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Medial Image Registration Based on Information Theoretic Approach

Mendpara Kishankumar, Patel Manish

Abstract— Image Registration is basic step in image processing applications. By matching of two or more images taken at different times, from different angles or from different sensors we can get registration of those images. The registration process aligns the reference and target images. The formal approaches can be categorized according to their nature of procedure and from four basic steps of image registration process like feature detection, feature matching, estimation of transformation and image resampling and transformation. Medical image registration techniques further can be classified according to different modalities involved in registration process. In survey papers related to image registration there are different methods of medical image registration can be found and based on that methods we can compare that different methods with information theory based methods.

Index Terms— Image Registration, Information Theory, Medical Image Processing, Mutual Information

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 geometrically aligns two images—the reference and sensed images. The present differences between images are introduced due to different imaging conditions. 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. Typically, registration is required in remote sensing, in medical, in cartography, and in computer vision. In general, registration can be performed on two or more images. One is usually referred to as the source or moving image, while the other is referred to as the target or fixed image. In this paper, the reference image is denoted by S, while the target image is denoted by T. The two images are defined in the image domain Ω and are related by a transformation W. The goal of registration is to estimate the optimal transformation that optimizes energy of the form

$$M\,(T, S \circ W) + R\,(W)$$

The previous objective function comprises two terms. The first term M, quantifies the level of alignment between a target image T and a reference image S. Throughout this paper, we interchangeably refer to this term as matching criterion, (dis)similarity criterion or distance measure.

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Mr. Mendpara Kishankumar, Department of ECE, B.H.Gardi College of Engineering and Technology, Rajkot, India.

Prof. Patel Manish, Department of ECE, B.H.Gardi College of Engineering and Technology, Rajkot, India.

The optimization problem consists of either maximizing or minimizing the objective function depending on how the matching term is chosen. The images get aligned under the influence of transformation W. The transformation is a mapping function of the domain Ω to itself, which maps point locations to other locations. The second term R, regularizes the transformation aiming to favour any specific properties in the solution that the user requires, and seeks to tackle the difficulty associated with the ill-posedness of the problem.
The major registration methods consist of the following four steps

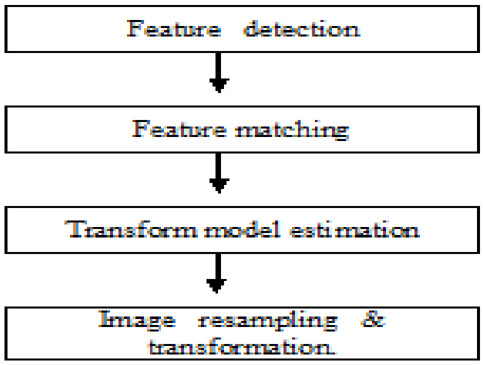

Fig. 1 Four steps of image registration

II. DIFFERENT APPROACHES FOR IMAGE REGISTRATION

Image registration algorithms can be classified in various ways, like based on modality, intensity or methods used for registration. Barbara Zitova and Jan Flusser [2] classified the image registration techniques as area based methods and feature based methods. Area based methods are preferably applied when in images prominent details are absent and distinctive information is provided by gray levels / colors rather by local shapes and structure. Feature based matching methods are applied when local structural information carried by image intensities are more. These methods make use of image features derived by feature extraction algorithm. Point of sharp variations such as edges, corners, contours, surfaces, point of intersection etc. what carries valuable information about images are used for matching.

a) Pixel Based Method

Cross-correlation is the basic statistical approach of registration. It is often used for template matching or pattern recognition in which the location and orientation of a template or pattern is found in picture. Cross correlation is a similarity measure or match metric. For template T and image I, where T is small compared to I, the two dimensional normalized cross-correlation function measures the similarity for each translation.

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$$C(u,v)=\frac{\sum x \sum y\, T(x,y) I(x-u,y-v)}{[\sum x \sum y I^2(x-u,y-v)]^{1/2}};$$

Where T is target image
and I is reference image

b) Feature Based Methods or Point Mapping Method

Feature based matching techniques do not use the grey values to describe matching entities. It makes use of image features derived by feature extraction algorithm. The purpose of feature extraction is to abstract substantial information from original data input and filter out the redundant information. Features are selected which are likely to be uniquely found in both images and more tolerant of local distortions. Computing of proper transformation depends on these features. Therefore sufficient number of features must be detected to perform calculation. After detecting features in each image, they must be matched. This technique is primary approach to register two images whose type of misalignment is unknown. This occurs if class of transformations cannot be easily categorized as translations or rigid-body movements. In this we can use landmarks and match them using general transformation.

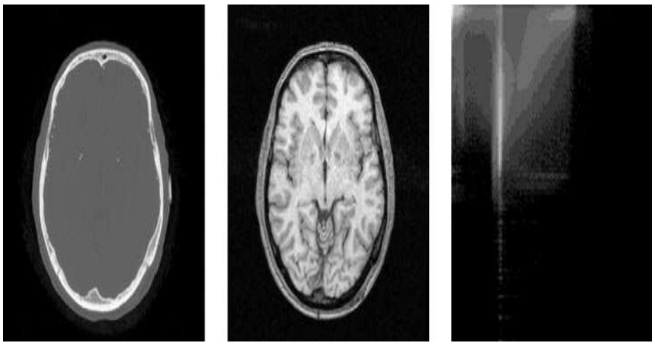
The method of point mapping consist of three stages-
• Computing features in the images
• Control points in reference image are corresponded with feature points in data image.
• Spatial mapping.

c) Image Registration Using Mutual Information

Multispectral image registration is also called as multimodal analysis. Images of the same scene are acquired by different sensors. The aim is to integrate the information obtained from different source streams to gain more complex and detailed scene representation. Different types of application are, in remote sensing fusion of information from sensors with different characteristics like panchromatic images, offering better spatial resolution, color/multispectral images with better spectral resolution, or radar images independent of cloud cover and solar illumination. Medical imaging applications are, combination of sensors recording the anatomical body structure like MRI, ultrasound or CT with sensors monitoring functional and metabolic body activities like PET, SPECT. Result can be applied, in radiotherapy and nuclear medicine. Registration of multispectral/ multisensor images is a challenging area. In general such images have different gray level characteristics and simple techniques such as those based on area correlation cannot be applied directly. This section is an attempt to solve this difficult problem by employing a basic concept from information theory.

III. INFORMATION THEORETIC APPROACH FOR IMAGE REGISTRATION

Information theoretic approaches were popularized by two different groups, one in US and one in Belgium. Both teams investigated the use of mutual information (MI) in multi-modal image registration. The difference between their approaches is the way entropy is estimated. Wells and Viola used a nonparametric estimator. Collignon and Maes used histograms instead. An important property of MI is its generality. MI does not assume any relationship between the image intensities. Both Collignon and Maes suggested to use entropy as a measure of registration. They constructed a feature space, which is a two-dimensional (2-D) plot showing the combinations of gray values in each of the two images for all corresponding points. Fig. 1 shows an example of such a feature space for a magnetic resonance (MR) and a computed tomography (CT) image. The difference with Woods' method is that instead of defining regions of similar tissue in the images, regions are defined in the feature space. These regions are based on the clustering one finds in the feature space for registered images.



(a) (b) (c)

Fig. 2 Joint histogram for (a) CT image and (b) MR image (c) Along the axes of the joint histogram, the gray values of the two images are plotted: from left to right for CT and from top to bottom for MR.

Once entropy, a measure from information theory, had been introduced for the registration of multimodality medical images, another such measure quickly appeared: mutual information. It was pioneered by Viola and Wells. Applied to rigid registration of multimodality images, mutual information showed great promise and within a few years it became the most investigated measure for medical image registration.
There are three form of definitions that best explains mutual information (MI)

1) $I(A,B) = H(B) - H(A|B)$
2) $I(A,B) = H(A) + H(B) - H(A,B)$
3) $I(A,B) = \sum_{a,b} p(a,b) \log \frac{p(a,b)}{p(a)p(b)}$

Where A and B are two images one is reference image and second is target image.

Properties of mutual information:
1) $I(A,B) = I(B,A)$
2) $I(A,A) = H(A)$
3) $I(A,B) \leq H(A), I(A,B) \leq H(B)$
4) $I(A,B) \geq 0$
5) $I(A,B) = 0$

The advantage of mutual information over joint entropy, is that it includes the entropies of the separate images. Mutual information and joint entropy are computed for the

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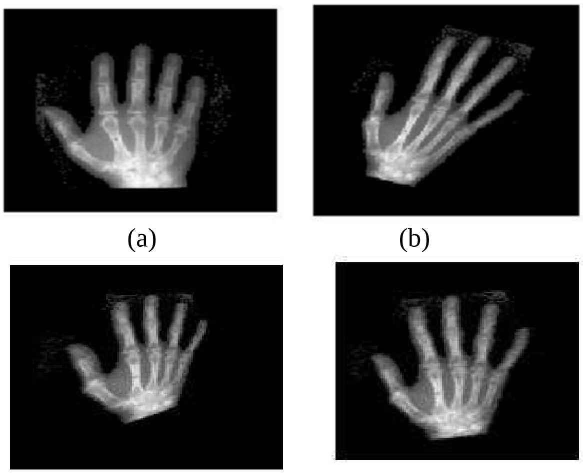
overlapping parts of the images and the measures are therefore sensitive to the size and the contents of overlap. A problem that can occur when using joint entropy on its own, is that low values (normally associated with a high degree of alignment) can be found for complete misregistrations.

IV. RESULT AND DISCUSSION

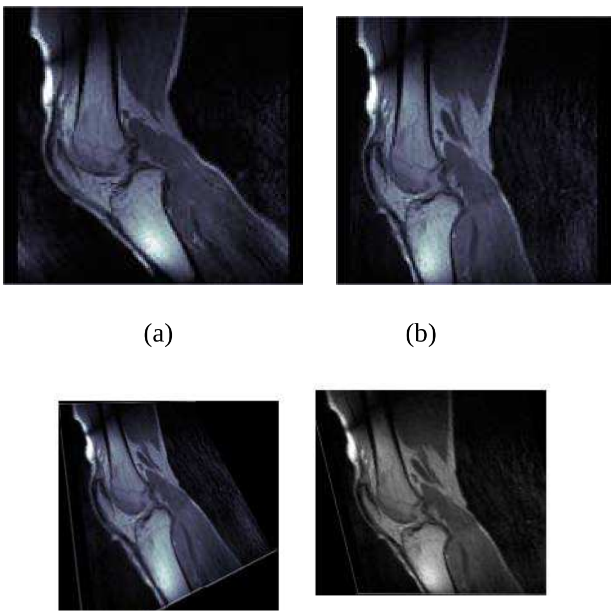
Using two different methods of image registration we register images and we can compare both methods. First method is point mapping method. Results of both methods are shown in figure 2 for x-ray hand images.



(a) (b) (c) (d)

Fig. 3 Registration of x-ray hand images (a) Reference Image (b) Target Image (c) Registered Image using point mapping method (d) Registered Image using mutual information method.

Second method is mutual information based method. Results of both methods are shown in figure 3 for x-ray leg images.



(a) (b) (c) (d)

Fig. 4 Registration of x-ray leg images (a) Reference Image (b) Target Image (c) Registered Image using point mapping method (d) Registered Image using mutual information method.

For comparison of result of registered images we use mutual information.

Method	MI of registered hand image with reference image	MI of registered leg image with reference image
Point Mapping	0.5298/1.3128	0.9603/3.5498
Mutual Information	1.1249/1.3128	2.2589/3.5498

Table 1 Comparison of two different methods using mutual information (MI)

V. CONCLUSION

There are many different image registration methods and these methods are classified according to specific application. In this paper we compared point mapping method and mutual information based method and after measuring the practical results, mutual information based methods are good for medical images. Because medical images have less features compared to other images. So information theory based methods give better results for medical image registration.

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