A , <B , <C} → { <E ,<F ,<D }
{ <A , <B , <C} → { <F ,<D ,<E }

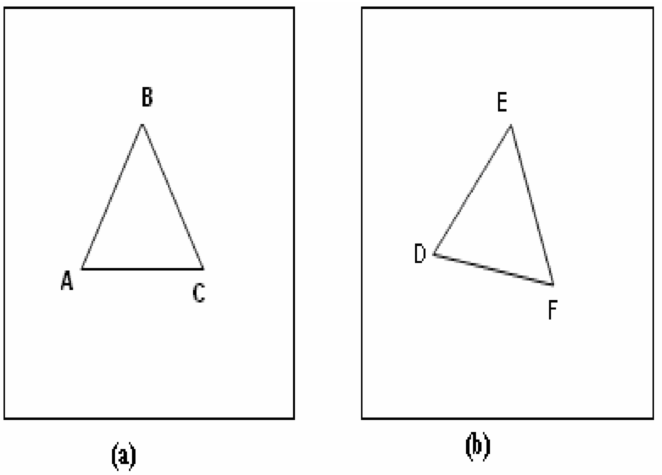


Fig. 1. Three segments {(AB),(BC),(AC)} and {(DE),(EF)(DF)} defines triangle in destination(a) and source images(b) respectively.

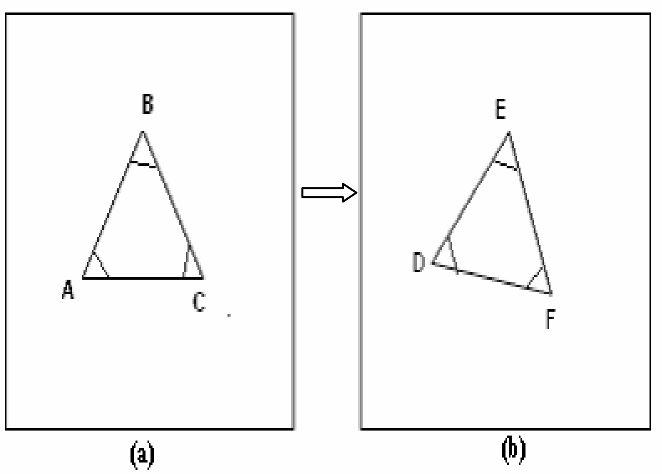


Fig. 2. Matching between a source (a) and destination(b) triangles depending on the order of angles will be done.

After this exhaustive test we will get matching of each triangle with respective triangle in source and destination images. Now those line segments have used to form triangles of that segments are taken to consider it's slope. Thus slope of each side have been calculated. Now the calculated slope will be useful for finding angle of rotation of source image triangles with respect to destination image triangles as shown in the "Fig. 3". Here with respect to single triangle pair it is explained.

Here 'T' is angle of rotation calculated in (2) of source image that will be computed and stored. If 'T' is not equal to zero then the image have rotation distortion.

$$T = \theta - \theta_1 \quad (2)$$

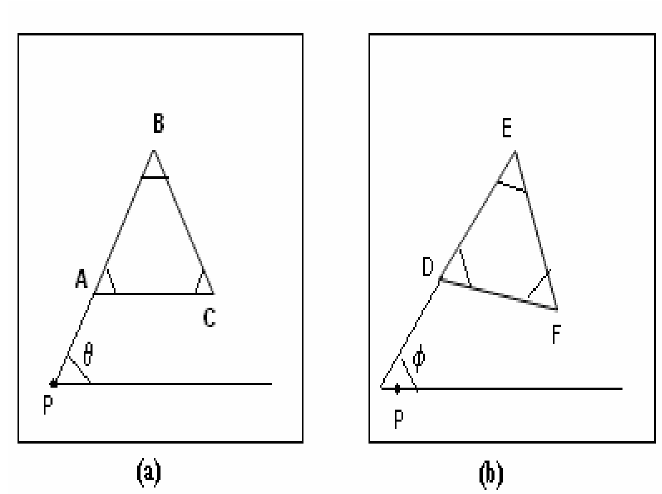


Fig. 3. Angles 'θ' and '∅' are calculated and considered to find rotation with respect to reference point 'p'.

The geometric transformation function for the image matching is,

$$p = (s1-s2)$$

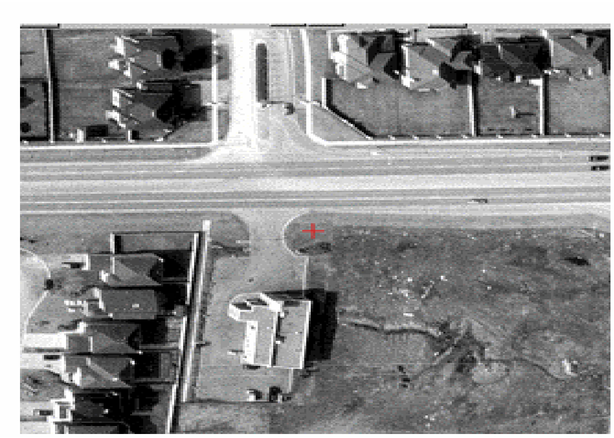
$$q = (s1+s2)$$

$$T=\tan^{-1}(p)/(1+q) \quad (3)$$

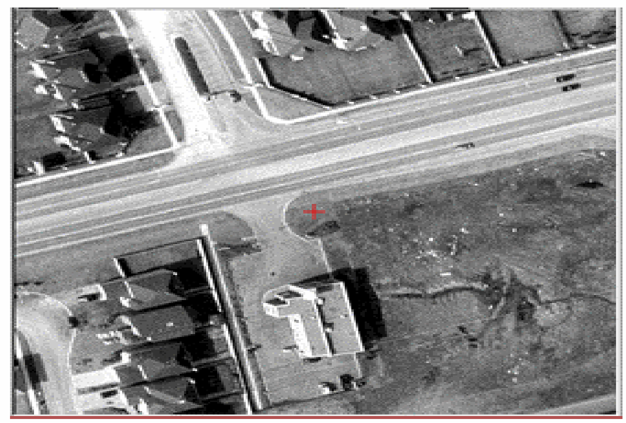
Here 's1' and 's2' are slope of lines of triangle sides those are matching from source and destination images. If 'T' in equation (1) is not equal to zero value then the angle of rotation distortion directly can find out by equation (2).

V. Experimental Results

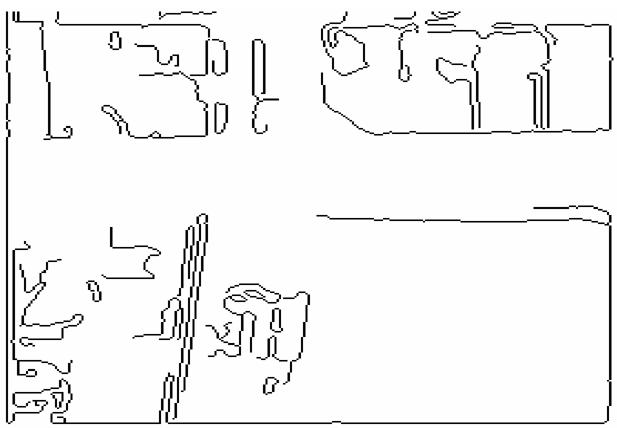
An example shown in "Fig. 4", for registration of visual-infrared images taken at different time of the same scene. Geometric variation between two images is quite large. The registration computing time depends mainly on the number of line segments. Here four line segments have considered to form triangles in both images so according to computation theory it will give four triangles in each image. As we increase line segments computation time will increase due to exhaustive search for matching triangles. So we can restrict number of segments to make algorithm work fast. The technique is useful for the images from any other spectral bands if the edge information content is sufficiently dense both images. By this algorithm we can achieve only rotation distortion



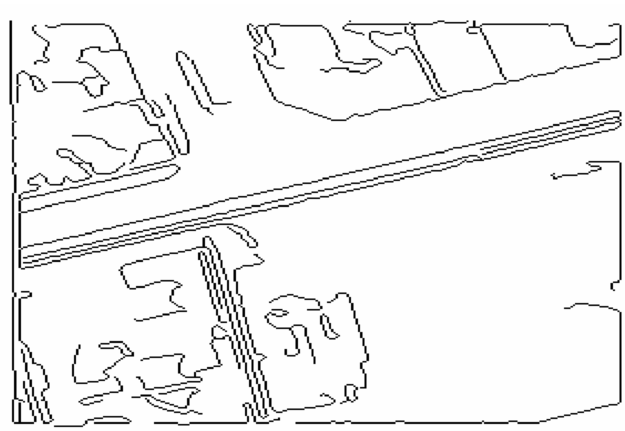
(a)



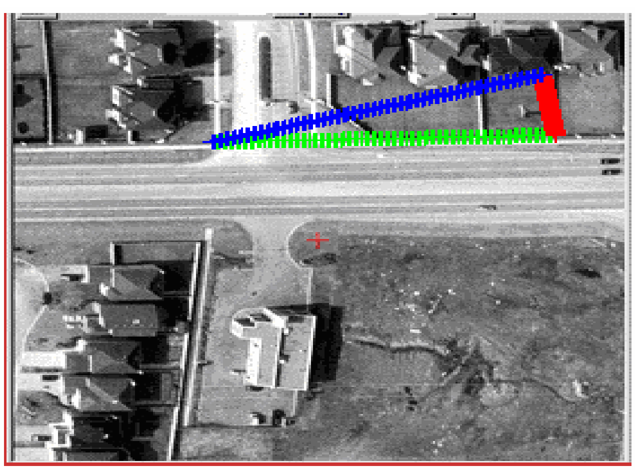
(b)



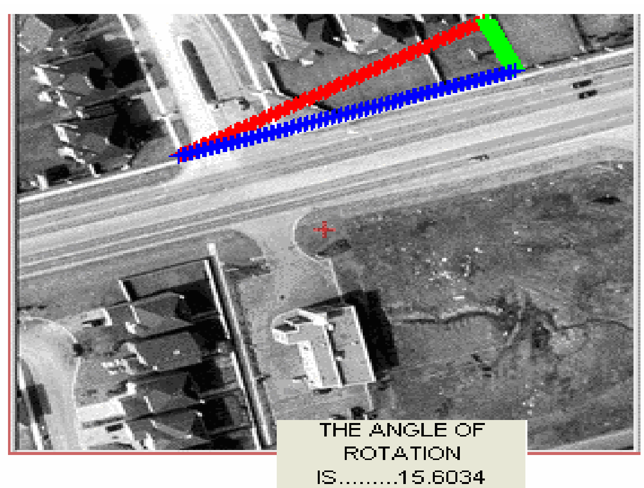
(c)



(d)

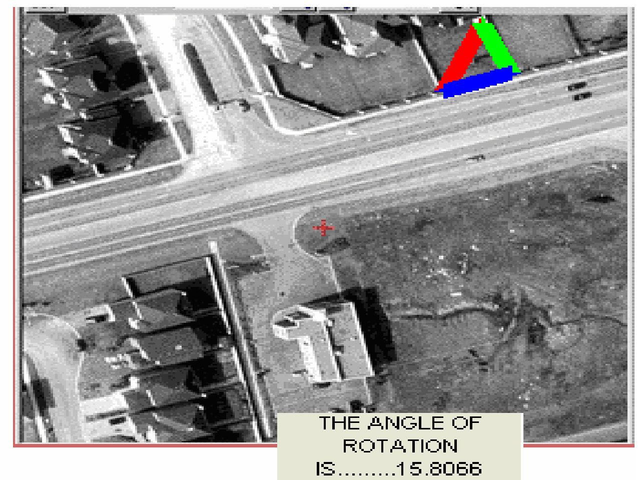


(e)



(f)

(g)



(h)

(i)

(j)

Figure (4): (a) & (b) are reference and distorted images respectively; (c)&(d) result of edge detection; ; (e)&(f) and (g)&(h) are sample of group of segments those are matching in reference and distorted images; (i) & (j) are registered images. Image (i) show reference image is aligned on distorted image and in image(j) over the previous result distorted image is aligned according to calculated angle.

VI. CONCLUSIONS

A new general registration algorithm for images of different nature is presented in this paper. In case of matching of only corners that is only single segment it fixes both position and orientation. Scale and skew could also be fixed if the segment extraction process preserved segment length and position, but this is not the case when dealing with images of different spectral bands. As gray-levels or textures cannot be used for the registration of images from separate spectral bands, a group of three segment based registration method is applicable for this. The registration process is automatic, without requiring either control points. Segment–Based registration schemes represented is a more robust approach than Point-Based methods. The effectiveness of the algorithm was verified by an experiment on real images to achieve rotation variation.

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