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Image Registration: A Simplified Review

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ABSTRACT: **From the past few years, Image registration has become an emerging and hot topic for researchers. Due to 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, in which the pixels or control points of one image are superimposed on the other image. The image which is superimposed is called reference image and the image upon which superimposition process is done is called target image. The input images are reference images and sensed images. By processing these images through image registration algorithms, the target images are created. During this process, the concentration is on various methods of mapping parameters. 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. Image registration has wide scope in medical field and research. This paper presents a review on basic image registration and its techniques.**

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

I. INTRODUCTION

Image registration [1] is a technique to map two different images of same scenes taken at different intervals of times. The taken images should be from different viewpoints of same scene. The sensors used to integrate the image information from different viewpoints should be same or different. It is a technique in which the pixels from reference image are superimposed on the target image by aligning both the images into the common coordinate system. Image registration technique can be used in remote sensing (image mosaicing, landscape planning, fusion of information, registration of aerial and satellite data into maps), 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). Images are aligned via different methods i.e. Geometrical transformation, Point based method, surface based method and Intensity based method. Image registration is widely used in clinical diagnosis, image fusion, change detection and some other related areas. Misalignment is caused between the two images may be due to viewpoints, sensor position, viewing characteristics or from the object movement and deformation [2]. Researchers have done a great deal of work in this field. More attention is paid while analyzing clinical images like mammography, x-rays etc. to diagnose some disease.

Image registration methods are utilized in a variety of application domains [1]. Generally, application domain can be divided into four main groups on the basis of image integration resources as shown in figure 1.

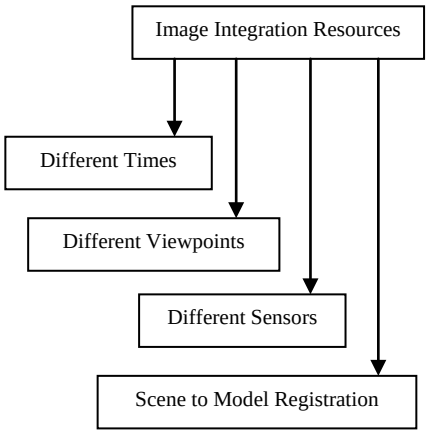

Figure1: Image integration resources

Different viewpoints: It is also called multi-temporal analysis. In this type, same images are acquired from different viewpoints for the registration process. The aim is to obtain a complete and multi-dimensional scanned scene. Application examples of different viewpoint are image mosaicing and shape recovery.

Different times: It is also called multi-view analysis. In this type, same images are captured at intervals of time i.e. at uniform time intervals, possibly with different imaging conditions. The main purpose of this registration procedure is to discover any changes in the original image. Application examples of different times are landscape planning and change detection etc.

Different sensors: It is also called multi-modal analysis. In this type, same images are taken from different sensor outputs. The main aim is to acquire the data from various sources and to compare them with desired applications. Application example of different sensors is fusion of images.

Scene to model registration: In this type, image and a model of the image with scene are registered. The aim is to localize the acquired image for a proposed method.

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Application example of scene to model registration are comparision, classification etc.

The present image registration techniques are classified into two groups: area based and feature based approaches [2]. Area based approach works on 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. IMAGE REGISTRATION PROCESS

Mapping pixels of one image onto the other is called mage registration process. Registration aims to fuse the data from two or more images. While considering image registration process, two images are taken. One is called reference image i.e. the original image which is kept untouched. The other is called sensed image and is used to register the reference image. Image registration procedure is realized [1] by implementing following steps:

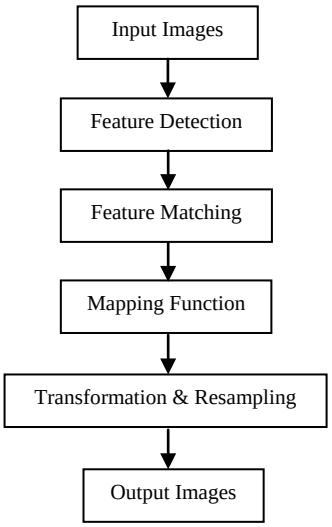

Figure 2: Steps involved image registration process

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. Feature detection mainly depends on the understanding of two approaches: Area based methods and feature based methods. Area based methods just matches the area of the reference image with the sensed image. It does not emphasis on the detection of any feature. On the other hand, feature based method relies on the detection of features like boundaries, curves etc. of sensed image. It compares the detected features of sensed image with reference image.

Feature matching

From the input reference and output sensed image, features are detected via image intensity values i.e. closest values in feature spatial; distribution or feature symbolic distribution. This approach is mainly divided into two methods: area based and feature based. Area based approach (also caked correlation-like method or template matching) deals with the matching approach as on the predefined size or even entire image rather than detecting 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.

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.

Transformation & Resampling

The sensed image is transformed and reconstructed with the help of mapping function constructed during the previous steps. The image is transformed as well as registered. The transformation can be realized both in forward or backward manner. In forward method, each pixel of the sensed image is transformed directly using mapping functions. This approach is complicated to implement because it sometimes overlaps the output image. In backward method, the pixels of sensed image are transformed using the co-ordinates of the target image. This is less complicate and accurate. Hence backward method is preferred over forward method.

III. RELATED WORKS

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 like area based and feature based method and are 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.

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Conclusion and Future Scope

In this review paper we studied about image registration, steps involved to carry out image registration procedure and the literature of image registration. 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.

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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