Feature - based Automated Aerial Image to Satellite Image Registration

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Abstract— **Image processing is required in number of fields like clinical diagnosis, remote sensing and computer vision. The need for overlaying of images exists in image processing. Image registration is the basis step in various applications of image processing. Registration involves digital preprocessing of the images. It is an important component of various systems including matching a target with a real-time image of a scene for target recognition, matching stereo images for autonomous navigation, aligning images for clinical diagnosis. This paper aims at providing an automated feature based image registration process for registering aerial image acquired through an unmanned aerial vehicle to a satellite image.**
Keywords- Image processing, Image Registration, Remote Sensing, Clinical diagnosis, Computer vision

I. Introduction

A fundamental task in image processing is image registration. It is very important in many applications of image processing, such as medical imagery, robotics, visual inspection, and remotely sensed data processing [1]. Image registration is defined as the process used to overlay two or more pictures/images taken at different times, by different sensors, from different viewpoints and/or under different lighting conditions [2].

It determines the most accurate match between two or more images. It transforms different sets of data into one coordinate system. Registration provides the “relative” orientation of two images with respect to each other, from which the absolute orientation into an absolute reference system can be derived [2]. Data may be multiple photographs, data from different sensors, from different times, or from different viewpoints. It estimates an optimal transformation between two images.

Computer vision and Pattern recognition, Medical image analysis and Remote sensing are the three major research areas where image registration techniques are applied. In these fields it is used for number of different tasks such as segmentation, object recognition, shape reconstruction, motion tracking, stereo mapping, character recognition, tumor detection and disease localization, target location and identification.

Image registration also finds application in manned and unmanned aircraft surveillance. Unmanned aerial vehicles are now-a-days more often used for surveillance applications as compared to the manned counterparts. In these applications, the UAV loiters over a target area and captures the image of the target and transmits online to the ground. The captured image is compared with the reference image, which is already acquired through the satellite.

Based on the image acquisition, image registration technique is categorized broadly into multimodal analysis, viewpoint registration, temporal registration and template registration [1] [2].

Viewpoint registration techniques can be used for mosaicing of images of the surveyed area in remote sensing field and for shape recovery in computer vision.

Temporal registration techniques aim at finding changes in the scene which appeared between the consecutive image acquisitions like monitoring of global land usage, landscape planning, automatic change detection for security monitoring, motion tracking , monitoring of the healing therapy, monitoring of the tumor evolution etc.

Multimodal analysis aims to integrate the information obtained from different source streams to gain more complex and detailed scene representation. It does fusion of information from sensors with different characteristics.

Template registration can be used to register aerial or satellite data into maps or other GIS layers, target template matching with real-time images, automatic quality inspection, comparison of the patient’s image with digital anatomical atlases, specimen classification.

Basically, image registration techniques can be categorized into two classes namely image intensity – based techniques and feature- based techniques. Intensity based techniques uses image intensity to estimate the transformation parameters which involves all the pixels of the image.

Feature based techniques extracts a set of features points from the images and estimate the transformation from them.

The feature based image registration techniques consist of the following steps

1. Image pre-processing
2. Feature points extraction
3. Finding correspondences between the feature points
4. Estimating transformation
5. Image re-sampling.
6. Image re-sampling.

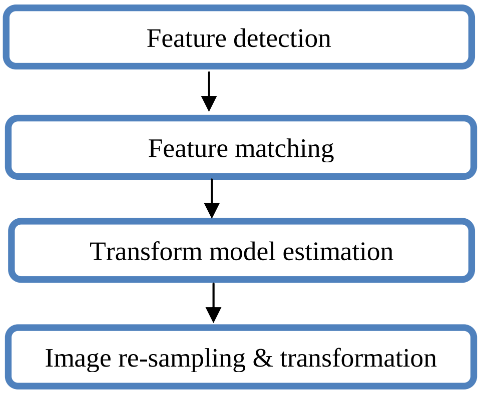


Figure 1. Schematic of image registration process

II. PROPOSED IMAGE REGISTRATION PROCESS

Feature-based techniques register images by locating image features such as points, lines, and contours and finding correspondences between them. Knowing the correspondences a transformation is then determined to map the target image to the reference image. Feature-based matching methods are typically applied when the local structural information is more significant than the information carried by the image intensities.

This paper provides an automated feature based image registration technique. This technique registers aerial image which may be distorted (rotated/scaled/translated) to a satellite image accurately.

This process follows four steps as of any feature based method. This process utilizes the feature point extractor that is based on scale interaction of Mexican-hat wavelets [3] [4]. A wavelet is a mathematical function useful in digital signal processing and image compression. In signal processing, wavelets make it possible to recover weak signals from noise. Images processed in this way can be "cleaned up" without blurring or muddling the details. Wavelet analysis provides similar type of analysis occurs in the human visual system. To be more precise, the human visual system performs hierarchical edge detection at multiple levels of resolution and wavelet transforms perform a similar analysis.

The multi-resolution wavelet decomposition transform is an intermediate representation between Fourier and spatial representations; it can provide good localization properties in both spatial and Fourier domains. The wavelet-based approaches preserve the spectral characteristics of the multi-spectral images better than the standard PCA and HIS methods.

The wavelet-based image registration can be performed in two ways:

(1) Selecting wavelet coefficients by selection rules such as the maximum absolute wavelet coefficient in the multi-spectral image and the high-resolution image for each band;

(2) Replacing partial wavelet coefficients of the high-resolution image with these of the multi-spectral low-resolution image.

This extracts two sets of feature points from the aerial and the satellite images respectively. Zernike moments invariants are used to find the correspondences between the extracted feature points. Zernike moments have information redundancy and low sensitivity to noise [5]. The magnitude of complex Zernike moments is rotational invariants [6]. Radon technique is used to estimate the transformation parameters.

A. *Feature Point Extraction*

A feature point extractor that is based on scale interaction of Mexican-hat wavelets can be used to extract feature points. This can be achieved in two steps. Getting the response of the image to a feature detection operation comprises the first step. Second step localizes the feature points by finding the local maxima [7].

The response in the first step can be obtained by finding the absolute differences of convolution of the image intensity with the Mexican-hat wavelet at different scales can be denoted as follows

$$\phi(x, s_{1,} s_2) = | R(x, s_1) - R(x, s_2) | \tag{1}$$

Convolving an image with Mexican-hat wavelet (MHW) results in a response, which more likely detects blob-like shapes, bright areas surrounded by dark pixels or vice versa. This can be represented as follows

$$R(x, s_m) = I(x) ** MHW(x, s_m) \tag{2}$$

Where the MHW is defined as

$$\mathrm{MHW}(x_1, x_2, s) = \frac{1}{\sigma}\left(2 - \frac{x_1^2 + x_2^2}{\sigma^2}\right)e^{-\frac{x_1^2 + x_2^2}{2\sigma^2}} \tag{3}$$

Where $\sigma = 2^{-S}$, S is a scale of the function, x_1 and x_2 are the vertical and horizontal coordinates respectively. When $\sigma = 1$, MHW(s) is the laplacian of $g(x_1, x_2) = e^{-0.5(x_1^2 + x_2^2)}$, a bi-dimensional Gaussian; it is isotropic. When scaled, its essential support is a disk with radius proportional to the scale. If $\sigma \neq 1$, we have the anisotropic Mexican hat, stretched out or shortened, and its support is an ellipse.

The figure 2 represents the four different stages of the feature extraction namely (a) Reference image (b) Response of applying Mexican hat Wavelet with scale 2, (c) Response of applying Mexican-hat wavelet with scale 4, (d) Absolute difference of the two responses.

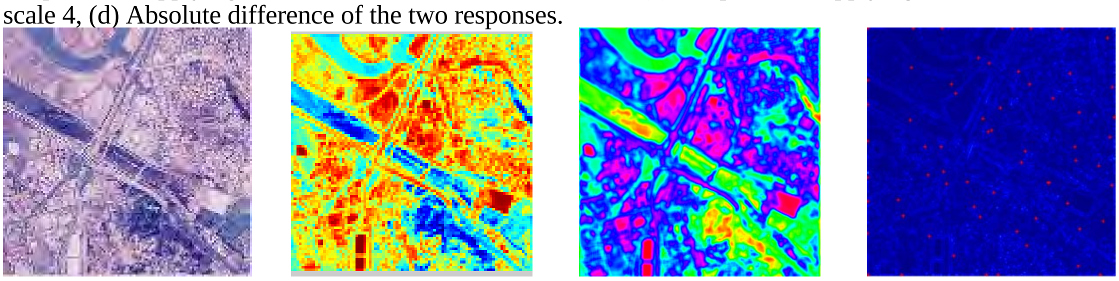


Figure 2. Feature extraction stages

The four merits of MHW are as follows, firstly, since the Mexican Hat wavelet scale interaction is formed by two scales, it allows different degrees of robustness (against distortion) by choosing proper scale parameters. At lower scale, MHW give high frequency detail like corner, thin edges in the image. At higher scale, it gives low frequency smooth or blurs effect in the image. In order to extract feature point from the image, we have to decide appropriate scale. The Mexican Hat Wavelet has perfect circular symmetry in frequency and spatial domains.

Second, since local variations such as cropping or warping generally affect only a few feature points in an image, the unaffected feature points can still be used as references during the detection process.

Third, this wavelet function is rotationally invariant. It means that most feature points may not change after image rotation. Fourth, since the Mexican Hat wavelet is essentially band limited, the noise sensitivity problem in feature extraction can be reduced.

The second step localizes the feature points of the image by finding the local maxima of the response. A point with maximum value in a disk shaped neighborhood of radius r_n, is the local maxima of the response.

The local maxima can be obtained by the following steps [8]:

(i) Find the maximal values that are greater than the specified threshold T_n in equally non-overlapped blocks of size NxN; such initial maximal values may include points on the boundaries of the blocks, which do not represent a local maximum of the response.

(ii)Take each maximal point as the centre of a disk-shaped neighborhood of radius rn and find one local maximum in each neighborhood; this will eliminate maximal points that are not local maxima of R (S1, S2) or local maxima that are too close to each other.

(iii) Repeat step (ii) until the obtained local maxima do not change locations.

(iv) In order to avoid the effects of the image borders on the feature extraction process, only the maxima found in the image area that is away from the image border by distance r_c are kept.

The following figure3 illustrates the feature extraction process.

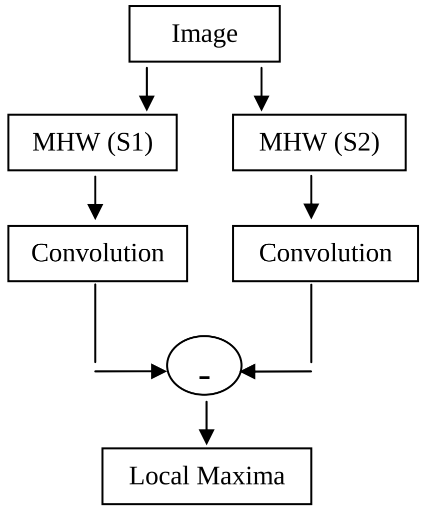


Figure 3. Feature extraction process

B. Finding Correspondences between the feature points

The correspondence between feature points in the two images can be obtained using the following steps:

1) For each point images, take a circular neighborhood of radius and construct a descriptor vector. When computing the Zernike moments of a circular neighborhood located around a feature point, the feature point is taken as the origin and the coordinates of each pixel inside the neighborhood are mapped to the range inside a unit circle.

2) Construct the distance matrix, where each entry represents the difference between the two descriptor vectors of the feature points in the first and the second images, respectively. In the distance matrix find the minimum distance coefficients along rows and along columns. A correspondence between two points is established if, and only if, the minimum distance coefficient in a row is also the minimum distance coefficient in the associated column.

C. Estimation of transformation parameters

After detecting, similar feature points from both images, a neighborhood around each feature point is chosen. Then descriptors around these feature points will be extracted on both the images. Using the ransac algorithm the descriptors around the feature points on the aerial image will be compared with the reference satellite image. This will give the average transformation.

The obtained transformation parameters are then used to transform the distorted acquired image to its appropriate size, orientation and position with respect to the reference image.

III. EXPERIMENTAL RESULTS

Two examples using images of different characteristic are presented to illustrate the performance of the algorithm: In Example 1, aerial images of a city are being used. The first image has an overlap with the second image of 80% of its area.

In Example 2, images taken in different view point(left side and right side view) of a terrain are being used and the first image has an overlap with the second image of 70% its area. The parameters of the geometric transformation are obtained using the proposed algorithm.

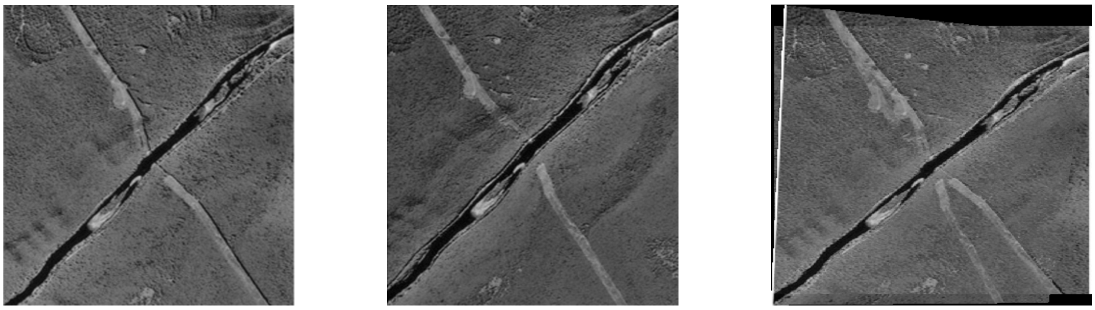
Results of registering the images for example1 are shown in Fig. 4. In fig 5, the registration of images of example 2 is shown along with the images of overlaying the transformed images on the corresponding reference images. This illustrates that algorithm accurately registers images with partial overlap in the presence of some additional image distortions.

IV. CONCLUSIONS

An algorithm for aerial image to satellite image registration has been proposed. The algorithm is based on three main steps: extraction of some feature points in both images, obtaining the correspondence between the feature points of the first and the second images, and estimating the transformation parameters. The feature point extraction process is based on scale-interaction of *Mexican-hat* wavelets and the correspondence between feature points is obtained using Zernike moments invariants. The proposed algorithm was evaluated using aerial images with only partial overlap.

(a) (b) (c)

Figure 4. Example 1 of registering aerial images: (a) First image, (b) Second image, (c) The transformed distorted image is overlaid on the corresponding reference image



(a) (b) (c)

Figure 5. Example 2 of registering images : (a) First image, (b) Second image, (c) The transformed distorted image is overlaid on the corresponding reference image

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