Survey on Image Registration

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Abstract-This paper aims to present a survey of image registration technique. It is a procedure of mapping points from one image to corresponding points in another image. The image registration geometrically align the two images (one is reference and second is sensed image). The procedure of image registration consists of four steps: feature detection, feature matching, mapping function design and image transformation and resampling which are explained in Section V. The goal of image registration, algorithms and steps for image registration methods have been presented in this review paper.

Keywords- image registration, feature detection, feature matching, feature mapping, resampling.

1. Introduction

Image registration is an important and fundamental task in image processing which is helpful for matching of two different images (one sensed image and other reference image). It is the process of overlaying two or more images of the same scene taken at different times, from different view points, or by different sensors [1], [2]. Basically it is a procedure of mapping points from one image to corresponding points in another image [3]. It is used for the detection of changes in the images of the same scene and integrate the information from different sensors. Image registration algorithms are broadly dived into two categories according to matching method: area based method and feature based method [4]. Image registration also determines the relative orientation between the two images [5].It is also known as image fusion, matching or warping [6]. Image fusion is used to designate the process of combining two or more images into a single image. Image matching is the process of establishing the correspondences among the structures in input images without explicitly aligning them [6].The objective of registration is to find an optimal spatial and intensity transformation such that images become aligned into the same coordinate frame. Mathematically, the problem of registering an input image $I(x,y)$ to a reference image $R(x,y)$ can be expressed as follows[7],[8]:

$$R(x,y) = g(I(T(x,y))) \quad (1)$$

where$T$ indicates a transformation function which maps two spatial coordinates, x and y, to the new spatial coordinates, $x$and y:

$$(x,y) = T(x,y) \quad (2)$$

and$g$ denotes a one-dimensional intensity or radiometric interpolation function. In general, function g is more complex but less important than T and can be partly solved by rectification.

2. Goal of Image Registration

The main objective of image registration is as follows [5,6]:

- The goal of an image registration method is to find the optimal transformation that best aligns the structures of interest in the input images.
- The objective of image registration is to find a spatial transformation such that dissimilarity metric
- Achieves its minimum between the two images taken at different times and from different viewpoints.

- The main objective of image registration is to determine the amount of rotation and the amount of translation that the sensed image has with respect to the reference image.

3.Misalignment Between The Images

The main source of the misalignment between the images may be due to change in sensor position, viewpoint and viewing characteristics or object movement and deformation [5]. The reference and sensed images could be different because they were taken at taken at different times, using different devices like MRI, CT, PET etc., from different angles in order to have 2D or 3D [3].The reasons and examples for taking images at different viewpoints, different times and from sensors are as follows [2]:

3.1 Different viewpoints (multiview analysis)

As images of the same scene are acquired from different viewpoints. The main motive behind is to gain larger a 2D view or 3D representation of the scanned scene. Examples of different viewpoints are remote sensing (mosaicking of images of surveyed area) and computer vision (shape recovery).

3.2 Different times (multitemporal analysis)

Images of the same scene are acquired at different times under different conditions. The objective is to find and evaluate the changes in the scene which appeared between the consecutive image acquisition. Examples are remote sensing (for monitoring of global land usage), Computer vision (for automatic change detection for security monitoring).

3.3 Different sensors (multimodal analysis)

Images of the same scene are acquired by different sensors. The motive is to integrate the information obtained from the different source streams to gain more complex and detailed scene representation. Examples are remote sensing (for fusion of information from sensors with different characteristics like panchromatic images), medical imaging (for combination of sensors recording the anatomical body structure like magnetic resonance image (MRI), ultrasound etc.).

4. Image Registration Algorithm

Image registration algorithms are broadly dived into two categories according to matching method: area based method and feature based method [4],[5].

4.1 Area based method

In area based method, a small window of pixels is used for sensed image and compared statically with windows of same size in reference image. The control points are used to solve for mapping function parameters between the reference and sensed images.
Correlation matching [10], [11], [12],[14]and least square matching methods are most commonly used as are based method.

4.2 Feature based method

It is divided into two parts:

1) Low level features such as edges and corners.
2) High level features such as identified objects.

The type of feature used for matching depends on the task to be solved. Feature based method is more reliable and robust as compared to area based method. It requires sophisticated image processing for feature extraction and depends on robustness of feature detection for reliable matching.According to F.P.M. Oliveira et al. [6] and M.S. Yasein et al. [13], the registration methodology based on voxel intensity are commonly known as intensity based registration.

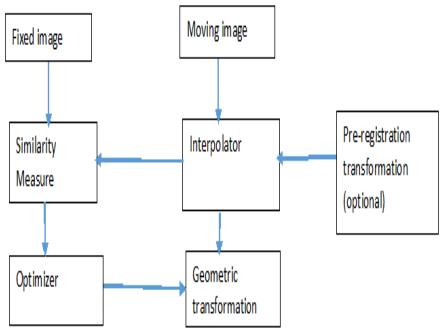

Fig.1 Diagram of the typical algorithms used in the intensity-based registration methodology

The main idea behind intensity based registration methodology is to search iteratively for the geometric transformation, which is applied to the sensed image, optimises, which mean minimises or maximises a similarity measure known as the cost function as shown in Fig. 1. The similarity measure is related to the voxel intensity and is computed in the overlapped regions of the input images. The optimiser has the function of defining the search strategy. The motive of the interpolator is to resample the voxel intensity into the new coordinate system according to the geometric transformation found. Whenever possible, a pre-registration transformation, which makes the moving (sensed) images closer to the fixed (reference) images in terms of the similarity measure is used as an initial solution for the registration algorithm.

For the feature-based registration methodologies, there are two main approaches to search for the optimal transformation after the feature segmentation process in the input images as shown in Fig. 2, which are as follows:

1) The matching among features is established using some criterion. Then the geometric transformation is established based on the matching found. Then the 'corresponding costs' are the 'distances' between the descriptors of the possible point pairs, and similarity measure between the input images is usually given by the sum of all the 'corresponding costs' established [6].

2) The matching and transformation are defined concurrently based on the optimisation of a similarity measure between the features extracted from the input images [6].

5. Steps for Image Registration

There are mainly four steps for image registration which are as shown in Fig.3 and explained below [2, 3, 7]:

5.1 Feature Detection

In feature detection step, salient and distinctive objects like closed-boundary regions, line intersections, contours and corners are detected in both the images (sensed and reference).

Feature detection is classified as area based methods and feature-based methods.

Area-based methods put emphasis on the feature matching step than on their detection.

Where feature-based approach is used for extraction of salient structures and features in the images. The significant regions like forests, lakes and fields, lines like region boundaries ,coastlines, roads and line intersections like points on curves with high curvature have been detected. Feature based method does not work directly with image intensity values. The features represent information on higher level. This makes this method more suitable for the situations where illumination changes are expected.

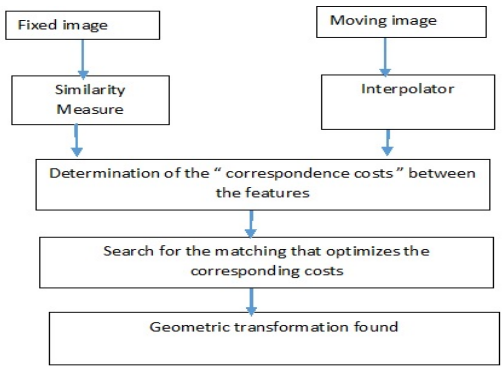

Fig.2 Diagram of a typical feature -based registration algorithm [6]

5.2 Feature Matching

Second step for image registration is feature matching used for the matching of features. In this step, the correspondence between the features in the reference and sensed image have been established in this step. Feature matching is categorised in two steps: area-based method and feature-based method.
Area-based method is also known as correlation-like methods or template matching. The drawback of this method is as follows:

1. Rectangular window used in this method is locally differ only by a translation. If the images are deformed by more complex transformations then this type of window is not able to cover the same parts of the scene in the reference as well as sensed image.
2. Another drawback of this method is that there is a high probability of window containing a smooth area without any prominent details will be matched incorrectly with other smooth areas in the reference image due to its non-saliency.

5.3 Transform model estimation

In this step, the type and parameters called mapping functions have been established, which align the sensed image with the reference image. The correspondence of the control points (CP) from both the images (sensed and reference images) together with the fact that the corresponding CP pairs should be as close as possible after the sensed image transformation are employed in the mapping function design [1]. The type of the mapping function should correspond to the assumed geometric deformation of the sensed image and to the method of image acquisition. Global mapping models, local mapping models, mapping by radial basis functions and elastic registration have been used for this purpose.

5.4 Image resampling and transformation

The sensed image is transformed by means of the mapping functions. The transformation can be done in two methods: - backward or forward [2].

In forward method, each pixel from the sensed image can be directly transformed using the estimated mapping functions. It is complicated to implement as holes can be overlapped in the output image.
In backward method, the registered image data from the sensed image are determined using the coordinates of the target pixel and the inverse of the estimated mapping function. The main advantage of this method is that there will be no overlaps of holes as interpolation is done.

6. Challenges for Implementation of Above Four Steps

The implementations of the above four steps has its typical problems which are as follows [2]:
1) Kind of features is appropriate for the given task should be properly decided. They should be distinctive objects which are frequently spread over the images and which are easily detected. The physically interpretability of the features is also one of the major demand for implementation.
2) The detection methods should have good localization accuracy and not be sensitive to the assumed image degradation.
3) In feature matching step, problems can also be raised by an incorrect feature detection or by image degradations.
4) Physically corresponding features can be dissimilar due to the different imaging conditions or due to the different spectral sensitivity of the sensors. Feature description and similarity measure has also to be properly choose.
5) The algorithms used for matching in the space of invariants should be robust and efficient.
6) The model used for mapping should be flexible and easy to handle.
7) The accuracy of feature detection method, the reliability of feature correspondence estimation and the acceptable approximation error need to be considered.
8) The choice of the appropriate type of resampling technique depends on the trade-off between the demanded accuracy of the interpolation and the computational complexity.

7. Applications of Image Registration

The image registration is useful in many applications like remote sensing with combination of feature and area based method [4], using SIFT descriptor[17,18],biomedical in iris recognition[12], subtraction angiography[15] using fuzzy theory[16], in physics technology for infrared thermal facial registration[19], in photogrammetry for light detection and ranging images [20], in digital for lesions detection[21], for blood vessel registration on animals[22], for X-ray images[24], agricultural [23].

8. Conclusion

It has been concluded that image registration is a fundamental step in image processing applications. It mainly consists of four steps: feature detection, feature matching, and transform model estimation and image resampling and transformation. Image registration has very wide applications in remote sensing, agricultural and biomedical as explained in Section VII.

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