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Image Registration Concept and Techniques: A Review

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ABSTRACT

In the past few years the global need for low computation, less time consuming, and good quality image mapping methods has caused an image registration technique alive in multiple application areas. Image registration is the method of superimposition the pixels or control points from one image over another image namely the target image and reference image respectively. The concentration is on various methods of mapping parameters. Input images are reference image and the sensed image. Basically image registration is of two types Area based and Feature based. Area based works on the intensity of image and feature based is based on feature points or objects of image. Also the simple and efficient registration techniques are very essential in many application areas. This paper presents a review on image registration techniques as well as the hybrid registration approach. Many authors have also reported the modified registration techniques, each technique is reviewed according to its merits and drawbacks.

Keywords – Feature detection, feature matching algorithms, image registration, keypoints, mapping function, transformation and resampling.

I. INTRODUCTION

Image registration [1] is a method to accomplish mapping between two different images of same scene taken at different times on regular time interval, from different viewpoints of same scene, and/or by different sensors to integrate the information. It's a method to superimpose the pixels from reference image to the target image by aligning the images into common coordinate system. The possible application areas of registration such as in remote sensing (image mosaicking, landscape planning, fusion of information, registration of aerial and satellite data into maps), in medical (monitoring of tumor evaluation, magnetic resonance image MRI, ultrasound, magnetic resonance spectroscopy, specimen classification, positron emission tomography PET, single photon emission computed tomography SPECT), and in computer vision (shape recovery, automatic change detection, motion tracking, automatic quality inspection, target template matching). Aligning the images using different methods like Geometrical transformation, Point based method, surface based method and Intensity based method. It has been widely used in change detection, image fusion, clinical diagnosis and other related areas. Misalignment between the two images may be due to viewpoints, sensor position, viewing characteristics or from the object movement and deformation [2]. A great deal of work has been done on this important topic. More and more attention has been paid on main approaches and point out interesting parts of the registration methods.
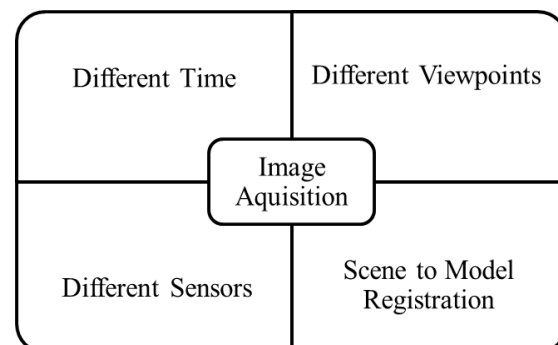

Fig. 1 Image aquisition resorces

Registration methods have been utilized in a variety of application domains [1]. In general its application domain can be divided into four main groups according to the image acquisition as shown in "Fig. 1". Images are taken at different times (multi-temporal analysis), image capturing at different viewpoints (multi-view analysis), images of same scene are acquired by different sensors (multi-modal analysis) and the registered model for image.

- **Different viewpoints-** Same scene are acquired for multiview registration from different viewpoints. The aim is to gain a complete and multi-dimensional scanned scene. Example of applications: image mosaicing and shape recovery.
- **Different times-** Same scene are captured at different times, on regular time interval, with possibly under different imaging conditions. The main application is to find and evaluate changes

in the scene. Example of applications: landscape planning, change detection etc.

- **Different sensors-** Same scene are acquired from different sensors. The main aim is to integrate the information obtained from different source streams and to compare them with desired applications. Example of applications: fusion of images.
- **Scene to model registration-** Scene and a model of the scene are registered. The aim is to localize the acquired image for a proposed method. Example of applications: comparision, classification etc.

The existing image registration techniques falls into two main categories: area based and feature based approaches [2]. Area based approach works on a image pixel values, existing algorithms like (Correlation Methods, Fast Fourier Transform) while feature based approach works with low level features of an image, algorithms are (Contour, Wavelet, Harris, SIFT etc).

II. REGISTRATION PROCESS

Image registration is a process of mapping one image onto another image or similar object by using a perfect transformation. Registration aims to fuse the data from two or more images. When two images are taken one of them is referred as a reference image called original image which is kept untouched and other is called as a sensed image or template image and is employed to register the reference image. To realize image registration procedure [1] the following steps has to be implemented as shown in "Fig. 2".
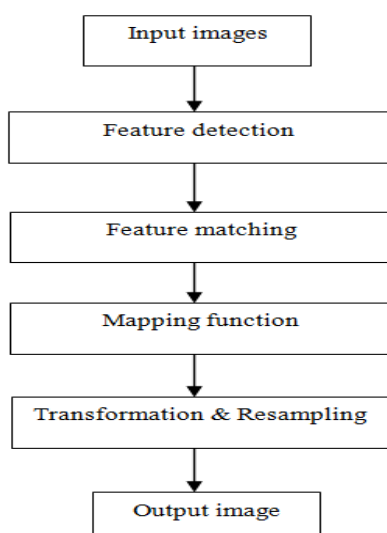

Fig. 2 Steps of image registration

1. Feature detection

In this step the extraction of salient features/structures and distinctive objects from both reference and sensed images (like significant regions, edges, corners, points, or lines etc) are carried out. These features are represented by control points (CPs) which are centre of gravity, line endings, distinctive points, object contours, coastal lines, roads, line intersections, and road crossings which are invariant with respect to rotation, scaling, translation, and skewing.

2. Feature matching

In this section the major focus is on the feature detected in reference and sensed images. This approach is mainly divided onto two methods area based and feature based. Area based approach deals with the matching approach as on the predefined size or even entire image rather than on the salient features. While in case of the feature based approach the control points are estimated for a perfect match between a reference and sensed image. The whole focus is on the spatial relations or various descriptors of features.

3. Mapping function

After the feature detection and feature matching approach the corresponding mapping function is designed. The reference and sensed images are matched together using the mapping function design with the corresponding control points. The control points mapping must be as possible as much to make a significant influence in the resulting registration.

4. Transformation & Resampling

The sensed image is transformed and reconstructed with the mapping function the images are registered. The transformation can be realized in a forward or backward manner. Forward manner in which using mapping function the pixels from the sensed image is directly transformed. While in case of backward approach the pixels from the target image is determined and the inverse mapping function is established.

III. LITERATURE REVIEW

Image registration is an important and useful area of study in computer vision. In this section a brief about all the research papers reviewed and studied is documented. Also a brief about the work done in the same include here.

Zitova and Flusser [1], describes the various approaches of image registration is described like area based and feature based method and are retained and further classified into subcategories according to the basic ideas of matching methods. Also the four basic steps of image registration procedure: feature detection, feature matching, mapping function design, and image transform & resampling are

mentioned. Major goals and outlook for future research as well as the advantages and drawbacks regardless of particular application area are discussed too.

Ezzeldeen et al [2], design a comparative study between a Fast Fourier Transform (FFT)-based technique, a Contour-based technique, a Wavelet-based technique, a Harris-Pulse Coupled Neural Network (PCNN)-based technique and Harris-Moment-based technique for remote sensing images to calculate the RMSE ranges, Timing results, and the average number of control points.

It is concluded that that the more suitable technique is the FFT but having largest RMSE is above 2, where least running time technique is Contour (2.103sec for 256*256 and 2.214sec for 512*512 image size) and the technique having the largest Control points is Wavelet 30.

Maes et al [3], proposed mutual information is a time consuming, but with the property of high precision image registration method. So to improve the computation efficiency images are registered with low resolution, and calculating entropy of reference and recent images, and the joint entropy of both. Now the pixels are mapped using the affine transform between the approximation coefficients. The coefficients parameterized with the six degrees of freedom of transformation.

So an adaptive search for optimum transformation parameters was performed in order to maximize the mutual information. Method is a user independent and no need of any data makes a method completely independent and highly robust. The approach with robustness evaluation and maximizing the mutual information are applied on rigid bodies of CT, MR, and PET images.

Li et al [4], proposed an efficient multiscale deformable registration framework, by combining the Edge preserving scale space (EPSS) with Free form deformation (FFD) for medical image registration. The proposed method shows the accuracy and robustness when compared to traditional methods for medical image processing by using the criteria of multiscale decomposition for medical images. The implemented framework also increases the efficiency of registration process, and improves the application for image guided radiation therapy with current medical system.

Huang et al [5], evaluates a hybrid method. In contrast with purely feature based or intensity based methods integrating the merits of both the approaches. By means of a small number of automatically extracted scale invariant salient region

features, whose interior intensities can be matched using robust similarity measures. The goal is to identify as many good feature correspondences as possible, and fully utilize these correspondences to predict an appropriate transformation model for registration.

The existing algorithms to feature matching consist of two steps: region component matching (RCPM) and region configural matching (RCFM), respectively. Procedure carried out by first finding the correspondence between individual region features now the joint correspondence detection between multiple pairs of salient region features using a generalized expectation-maximization framework and finally the joint correspondence is then used to recover the optimal transformation parameters.

Huang and Li [6], introduces a feature based image registration using shape content for object recognition and in hand written digits. Use of thin-plate spline interpolation is the mapping function in this technique. Method implementation is first by shape content and calculating the control points in both reference image and target image. To eliminate speckle noise Lee filter is designed, control points are extracted using the Harris operator and the edge features or corners are extracted from both the images by canny operator.

Based on the shape content the control points are matched within a described N×N pixel area. Invalid control points are removed and the affine transformation is the mapping parameter based on both the images. And finally the Thin-plate spline is used to wrap the images. The proposed method is for the optical-SAR images and multi-band SAR images.

Mekky et al [7], introduces the concept of wavelet based image registration techniques. Four different image registration techniques are compared namely cross-correlation based registration, mutual information (MI) based hierarchical registration, scale invariant feature transform (SIFT), and hybrid registration approach using MI and SIFT.

The proposed method is the wavelet-based decomposition of the reference and the new image, now intensity based registration with MI and with transformation model rough results are implemented using the SIFT algorithm and the outliers are removed using the RANSAC algorithm. Results obtained by the hybrid approach have same impact as the MI and SIFT independently.

Sarvaiya and Patnaik [8], proposed a combined approach using Mexican hat, Wavelet, and Radon transform are the feature based approach of image

registration. Features points are extracted using the Mexican hat and Wavelet transform with invariant moments and corresponding control points are registered using the Radon transform.

Feature points extraction using the Mexican hat is the process of calculating the local maxima and convolving the image with Mexican hat wavelet. Laplacian of Gaussian with Gabor wavelet makes a better impact while feature extraction. Around the feature points a circular template is considered to determine invariant moments. Radon transform impact is on the scaling, and rotation while matching the feature points. Result of proposed method shows a better performance with high degree of rotation and scaling up to 1.8.

Lowe [9], designs SIFT algorithm, stands for scale invariant feature transform algorithm was first proposed by D. G. Lowe in 1999. SIFT is a feature detection algorithm used to identify the similar objects in two different images. SIFT algorithm identifies different objects using corner detection approach invariant to scale. The main advantage of this approach is to identify a large number of features in an image for reliable identification. The procedure of this algorithm is to first find the best suitable features from a single or a set of reference images and storing them into a self designed suitable database. The features from the predesigned database are individually matched to a new image or target image and finding the matching features based on Euclidean distance of their feature vectors. Set of image features are generated using the major stages of computation are Scale-space extrema detection to identify the interest points in an image which are invariant to scale and orientation, Keypoint localization to proper identification of keypoints in reference image selected based on measures of their stability, Orientation assignment based on local image gradient direction and orientation, thereby providing invariance to these transformations, and Keypoint descriptor which are the image features that are transformed into a representation that allows for significant level of shape distortion and change in illumination.

Liu et al [10], proposed SIFT feature in Steerable-Domain for remote sensing images using multiscale registration. Steerable-domain deals with the large variation to scale, rotation, and illumination between images. Reference and sensed images with First in Last Stage gradual optimization are adopted to achieve the registration results. Because of the external image feature measurement in transformed image, the dominant gradient orientation around the point is computed.

The steerable pyramid transform decomposes the image for computer vision applications. Author compares the performance of propose robust S-RSIFT algorithm with the SIFT and SIFT+SVD approach, and gets a good result with large scale of variations, rotation, and intensity changes.

Chen et al [11], introduces a new method, which is based on linear search with SIFT and nearest neighbour algorithms. This method is proposed for accelerating the registration of partially overlapping images. Using low resolution correspondence of candidate images by a SIFT-based method overlapping areas of images is rapidly estimated. The purposed approach reduces the computational cost to 10%-30% but with little compromise in accuracy.

Hongbo et al [12], proposed a rapid automatic image registration method based on Improved SIFT for narrow-baseline images. This approach achieves the great improvement in the speed and accuracy of image registration. By accelerating the matching speed and reducing the number of candidate keypoints by lessing the complexity of the feature descriptor. Time consuming during the process of extracting keypoints and finds correspondence is shorten by 1.451sec.

Author uses the SIFT algorithm to extract the features called candidate keypoints from both the images as well as the amount of inliers. Computing the corner response of each keypoint by harris approach and filtering them by corner responses. Matching keypoints by Best-bin-first search method and checking the consistency and removing the outliers by RANSAC. Least-square approach is for transformation matrix calculation, and finally overlapping the target image over the reference image.

ViniVidadharan and SubuSurendran [13], presented a automatic image registration technique using Scale invariant feature transform (SIFT) and Normalized cross-correlation (NCC) method to determine the feature points of overlapping area in both reference and target images. Author describes the combination of Best bin first search using k-d tree for feature matching and also the images containing the large numbers of speckles, noise, and some distortion are eliminated using RANSAC.

The approach works successfully with different set of images when tested against various scale, rotation, and illumination.

Moorthi et al [14], design a framework for remote sensing images from different sensors using the corner detection algorithm. Algorithm used by author

is Harris corner detection and Random sample consensus (RANSAC) to remove the outliers. Steps involving to design a proposed work is the feature point extraction in both the images, control points plays a vital role in feature matching step using the spatial transformation using least square estimation and finally the image is resampled. Unwanted control points or the outliers are removed using the RANSAC algorithm.

The results shows the accuracy in image registration using four different images from Indian remote sensing satellite (IRS) with 599, 608, 587, and 469 control points and RMSE (in pixels) 0.57, 0.62, 0.48, 0.54 respectively.

Mahesh and Subramanyam [15], proposed a new corner detection algorithm using Steerable filters and Harris algorithm for vast application in image processing and computer vision. He compares the performance of proposed method with the SUSAN and Harris corner detection algorithms. Steerable filters are used as a basic filter bank while transformation is translation, shiftable, or rotation. Steps involves in proposed method with first decomposing the image using steerable filters, detecting the corners, combining all the detectable corners with dilation to make the one and finally finding the centroid of these corners.

Better results are obtained even after rotation, scaling, and translation of an image from the proposed approach with true corners and minimum number of false or missed corners.

Nichat and Shandilya [16], proposed a scheme for area matching by using different transform based methods. This paper implements image registration technique based on different transforms. The procedure is carried out with comparing the reference image with the target image by finding out an object or area from unregistered image using the area based approach of image registration. HAAR and WALSH transform used for comparision between results obtained by these two transforms and the root mean square error (RMSE) is used as similarity measures.
Above approach is simple, fast and easy with advantage of Walsh transform reduces the computational time by a considerable amount so, it greatly reduce the complexity of computation.

Pandey et al [17], implements the Speeded up robust feature detector (SURF) algorithm and increases the matching points of images for automatic image registration. Because of its fast feature detection and with less time consuming property SURF algorithm is mostly used. Increasing the matching points gives rise to a proper image registration. For feature extraction SURF is used which is based on

approximated Hessian matrix. Nearest neighbour algorithm is for keypoint matching with minimum Euclidean distance for invariant descriptor vector. For outliers elimination RANSAC is used and affine transformation is used as transformation model.

As in panoramic images increase in matching points may improves the quality of image and by using the SURF algorithm for feature extraction leads to quick image registration.

Korman et al [18], proposed a Fast affine template matching algorithm is a approximate template matching under 2D affine transform that minimize the Sum-of-Absolute-Differences (SAD) error measure. SAD errors are randomly examined and with consideration to pixels and the further transformation parameters are solved out with Branch-and-Bound algorithm.

Experiments performed by author within same image, different images of same type, and different image of same scene. Performance evaluation with SIFT during the affine template matching, with varying condition of scene types, and matching in a real world scenes. Result shows that FAST algorithm best deals with the photometric changes as well as the blur and JPEG images.

IV. CONCLUSION

Image registration is a method to accomplish mapping between the reference image and sensed image. The four basic continuous steps of image registration provide a great impact on multiple applications. Image registration algorithms offer an enormous variety of approaches for image mapping to achieve the resulting image. Multiple applications like in image fusion of multiple images, change detection for a particular area, super-resolution imaging for good results, and in building image information systems, among others. From the above studied literature and the recent developments in image registration techniques we are able to find the best performance under all uncontrolled circumstances. The choice of these techniques are based on the specific content, object characteristics, and viewing conditions. The techniques reviewed can be applied a wide class of problems involving features may be corners, edges etc and are represented by the control points.

Most of the strategies have been analyzed with their corresponding results. Mutual information based registration is data independent and fully automatic. Registration using the Mexican hat and radon transform match images with great degree of rotation and scale. Harris corner detection approach is a feature matching approach better to find the intersecting points and rotationally invariant. SIFT is invariant to the affine, scale, rotation and generate

large number of features as well as most effective in noise. SURF algorithm improves the quality of image by increasing the matching points. The FAST algorithm is both rotation and scale invariant with improved execution time. From the above study we conclude that SIFT algorithm is much suitable for feature detection with little compromise in running time. This review helps in making the technique of image registration better, compact, efficient as well as to reduce the errors produced in the process of image registration.

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