RESEARCH ARTICLE OPEN ACCESS

A Study on Image Registration Schemes

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Abstract:

Computer vision is a field of computer science that includes methods for acquiring, processing, and analysing images. Image registration is one of the methods used in computer vision to transform different sets of data into one coordinate system to align images. Registration is important in order to be able to compare or integrate the data obtained from multiple measurements. In this paper, the related pieces of work done in the field of image registration that are studied in the literature are presented.

Keywords **—Image Registration, Feature Detection, Fast Fourier Transform.**

I. INTRODUCTION

Registration of two dimensional images acquired from the same scene taken at different times, from different geometric viewpoint, or by a different image sensor is a fundamental problem in the image processing. Image registration is the preprocessing step for analysis and fusion of the images. It geometrically aligns two images the reference and sensed images. Image registration is a crucial step in all image analysis tasks in which the final information is gained from the combination of various data sources like in image fusion, change detection, and multichannel image restoration. It is widely used in different fields such as remote sensing for multispectral classification, environmental monitoring, change detection, creating super-resolution images and integrating information into geographic information systems (GIS) [51]. In medical applications it is used for combining computer tomography (CT) and nuclear magnetic resonance (NMR) data to obtain more complete information about the patient, monitoring tumor growth, treatment verification, comparison of the patients data with anatomical atlases. Image registration is also used in cartography for map updating and in computer vision for target localization and automatic control.

Image registration can be defined as a mapping between two images both spatially and with respect to intensity. If we define images as two two-dimensional arrays of a given size denoted by I_1 and I_2 where $I_1(x,y)$ and $I_2(x,y)$ each map to their respective intensity values, then the mapping between these two images can be expressed as:

$$I_2(x,y) = g(I_1(f(x, y)))$$

where f is a two dimensional spatial coordinate transformation,
i.e.,

$$(x', y') = f(x,y)$$

and g is one dimensional intensity or radiometric transformation.

To find the relationship between two images we rely on the estimation of the parameters of the transformation model. Number of parameters depends on the chosen transformation model. A common assumption is that the coordinate transformations between two images are rigid planar models. Rigid planar transformation is composed of scaling, rotation, and translation changes, which map the pixel (x_1,y_1) of image f_1 to the pixel (x_2,y_2) of another image f_2:

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = sR \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} + \mathrm{T}$$

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = s \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}$$

The rigid transformation is sufficient to match two images of a scene taken from the same viewing angle but from different position. That is, the camera can rotate about its optical axis. In the case of remote sensing, where the distance approaches infinity, the transformation between the captured images behaves like a planar rigid transformation.

A. Methodology

Image registration essentially consists of following steps as per Zitova and Flusser [51]. Fig. 1 illustrates the process.

- **Feature detection**

  Salient and distinctive objects (closed-boundary regions, edges, contours, line intersections, corners, etc) in both reference and sensed image are detected.
- **Feature matching**

  The correspondence between the features in the reference and sensed image established.
- **Transform model estimation**

  The type and parameters of the so-called mapping functions, aligning the sensed image with the reference image, are estimated.
- **Image resampling and transformation**

  The sensed image is transformed by means of the mapping functions.

B. Image registration techniques

Many techniques that have been proposed to solve the registration problem in different forms that can be broadly classified into three categories, namely feature-based matching, intensity-based matching and hybrid approaches. Each of these approaches has its advantages and disadvantages.

1) Feature-based registration: Feature-based approaches attempt to find the correspondence and transformation using distinct anatomical features that are extracted from images. These features include points [6], [1], [12], curves [44], [13], [8], or a surface model [45], [47], [3] of anatomical structures. Feature-based methods are typically applied when the local structure information is more significant than the information carried by the image intensity. They can handle complex between-image distortions and can be faster, since they don't evaluate a matching criterion on every single voxel in the image, but rather rely on a relatively small number of features. The simplest set of anatomical features is a set of landmarks. However, the selection of landmarks is recognized to be a difficult problem, whether done automatically or manually. For many images, this is a serious drawback because registration accuracy can be no better than what is achieved by the initial selection of landmarks. For practical reasons, the number and precision of landmark locations is usually limited. Hence, spatial coordinates and geometric primitives often oversimplify the data by being too sparse and imprecise.

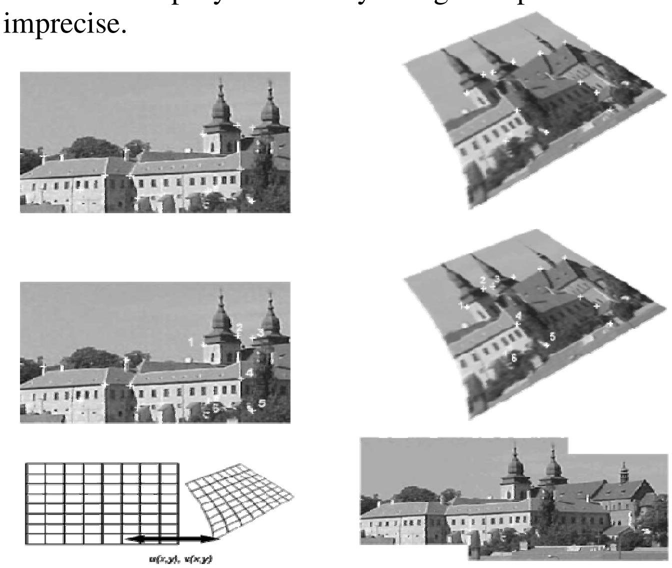

Fig. 1. Steps of image registration: Top row - feature detection. Middle row - feature matching. Bottom left – transform model estimation. Bottom right - image resampling and transformation.

2) Intensity-based registration: The intensity-based registration methods operate directly on the image gray values, without reducing the gray-level image to relatively sparse extracted information. The basic principle of intensity-based techniques is to search, in a certain space of transformations, the one that maximizes (or minimizes) a criterion measuring the intensity similarity of corresponding voxels. Some measures of similarity are sum of squared differences in pixel intensities [2], regional correction [11], or mutual information [20]. Mutual information has proved to be an excellent similarity measure for cross-modality registrations, since it assumes only that the statistical dependence of the voxel intensities is maximal when the images are geometrically aligned. The intensity similarity measure, combined with a measure of the structural integrity of the deforming scan, is optimized by adjusting parameters of the deformation field. Such an approach is typically more computationally demanding, but avoids the difficulties of a feature extraction stage.

3) Hybrid registration: Further hybrid approaches, based on a combination of feature-based and intensity-based criteria, are likely to benefit from both the advantages of each strategy. Christensen et al. [9] introduced a hierarchical approach to image registration combining a landmark-based scheme with a intensity-based approach using a fluid model. This registration approach is applied on 3D cryosection data of a macaque monkey brain and also on MR images of the human brain.

II. RECENT WORK

Many image registration methods have been proposed in the past 25 years [4], [7], [25], [27], [32], [33], [39], [48], [51], [52], which can be categorized into two major groups: the feature based approach and the area based approach.

Feature based methods deal with detecting the feature points in the two images and register them. Color gradients, edges, geometric shape, contour, image gradient are said to be the features. To extract features from image and then the scale and rotation parameters, Lowe [31] proposed scale invariant feature transform (SIFT) method that can extract image features that are invariant to illumination change, scale, and rotation. Mikolajczyk and Schmid [34] combined Harris corner detection [16] and Laplacian-of-Gaussian in order to extract features from the images. Jackson and Goshtasby [18] proposed a method using the projective constraint for registering video frames of a scene consisting of flat background, moving objects and three-dimensional structures captured by a moving frame. It selects a set of stable feature points in each frame, then it finds the correspondence between the feature points in the frames, next it distinguishes feature points that belong to the planar background from other feature points using the projective constraint, and then it uses the coordinates of corresponding background feature points to align the frames. Thus frames in an aerial video are registered at their common background.

When an image is not rich in details, then the features in it will be difficult to distinguish from each other, in this case the area based approach will be quiet useful. Normalised cross correlation [27] is a widely used approach in the area based method. Combining the phase correlation technique with the log-polar transform (LPT), the Fourier Mellin [39], [43] approach was proposed as a breakthrough area-based method that yields invariant properties to translation, scale and rotation. Wang et al. [49] employed a probability density gradient based interest point detector to extract the stable point features. They proposed global parallax histogram based filter to discard the outlier induced by classical correlation method. Kybic [26] proposed a method that uses bootstrap resampling in order to estimate the uncertainty of area based image registration algorithm on a particular pair of images. Lin et al. [29] proposed a method for automatic registration. In this, they first applied Harris operator to extract the corner features after that Canny operator is implemented to detect the image edges. The correlation between the image pairs yields the corner points. The affine transformation between the image pair is established, which calculates the parameters, according to that the images are registered.

An iterative algorithm to increase image resolution, together with a method for image registration with subpixel accuracy is presented by Irani and Peleg [17]. Reddy and Chatterji [39] presented a registration method that uses the Fourier domain approach to register the target image in the source image. The Fourier method searches for the optimal match based on the information in the frequency domain. Because of this distinct feature it differs from other registration strategies. Liu et al. [30] developed pseudo-log-polar Fourier transform (PLPFT) to detect large geometric transformation. Matungaka et al. [33] proposed an adaptive polar transform instead of log-polar transform for registering the images. They combined adaptive polar transform with projection transform along with matching mechanism to recover the scale, rotation and translation. Kim et al. [21] proposed a Fourier transform based image registration using pyramid edge images and a simple line fitting. This approach computes the accurate information at sub-pixel precision and carried out fast for image registration.

A fast approximate Harris corner detector was proposed by Han et al. [15], which relied on the integral images and box filters to convolute image. This fast algorithm replaced Gaussian filter process just by 3 additions and made it completely independent of the filter mask size. When more than two images of the same content is registered together then collection of these images are called as an ensemble. The problem of registration becomes more difficult when the images come from different sources. Because the image intensity cannot be compared directly, although the images depict same content, they do with different transfer function. Such registration problems are called as multisensory registration. Orchard and Mann [36] proposed multisensory ensemble registration method to overcome the above problem. Tzimiropoluos et al. [48] have reported fast Fourier transform (FFT) based registration scheme with image gradients. They replaced the image functions with the complex gray level edge maps and then performed FFT. Then resampled it on the log-polar grid and then used normalised gradient correlation (NGC) to detect the geometric transformations.

Krish et al. [22] introduced a new feature based image registration algorithm that detects the scale and rotation and then it is matched using Hough transform. Once the correspondence between the feature are matched then the transformation parameters are estimated using non linear least square and standard RANdom Sample And Consensus (RANSAC). Gonzalez [14] proposed a phase correlation technique to estimate the geometric transformation. Thangavel and Kokila [46] proposed an extension of FFT based image registration. Sarviya and Patnaik [41] presented a feature based approach that combines the mexian hat wavelet transform, invariant method and randon transform. Je and Park [19] presented an accurate and fast image registration algorithm based on the optimized hierarchical block matching and color alignment methods. This method dramatically speeds up the image registration task with the substantial increase of the matching accuracy and color alignment scheme efficiently compensates for the color inconsistency in a pair of images, and increases matching accuracy. Kokila and Thangavel proposed a corner response [16] based image registration technique [23].

Collignon et al. [10] proposed an information theoretic approach for rigid body registration of 3D multi-modality medical image data. Wu and Chung [50] proposed a straight forward multimodal image registration method based on wavelet representation, in which two matching criteria are used including sum of absolute difference (SAD) for improving registration robustness and mutual information (MI) for assuring the registration accuracy. Serlie et al. [42] presented a method that models the partial volume effect (PVE) to estimate material fractions in the edge region. The method deals with two-material transitions based on locally estimated derivative values. Liao and Chung [28] proposed a new feature based non-rigid image registration method for magnetic resonance (MRI) brain image. Roozgard et al. [40] proposed a dense registration technique by aligning local three-dimensional features of two CT images using sparse coding and belief propagation. To register smaller images such as tumor or fractures in an image, proposed a Gabor filter based medical image registration technique [24].

Pan et al. [37] proposed a multi-layer fractional

Fourier transform (MLFFT), that uses the fractional Fourier transform to create several spectrums with different resolutions from an image and sums them into one for the log-polar transform. This strategy makes the Fourier transform based image registration more accurate than the other Fourier transform based methods. Pan et al. [38] proposed medical image registration based on single value decomposition (SVD) and Modified peak signal-to-noise ratio (MPSNR). Myronenko and Song [35] proposed a intensity-based similarity measure to deal with complex spatially-varying intensity distortions.

III. CONCLUSIONS

In spite of the above developments, researchers are still actively engaged in finding new strategies to devise new and faster registration algorithms for locating better geometric trans-formation parameters. The studies reported are not exhaustive, as the literature in each area is very large. Only selected works are cited.

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