

A Survey of Recent and Classical Image Registration Methods

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Abstract

Image Registration is the process of aligning two or more images of the same scene taken from different viewpoints, at different times, from different sensors. Image registration aligns two images, i.e., base image and reference image, geometrically. There are different approaches of image registration and these approaches are categorized according to their nature that is areas based and feature based. These approaches are also categorized according to the four simple steps of image registration procedure: feature detection, feature matching, function mapping and transformation and re-sampling. Advantages and disadvantages of different methods are discussed in the paper. The main aim of this paper is to provide the knowledge of different image registrations methods used in different application area.

Keywords: Image registration, feature detection, feature matching, mapping function, sampling

1. Introduction

Image registration is the process of aligning two or more images of the same scene taken from different views, at different times and from different sensors. It geometrically aligns two images- base and the reference image. Image registration is a very important step in the process of analyzing an image through which necessary information is found by combining information from different data sources. Generally image registration required in remote sensing (for monitoring environment, weather forecasting), in medical image processing (combining CT, monitoring tumor growth) and in computer vision.

The comprehensive study of image registration techniques was published in 1992 by Brown. The goal of this paper is to introduce techniques came after that and maps the current development of image registration. We did not go into the details of particular algorithm and not shows the results of comparative experiments. Instead of it we summarize the useful approaches and point out interesting part of image registration.

In section II both the concepts and problems of image registration are discussed. In section III both area based and feature based techniques of feature detection is discussed. In section IV various feature matching algorithm is discussed. In section V different methods for mapping

Function is discussed. In section VI different methods for image sampling and transformations are discussed. Section VII shows the future trends in image registration.

2. Image Registration Methodology

Before proceeding towards various image registration methods we have to understand the terminology for better understanding [3]:

- Target image: The image which doesn't change and is used as the basis of other images.
- Source image: The image which is geometrically aligned with the target image.
- Transformation and Warping: The mapping function which is used to modify the source towards the target image.

2.1 Classification of Image Registration Techniques

In general image registration techniques can be categorized according to the various distinguish points. Based on image acquisition, Brown in 1992, divided image registration in four classes [1]. Barbara Zitova and Jan Flusser have categorized the image registration techniques in the area based methods and feature based method. Maintz proposed a nine-dimensional method that provides a categorization, which basically used in medical imaging application.

2.1.1 Classification Based on Application

Image registration can be categorized into four different classes according to the image application [1].

- Different viewpoints: Same scenes of the image are captured from different viewpoints. The purpose behind this to achieve a two-dimensional image representation. Example is remote sensing- For the mosaicking of image.
- Different times: Same scenes of the image are acquired at different time depending on different conditions. The purpose behind this is to find and evaluate changes occur in the scene during different time period. Example is remote sensing and computer vision.
- Different sensors: Same scenes of the image can be acquired from different sources. The purpose behind this is to analyze the information from different sources for obtaining the more detailed information. Example is remote sensing and medical imaging.
- Scene of model registration: Image of the scene and model are to be registered. The purpose behind this is to localize the acquired image in the model and compare them. Example is computer vision, remote sensing and medical imaging.

2.1.2 Classification Based on Nine Dimensional Scheme

Maintz proposed a nine-dimensional scheme to characterize an image registration which is basically used for medical imaging [3].

- Dimensionality: it refers to the number of geometric dimensions which any image space has. It can be two dimensional or three dimensional.
- Nature of registration: it is the aspect of two views used to effect registration. It may be intensity based or surface based methods.
- Nature of transformation: it refers to the property which holds various transformations like affine, projective, and rigid.
- Domain of transformation: it tells whether transformation is calculated local or global.
- Degree of interaction: it refers to the control given by human over the registration algorithm.
- Optimization procedure: it refers to the standard approach in which the quality of registration is estimated continually during registration.
- Modalities involved: it refers to the means by which the images to be registered are acquired.
- Subject: it refers the sensed image.
- Object: it refers to the region to be registered.

2.1.3 Classification Based on Essentials

Barbara and Jan classified the image registration techniques as follows [1, 3]:

- Area Based Methods: These methods are applied information about image is absent and distinctive information is provided by gray level or colors.
- Feature Based Methods: These methods are applied when local structure information about an image is given.

2.2 Steps Involved in Image Registration Process

Due to diversity of image to be registered and various degradation in images it is impossible to define a universal method for image registration. That why each image registration method has its own importance. Majority of image registration method have four basic steps [1]:

- Feature Detection: salient and different objects in an image (edges, lines, contours) are detected manually or automatically. These feature points are represented by their descriptors.
- Feature Matching: In this step, the features detected in the reference image and those detected in sensed image has been matched. Feature descriptor and similarity measure are used for this purpose.
- Transform Model Estimation: the type and parameter of mapping function is established which is used to align the sensed image with reference image.
- Image Re-sampling and Transformation: The sensed image is transformed by establish mapping functions.

The implementation of each registration step has its own typical problems. First we have to decide what kind of feature is appropriate for the given task. The features should be frequently spread over the image and easily detectable. The detected features in both the sense image and reference image must have enough common elements. The detection method should have good spatial accuracy and has not been affected by assumed degradation.

In the feature matching step, the problem caused by incorrect feature detection and image degradation can arise. Feature can be dissimilar due to different imaging conditions. We have to choose feature descriptor and similarity measure carefully so that it doesn't affect the matching. They have to be discriminable enough.

The type of mapping function should be chosen according to the prior information about image degradation. If no information is available then it should flexible enough to handle all kind of degradation.

Finally, the choice of the appropriate type of re-sampling technique based on the accuracy of the interpolation and computational complexity. Some cases use bilinear and nearest neighbor approach.

3. Feature Detection

Formerly, the features are objects detected by manually by expert. There are two main approaches to feature understanding [1, 3].

3.1 Area-Based Methods

Area-Based methods put emphasis on feature matching rather than detection. No features are detected in this approach. So the first image registration step is omitted in area-based methods.

3.2 Feature-Based Methods

Feature-based approach is based on the extraction of salient features in the images. Regions, lines, points are understood as features here. They should be spread over the image and efficiently detectable in both images. The number of common elements of the detected set of features should be high, regardless of image geometry, additive noise. Feature based methods do not work on image intensity values as opposed to area-based method.

3.2.1 Region Feature Detection

The region features can be the closed boundary of appropriate size, reservoirs, forest, urban areas. Regions are generally represented by their center of gravity. Region feature are detected by means of segmentation methods. The accuracy of segmentation significantly influences the resulting registration. S.K. Pal [4] proposed a method as a refinement to segmentation to produce better registration accuracy. In 2004, Harris-Laplace region detector [3] locates potential relevant points with the Harris corner detector and then selects the point with a characteristic scale. A new region feature descriptor based image registration proposed in 2012.

3.2.2 Line Feature Detection

The line features can be represented by line segments, object contours, roads or anatomical structure in medical imaging. Standard edge detection methods like canny detector or Laplacian detector are used for line feature detection. The Marr-Hildreth edge detector [6] has been a very popular edge detector before canny presented his paper. Canny edge detector [5] is widely considered to be the standard edge detection algorithm. A recent detailed comparative study of various edge detection algorithms can be found in [7]. Apart from it Li proposed a new method to detect the lines in the reference and source image. Figure 1 shows the artificial image and its corresponding line segments and edges.



Figure 1. Artificial Image Contains Thick Line Segments Running Horizontally, Vertically and Obliquely Across the Image, in Second Image Detected Line Segments are Present and in Third, Fourth Edge Detection is Figured

3.2.3 Interest Point and Corner Feature Detection

Corners are estimated as points of high curvature on the region boundaries. The first corner detector has been in the late 1970's. In 1977, Moravec [8] defined the concept of "point of interest" as different regions in images. Based on Moravec concept Harris developed the algorithm known as Harris corner detector. Figure 2 shows the image containing different types of corners.

A comparative study of interest point performance on a data set can be found in 2011 and different detection method can be found in 2009.



Figure 2. Artificial Image Containing Different Corner Types and Real Image of Block and House Scene

3.2.4 Shape Feature Detection

Some objects may be recognized by their outline shape and it is a very powerful feature in image processing. Yang Mingqiang and KpalmaKidiyo in 2008 discussed the essential properties of shape to be feature that includes rotation, translation, scaling, noise resistance and reliability [9]. Figure 3 shows the shapes of different objects like wing and palm tree.



Figure 3. Wings are Longish and Triangular, Palm Trees Consist of a Lengthy Stem and a Bushy Head

4. Feature Matching

After detecting the features, we have to match them. We can say that we have to determine which feature come from corresponding locations in images that are different. Again we have to discuss two different aspect of feature matching. One is area based and other is feature based.

4.1 Area Based Methods

All techniques in area based methods merge the feature detection step with feature matching step and deal with the images without detecting the salient feature of object.

4.1.1 Correlation or Pixel Based Methods

Cross correlation is the first basic approach of registration process. It is generally used for pattern matching. The classical method of area based method is cross correlation [3].

Cross correlation is a type of similarity measure or match metric $C(u, v)$ of image $I(x, y)$ with displacement u in X direction and v in Y direction. Two dimensional cross correlation functions is shown below.

$$C(u, v) = \frac{\sum_x \sum_y T(x, y) I(x - u, y - v)}{\sqrt{\sum_x \sum_y I(x - u, y - v)}} \quad (1)$$

This similarity measure is computed for window pairs from the sensed and target images. The window pair for which the maximum is found should be set as the corresponding one.

Two main disadvantages of the correlation like methods has the high computational complexity.

4.1.2 Fourier Methods

Correlation theorem states that the Fourier transform of the correlation of two images is the product of the Fourier transform of one image and complex conjugate of Fourier transform of other [10].

The Fourier transform of image $f(x, y)$ is a complex function in which each function has a real part $R(\omega_x, \omega_y)$ and an imaginary part $I(\omega_x, \omega_y)$ at each frequency (ω_x, ω_y) of frequency spectrum.

$$F(\omega_x, \omega_y) = F(\omega_x, \omega_y)e^{-\varphi(\omega_x, \omega_y)} \quad (2)$$

Where $F(\omega_x, \omega_y)$ is a magnitude and $\varphi(\omega_x, \omega_y)$ is a phase angle.

The phase shift correlation method is based on the Fourier shift which is proposed for the registration of translated image.

Recently, image mosaic based on phase correlation and Harris operator is proposed by yang in which first the scaling and translation is performed then the unregistered image is adjusted. After that feature point are detected and matched.

It is observed that if the computational speed is required or the images are corrupted by noise then Fourier methods are preferred than correlation methods.

4.1.3 Mutual Information Methods

Mutual information based registration process begins with the estimation of the joint probability of the intensities of corresponding pixels in the two images. Mutual information between two random variables X and Y is given by the formula [3].

$$MI(X, Y) = H(Y) - H(Y/X) \quad (3)$$

Where $H(X) = -\sum P(X) \log P(X)$ represents "entropy of random variable" and is probability distribution of X. this method is based on maximizing MI.

It is observed that MI gives accurate result than any other registration method. But when images have low resolution or it contains little information then it gives worse results.

4.2 Feature Based Methods

Feature based method used image feature derived by feature extraction algorithm instead of intensity values for matching purpose.

4.2.1 Methods using Spatial Relations

Methods based on spatial relations are usually applied if detected feature are not clear or their neighbors are distorted.

Barrow in 1977 has introduced the chamfer matching for image registration. Line feature detected in image are matched by the minimization of the distance between them. Recently, Gongjian wen developed high performance feature matching method for image registration by combining spatial and similarity information [12].

4.2.2 Relaxation Methods

In the relaxation method, one of the famous method is consistent labeling problem (CLP) in which we label each feature from the sensed image with the label of a feature from the targeted image. So it is consistent with other images [12].

Another solution to CLP problem and to the image registration is backtracking, where consistent labeling is generated recursively.

4.2.3 Pyramids and Wavelets

In 1977, when a sub-window was used to find out the probable candidates of the corresponding window in reference image and then full size window is applied. After that a rectangular grid of windows is taken on which cross correlation is performed for reducing the computational load. All these techniques are just an example of early pyramidal methods [3].

Recently, wavelet decomposition of the images was proposed for pyramidal approach. There are many comparison tests have been carried out to establish which wavelet family has the best performance.

4.2.4 Methods using Invariant Descriptor

Another method for exploiting the spatial relations is the correspondence of features can be estimated by their descriptor. Descriptor contains information about feature points detected in both the reference image and source image. The most common method is to use closed boundary regions as features. Theoretically any invariant and discriminative enough shape descriptor can be employed in region matching such as shape vectors. There are various types of descriptors are used but we will proceed with the examination of the SIFT, SIFT variants and SURF feature matching.

- **SIFT Descriptor and Its Variants**

A different algorithm of feature extraction is registration based on Scale Invariant Feature Transform (SIFT) proposed by David G. Lowe in 1999[11]. Lowe in 2004 proposed SIFT for extracting distinctive invariant features from images that can be invariant to rotation and scaling. It was widely applied in mosaicking recognition, retrieval *etc.*, There are various variants of SIFT that proposed for different types of images which provide better result. Some of them are listed below with comparison to SIFT on the basis of time and computational complexity.

Table 1. Comparison of Different SIFT Image Registration Methods

S. NO.	NAME OF THE ALGORITHM	EVOLUTI-ON YEAR	TYPE OF IMAGE	COMPARIS-ON WITH SIFT
1.	Distinctive SIFT	2004	All types of images	Same as SIFT
2.	PCA SIFT (Principal Component Analysis)	2004	Gradient Images	Fast descriptor but less than Distinctive SIFT
3.	GLOH (Gradient and orientation histogram)	2005	Gradient Images	More robust than SIFT and PCS SIFT
4.	CSIFT (Color)	2006	Colored images	Performs better with respect to the number of the detected features
5.	ASIFT (Affine)	2009	Object Images having smooth boundary	Reduce complexity
6.	OCT SIFT (Octave)	2010	Synthetic Aperture Radar	Reduce processing time
7.	ROBUST SIFT	2010	Remote sensing images	More accuracy and correct match rate

8.	BF SIFT (Bilateral Filter)	2012	Synthetic Aperture Radar	Non iterative and fast
9.	Multilevel SIFT	2012	Large size VHR images	Solves memory problem and reduce computational complexity

- **SURF Descriptor**

SURF (Speeded UP Robust Feature) is a local robust feature detector and firstly presented by Herbert BAY in 2006 that can be used in various computer vision tasks like object recognition, feature matching. SURF is inspired by SIFT descriptor. The standard version of SURF is several times faster than SIFT and it is also more robust against SIFT [13].

5. Transform Model Estimation

After the feature detected and matched properly then the mapping function is constructed. In this step we choose the type of mapping function and its estimation. We can divide the mapping function into two broad categories according to the amount of image they used *i.e.*, Global model and local model [1]. Global model uses all control points into consideration for estimating one set of mapping function which is valid for an entire image. On the other hand local mapping function takes the image as a combination of patches and mapping function depends on the location of their support in the image. When sufficient matching points is given then scaling parameter, rotation angle and translation parameter can be retrieved by least square method [2].

6. Image Resampling and Transformation

After feature extraction and feature matching step, we have to perform transform model which we have estimated in transform model estimation step. It is required to calculate mapping function. Models of mapping function are of two different types [14].

6.1 Global Models

This model uses all matching points to calculate one mapping function parameter which is applied on the whole image, also known as rigid transformation. Global model use a polynomial with two variables and it is called bivariate polynomial of low degree. This transformation consists of rotation, scaling and translation.

6.2 Local Models

This model emphasis on dividing the entire image into different regions and mapping function parameters are calculated for each part and it is known as elastic transformation.

Image resampling is performed after transformation model estimation. In this step, each pixel in the image is either increased or decreased.

Practically image resampling is carried out by convoluting image with interpolating function such as bilinear and bi-cubic functions, cubic B-splines and Gaussian and sin functions.

7. Conclusion

Image registration is one of the important tasks when we want to integrate and analyze information from different sources to obtain the more accurate information. This paper gives a survey and review of the classical and recent registration methods. The main aim of this

survey is to present the major advances in the field of image registration. Image registration involves a vast problem set which includes different problems faced in image processing like image fusion, object detection and others. This paper makes genuine efforts to cover all possible techniques and work done in the image registration field.

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