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A Survey : Methods of Feature Based Image Registration

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***Abstract* — Image registration is the fundamental task used to match two or more partially overlapping images and stitch these images into one panoramic image comprising the whole scene. To register two or more different images, image registration estimates the parameters of the geometrical transformation model that maps the sensed images back to its reference image. The purpose of this paper is to provide a comprehensive review of the existing literature available on Feature based Image registration methods. The reviewed approach is based on the methods used in different applications of Image Registration. This paper also covers the advantages and disadvantages of the methods mentioned in the paper.**

***Keywords* — Feature detection, Feature matching, Image registration, Mapping function, Resampling.**

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 is the process of geometrical alignment of two images—the reference and sensed images [1], [3], [6], [9]. In general, all large systems which evaluate images require the registration of images as an intermediate step. Image registration, sometimes called image alignment, is an important step for a great variety of applications such as remote sensing, medical imaging and multi-sensor fusion based target recognition. It is a prerequisite step prior to image fusion or image mosaic. It is a fundamental image processing technique and is very useful in integrating information from different sensors, finding changes in images taken at different times, inferring three-dimensional information from stereo images, and recognizing model-based objects [3].

Image registration can be performed either manually or automatically. In manual mode, human operators manually select the corresponding features in the images to be registered. In order to get reasonably good registration results, an operator has to choose a considerably large number of feature pairs across the whole images, which is not only tedious and wearing but also subject to inconsistency and limited accuracy [6]. Thus, there is a natural need to develop automated techniques that require little or no operator supervision.

Automatic image registration falls into two types: area- and feature-based techniques [2], [12]. In area-based methods, a small window in the sensed image is statistically compared with a window of the same size in the reference image [12]. Area-based methods are relatively accurate and are preferably applied when distinctive information is provided by grey values rather than by local shapes and structures [1], [2], [12]. Feature-based methods are typically applied when the local structural information is more significant than the image intensity information. They allow the registration of images of a completely different nature and can handle image distortions to some extent [2], [11].

Also the image registration techniques can be classified into two broad categories, i.e., global and local techniques [12]. Global techniques make the most of image information in both reference and sensed images to estimate the geometric transformation between the two. The global techniques have many advantages. First, they usually employ image data or data that have been simply processed and transformed to define the similarity measure and to avoid complicated feature extraction. Second, many similarity measures defined in the literature can be suitable for registering multisensor images. Third, they have comparatively high registration accuracy. However, their main disadvantage is their high computational complexity. Recently, some researchers have proposed methods using multiresolution [6] and subsampling techniques to alleviate the problem.

Local techniques compute the global mapping functions using few control points, which comprise three steps. First, many control points (CPs) are selected or extracted from the reference and sensed images. Second, the type and the parameters of the transform model that aligns the sensed image with the reference image are estimated using the CPs. Third, the sensed image is transformed and resampled by means of the transform model. It has wide application in remote sensing Image Registration [12], [14].

Over the years, a broad range of techniques has been developed for various types of data and problems. These techniques have been independently studied for several different applications, resulting in a large body of research. This paper is useful for understanding the merits and relationships between the wide variety of existing techniques and for assisting in the selection of the most suitable technique for a specific problem.

A frequent problem arises when images taken, at different times, by different sensors or from different viewpoints need to be compared. The images need to be aligned with one another so that differences can be detected. A similar problem occurs when searching for a prototype or template in another image.

To find the optimal match for the template in the image,

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the proper alignment between the image and template must be found. All of these problems, and many related variations, are solved by methods that perform image registration. A transformation must be found so that the points in one image can be related to their corresponding points in the other. The determination of the optimal transformation for registration depends on the types of variations between the images. The objective of this paper is to provide a comprehensive survey of classical and existing image registration algorithms.

II. Image Registration Methodology

Image registration is widely used in remote sensing, medical imaging, computer vision, video processing, and many others [3], [6]. In general, its applications can be divided into three main groups according to the manner of the image acquisition [1]:

Different viewpoints (Multi-view analysis): Images of the same scene are taken from different viewpoints. The aim is to get complex view, a 2D view or a 3D view representation of the scanned scene, to acquire more information [1]. Examples of applications are image mosaicing of the surveyed area in remote sensing, shape recovery and structure from motion in computer vision, and sprite generation and coding in video compression.

Different times (multi-temporal analysis): Images of the same scene are taken at different times, often on regular basis, and possibly under different conditions. The aim is to find and evaluate changes in the scene which appeared between the consecutive image acquisitions. Examples of applications are landscape planning in remote sensing, automatic change detection in video surveillance, motion tracking in computer vision, monitoring of healing therapy and tumor evolution in medical imaging, and motion estimation and super resolution reconstruction in video processing.

Different sensors (multi-modal analysis): Images of the same scene are taken by different sensors. The aim is to integrate the information obtained from different source streams to gain more complex and detailed scene representation. Examples of applications are multisensor image fusion in remote sensing and medical imaging, monitoring activities in multisensor surveillance, and image fusion in vehicular navigation.

Scene to model registration: Images of a scene and a model of the scene are registered. The model can be a computer representation of the scene, for instance maps or digital elevation models (DEM) in GIS, another scene with similar content (another patient), 'average' specimen, etc. The aim is to localize the acquired image in the scene/model and/or to compare them.

Due to differences in acquisition of images to be registered and various types of degradations it is impossible to design a universal method applicable to all registration tasks. Every method should take into account not only the assumed type of geometric deformation between the images but also radiometric deformations and noise corruption, required registration accuracy and application-dependent data characteristics.

Nevertheless, the majority of the registration methods consist of the following four steps [1], [6]:

1. *Feature detection*:

This involves finding salient features in the two images to be registered. An interest point detector is first employed to detect characteristic points in the image. These may include corner points, edges etc. Ideally, we want these points to be invariant to geometric and photometric transformations. A survey of the literature shows many approaches including the Wavelet based Feature Transform [6] and Scale Invariant Feature Transforms (SIFT) [2].

2. *Feature matching:*

Once features have been detected in the two images, the next step is to match them or establish correspondence. The common approach to feature matching is to build local descriptors around the feature point and then matching the descriptors. This is an important step because the percentage of correct matches identified here determines the how well the transformation can be estimated in the next step. The most commonly used methods are cross-correlation matching and least-squares matching, Euclidean distance matching, Fourier transform, Relaxation-based image matching techniques [6], invariant moments and nearest neighbor based matching.

3. *Transform model estimation*:

Once feature correspondence has been established, the next step is to solve for the parameters of some global transformation. Usually this involves finding the translation, rotation and scale parameters to transform one image to another.

4. *Image re-sampling and transformation*:

The final step of any registration algorithm involves the actual mapping of the one image to the other using the transform model estimated in step 3.

III. Methods of Image Registration

A. Weights Proximity Matrix for IR based on R- SIFT [2]

When large intensity and geometric changes in scene occur then to improve the performance of image registration weights proximity matrix based on R-SIFT is employed.

A robust SIFT descriptor algorithm is developed based on SIFT (Scale Invariant Feature Transform) descriptor to extract and describe image features, which is invariant to affine transformation [9]. Further, the adaptive weights proximity matrix is built based on the R-SIFT descriptor and the geometric information of feature points. Finally, the corresponding feature point pairs are determined by the SVD (Singular Value Decomposition) of the adaptive weights proximity matrix, and then transformation parameters between the two images can be computed.

This method returns better performance as compared to the SVD method; SIFT method and S-SVD method. Meanwhile, good performance on the change detection of barrier lake is obtained using this method.

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B. Image Registration using Evolutionary algorithms [3], [4]

Image Registration has been applied to a variety of real world problems ranging from remote sensing to medical imaging, artificial vision, and computer-aided design. It is a robust approach to the problem. The main advantage of this method is not requiring a good initial estimation of the image alignment [3]. To get optimal transformation *f* an iterative process is often followed (see Fig. 1) [3]. It usually finishes when convergence is achieved, i.e., when the similarity metric is bellow a given tolerance threshold. In EIR, we focused our attention on the optimizer component (Genetic Algorithm) [4] which is of crucial importance in the success of any IR method.

Two search approaches for optimization have been suggested, which are: Matching Based approach and Parameter based IR [3], [4]. One of the most known feature-based algorithms for IR is the iterative closest point (ICP), proposed by Besl and McKay based on the former approach (matching space search) [4].

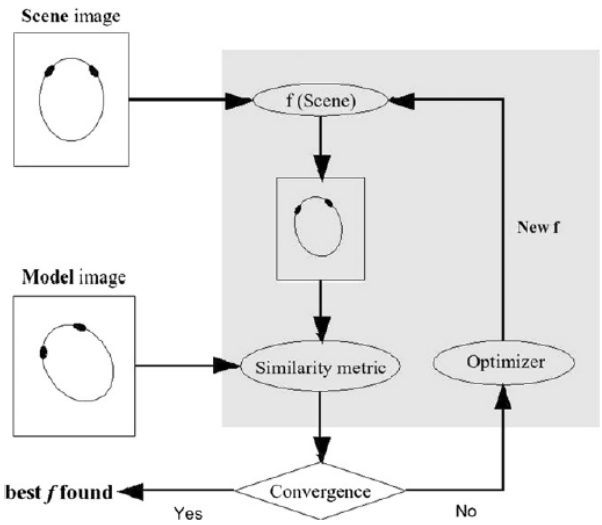

Figure 1 The IR Optimization Process [3]

C. Wavelet based Image Registration [6], [8]

It is an important image processing procedure in remote sensing. To get high-resolution remote sensing images is the big challenge for the researchers. A number of problems exist in the registration of high-resolution images: geometric distortions, location of control points, a large number of control points are required for a precise registration, which is a tedious and time-consuming process; and processing speed. Thus, to overcome the said problems a new image registration technique, which is based on the combination of feature-based matching (FBM) and area-based matching (ABM) is proposed [6]. A wavelet-based feature extraction technique and a normalized cross-correlation matching and relaxation-based image matching techniques are employed in this new method [6].

An innovative image registration algorithm that combines the ABM with FBM techniques can be divided into three major steps: (1) finding the feature points, (2) refining the control points and obtaining accurate control point pairs, and (3) building a mapping function according to the accurate control point pairs and then resampling the sensed image.

Following are the advantages of the high-resolution image registration technique discussed in [6] over the traditional Image registration methods: (1) manually selecting a large number of control point pairs, (2) high volume data, and (3) local distortion existing in different sensors and different temporal images. However, the limitation of the proposed algorithm in [6] is the relief displacement of individual above ground objects, such as buildings and trees, cannot be solved. To solve this problem, a true ortho rectification technique is suggested.

As discussed earlier several approaches have been developed for feature point extraction but the points extracted by these methods differ in locations and structure. A method based on Scale Interaction of Maxican Hat Wavelet (MHW) is suggested in [8] as a feature point extractor that is robust to the most common geometric transformations and any possible degradation. The main advantage of the MHW against the traditional methods are registration accuracy and robustness against several image deformations and image processing operations. This method is based on finding the local maxima of the response of a feature detection operation, which involves convolving the image with the Mexican-hat wavelets [8].

D. Image Registration by combining Feature based matching and GLS based motion estimation [9]:

In the literature survey it is found that there are two main research directions in Image Registration: feature-based and optimization-based [9].

The accuracy of feature based image registration is depends on how the detection and extraction of the features from the images are performed. On the other hand, optimization methods, which use directly the grey level of all pixels, are based on estimating a vector of parameters that minimize (or maximize) an objective function. It is suffer from initialization problems due to its iterative nature: the initial parameters must not be very far from the solution in order to avoid falling in local minima. A well-know technique to cope with this initialization problem is the use of a hierarchical (coarse-to-fine) technique. Still with the use of hierarchical techniques, optimization methods are not able to cope with very large motion. The main advantage of the optimization methods is their estimation accuracy.

To overcome the problems of large deformation, feature detection and feature extraction, a combination of feature based and optimization based image registration technique is suggested in [9], [2]. Raul Montoliu, Filiberto Pla et al., 2005 [9] suggested that, First a feature-based method is used to obtain a good initial motion parameters that are not very far from the true solution. Using this initialization, in the second step, an optimization-based algorithm is applied, which refines the estimation of the motion parameters until the accuracy level desired by the user.

At the first step, a robust Scale Invariant Feature Transform (SIFT) algorithm is used to detect and descript interest points due to its excellent performance against changes in scale, rotations, illumination and partially affine transform. In second step, a Generalized Least-

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Squared (GLS) motion estimation method is used. The use of a GLS estimator is an effective way of solving regression problems, allowing obtaining accurate estimation of the parameters in Image Registration.

E. FBIR using Hough Transform [10]

In paper [10] J N Sarvaiya et al., describes and compares two different methods to register images in Hough space. In the first method Hough transform is combined with 1D phase correlation to find the angle of rotation and 2D phase correlation to find the translation in x and y direction. Second method is straight line based image registration method. This method simultaneously determines the correspondences between the points and solve for the parameters involved in the registration transformation function in Hough space. By experiments it is found that, the first method can detect rotation and translation efficiently in different types of images while second method can detect rotation and scale for the images rich with straight lines.

F. FBIR using Shape Context [11]

LEI HUANG, ZHEN LI et al., 2010 [11] proposed a new feature-based method named shape context for airborne multi-sensor image matching. This method has been found to be robust in hand written digit and object recognition.

In the Shape Context method, control points (CPs) are extracted on the reference image, and edge features are extracted on the reference and the sensed image, respectively. The shape context exploits feature similarity between circular regions of the two images to find corresponding CPs on the sensed image. Finally, the sensed image is warped according to the CPs using thin-plate spline interpolation [11]. Generally, the feature matching strategies rely on “strong” features, such as special points, islands, closed lakes or straight lines. While, the shape context [11] is used even for “weak” feature areas.

G. Soft Computing based Image Registration

Methods based on soft computing techniques such as neural network [7], Genetic Algorithm [4], Fuzzy logic [5], [7] etc are recently being used.

An artificial neural network (ANN), often just called a "neural network" (NN), is composed of simple elements, operating in parallel, are inspired by biological nervous systems [13]. As in nature, the connections between elements largely determine the network function. Neural networks are adjusted, or trained, so that a particular input leads to a specific target output. The network is adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically, many such input/target pairs are needed to train a network. In more practical terms neural networks are non-linear statistical data modeling tools. An artificial neural network (ANN) is a computational structure that is composed of a number of single processors connected through a set of links, which have some weight associated with them [13]. Neural networks have been trained to perform complex functions in various fields, including pattern recognition, identification, classification, speech, vision, and control systems.

A genetic algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms (also known as evolutionary computation) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination). Genetic algorithms are implemented as a computer simulation in which a population of abstract representations (called chromosomes or the genotype or the genome) of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem evolves toward better solutions. Traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached [13].

O. Cordon, S. Damas, J. Santamari [4] have presented a method, CHC evolutionary algorithm based on a genetic algorithm to achieve Feature based Image Registration.

Fuzzy sets are sets whose elements have degrees of membership. Fuzzy sets (FS) have been introduced by Lotfi A. Zadeh (1965) as an extension of the classical notion of set. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition - an element either belongs or does not belong to the set. By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1]. Fuzzy sets generalize classical sets, since the indicator functions of classical sets are special cases of the membership functions of fuzzy sets, if the latter only take values 0 or 1.Fuzzy sets technology depend on linguistic terms (e.g.: small, large, tall, short, etc.) to summarize the domain knowledge explicitly.

Consequently, the results are clearly interpretable. FS are able to express the notion of partial membership (expressed by a real number in the unit interval [0, 1] of an element to a particular information granule. This property allows Fuzzy sets to handle uncertainty and imprecision [13]. L. Ramirez, N. G. Durdle, V. J. Raso [7] and Fu-Lai Chung, Zhaohong Deng, and Shitong Wang [5], have mentioned use of fuzzy sets in image registration.

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IV. Conclusion

Image registration is one of the most important tasks when integrating and analyzing information from various sources. It is a key stage in image fusion, change detection, high-resolution imaging, and in building image information systems, among others. This paper provides a comprehensive survey of classical and existing image registration algorithms, classifying them according to their nature and application as well as according to the four major registration steps. Although a lot of work has been done, automatic image registration still remains an open problem.

Evolutionary computing is a family of stochastic search techniques that mimic the natural evolution proposed by Darwin. If we consider intelligence as a kind of capability of an entity to adapt itself to ever changing environment, we could consider evolutionary algorithms as a subdivision of soft computing. These algorithms are made of the several iterations of basic evolution cycle. Evolutionary algorithms include various optimization methods such as Genetic Algorithm, Genetic Programming, Evolutionary Programming, Evolutionary Strategies etc.

Recently the growing use of Neural Network and Fuzzy Logic in image registration, various papers suggest that these techniques give variable. In order to address these limitations, an add on to existing strategies is required. This may be the use of Neural Network and Fuzzy logic, Wavelet with spectral parameter constrains etc for image registration.

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