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FUSION OF MEDICAL IMAGES USING MUTUAL INFORMATION AND INTENSITY BASED IMAGE REGISTRATION SCHEMES

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ABSTRACT

Image fusion is the process of combining two or more images for providing more information. Medical image fusion refers to the fusion of medical images obtained from different modalities. Medical Image Fusion helps in medical diagnosis by way of improving the quality of the images. In diagnosis, images obtained from a single modality like MRI, CT etc, may not be able to provide all the required information. It is needed to combine information obtained from other modalities also to improve the information acquired. For example combination of information from MRI and CT modalities gives more information than the individual modalities separately. The aim is to provide a method for fusing the images from the individual modalities in such a way that the fusion results in an image that gives more information without any loss of the input information and without any redundancy or artifacts. In the fusion of medical images obtained from different modalities they might be in different coordinate systems and they have to be aligned properly for efficient fusion. The aligning of the input images before proceeding with the fusion is called image registration. The intensity based registration and Mutual information based image registration procedures are carried out before decomposing the images. The two imaging modalities CT and MRI are considered for this study. The results on CT and MR images demonstrate the performance of the fusion algorithms in comparison with registration schemes.

Keywords: image registration, mutual information, control point registration, phase correlation, intensity based image registration, image fusion

1. INTRODUCTION

Image registration is one of the important research areas in Medical Image Fusion [1]. Nowadays, the image acquisition technology has been enhanced to obtain higher quality images, so the need of an automatic and reliable process to register multiple images is still increasing, especially in the field of medical imaging [2]. In many image processing applications it is necessary to compare multiple images of the same scene acquired by different sensors. Image registration is the fundamental step in image processing applications. The goal of image registration is to establish the correspondence between two images. Image registration is used to comparing common features in different images. The need to register images has arisen in many practical problems in diverse fields. Registration is necessary for integrating information taken from different sensors and finding changes in images taken at different times or under different conditions.

Image registration finds its applications in various fields like remote sensing, environmental monitoring, change detection, image mosaicing, weather forecasting, creating super-resolution images, integrating information into geographic information systems, in medicine - combining data from different modalities e.g. computer tomography (CT) and magnetic resonance imaging (MRI), to obtain more complete information about the patient, monitoring tumor growth, treatment verification, comparison of the patient's data with anatomical atlases, in cartography and in computer vision.

2. IMAGE FUSION

Image fusion is the process of combining significant information from two or more images into a single image. Image fusion is central to many challenges in medical imaging today and has a vast range of applications. The acquired CT and MRI images are in different coordinate system and in order to fuse these images, they must be in a common coordinate system. Hence, the first step in the proposed medical image fusion algorithm is image registration. In this study, intensity based image registration is applied as it is often well suited for medical images. The proposed approach integrates CT into MRI and vice versa. Figure-1 show the overall automated approach for image fusion technique.

Image fusion based on Discrete Wavelet Transform (DWT) developed faster. It has good time-frequency characteristics. The drawback of DWT is that problem of filling missing data occur. Fast Discrete Curvelet Transforms (FDCT) [3] is simpler, faster, and less redundant than DWT. The DTCWT [4-5] is an enhancement to the discrete wavelet transform (DWT), with main properties: It is close to shift invariant and directionally selective in two or higher dimensions. It achieves with a redundancy factor of two dimensional signals, which is substantially lower than DWT. After image registration, the registered image and the image to be fused are decomposed by using DTCWT at predefined scale. As DTCWT is a multi resolution analysis, the image is viewed at various level of resolution. It divides the image into several images at a different scale and can reduce the size of the image as the level increases. However, the overall characteristic of the original image

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can be approximated. After decomposition of both images, the proposed fusion approach is carried out on each subband independently.

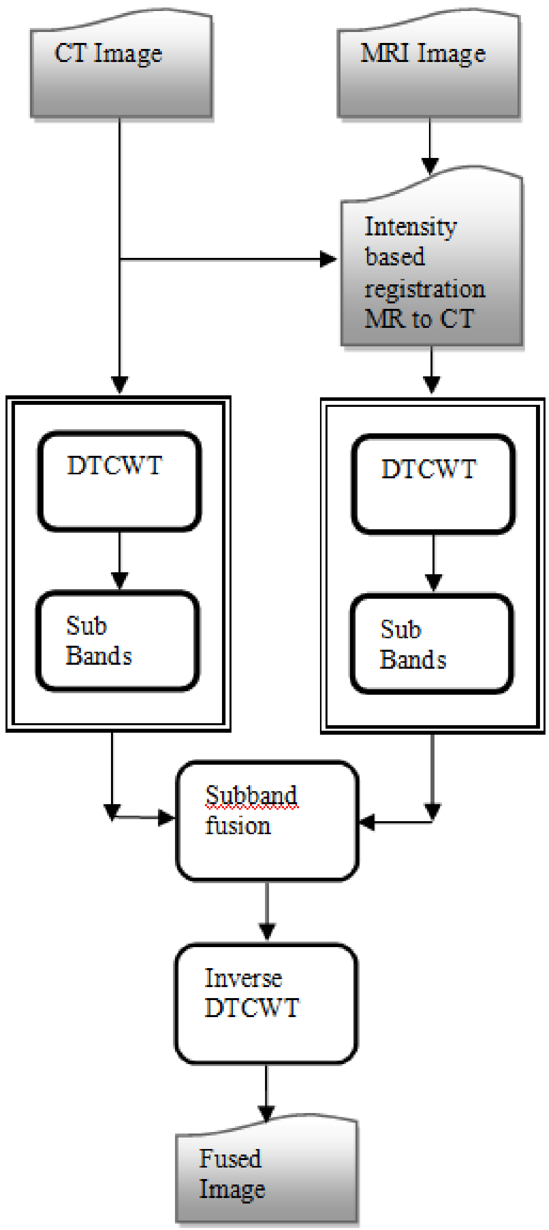

Figure-1. Block diagram of the medical image fusion technique.

In order to identify the salient region in each sub-band, thresholding is applied. In this study, clustering based image thresholding is used [13]. It assumes that the input image has bi-model histogram and calculates optimum threshold value based on their intra class variance.

3. STEPS INVOLVED IN IMAGE REGISTRTATION

Image Registration Methods consist of the following steps as per Zitova and Flusser [6]: Feature Detect, Feature matching, Transform model estimation and image resampling. Figure-2 illustrates the steps involved in Image Registration.

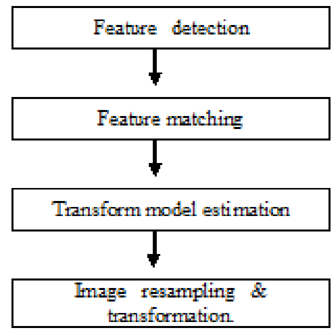

Figure-2. Steps involved in Image Registration.

- Feature detection: Salient and distinctive objects (closed-boundary regions, edges, contours, line intersections, corners, etc.) in both reference and sensed images 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 [6].

The image registration process involves designating one image as the reference (also called the reference image or the fixed image), and applying geometric transformations to the other image [8]. So that they align with the reference. Images can be misaligned for a variety of reasons. Commonly, the images are captured under variable conditions that can change camera perspective. Misalignment can also be the result of lens and sensor distortions or differences between capture devices. A geometric transformation maps locations in one image to new locations in another image [9]. The step of determining the correct geometric transformation parameters is key to the image registration process. The different types of transformation models are:

- Rigid Transformation Model - It is a linear transformation and can be represented as a 4x4 matrix. It composed of 3 rotations and 3 translations. It is used for within-subject registration when there is no distortion.
- Affine Transformation Model - It is a linear transformation and can be represented as a 4x4 matrix. It composed of 3 rotations, 3 translations, 3 stretches and 3 shears. It used for within-subject registration when there is Global-overall distortion.

- Piecewise Affine Transformation Model - It is a non-linear transformation and typically use different affine transformation for different parts of the image.
- Nonrigid Transformation Model - It is a non-linear transformation and has no matrix representation. It needed for inter-subject registration and distortion correction.

4. IMAGE REGISTRATION TECHNIQUES

The process of image registration is an automatic or manual procedure which tries to find corresponding points between two images and spatially align them to minimize a desired \error", i.e. a consistent distance measure between two images [10]. This process is needed in various computer vision applications, such as stereo depth perception, motion analysis, change detection, object localization, object recognition, and image fusion [11]. The various image registration schemes are

- Intensity Based Image Registration [12] - maps certain pixels in each image to the same location based on relative intensity patterns. This approach is best suited for workflows that involve a large collection of images.
- Control Point Registration - allows to manually selecting common features in each image to map to the same pixel location. This method of registration is best suited for images that have distinct features.
- Image Registration using Mutual Information - allows to aligning images by rotation and translation. Mutual Information is calculated using Joint histogram [14] calculation between two images. For each angle of rotation all translation parameters are checked. The images must have correct relative sizes with respect to each other. No resizing is incorporated in this registration.
- Phase correlation based Image Registration - The phase correlation technique determines the translational movement [19]. This method shows excellent robustness against random noise.

5. INTENSITY BASED IMAGE REGISTRATION

In intensity-based automatic image registration, the following are specified [15].

i) a pair of images
ii) a metric
iii) an optimizer and
iv) the transformation type.

The image similarity metric compares two images and a scalar value is returned. The method used to minimize or maximize the similarity metric is defined by the optimizer [15]. The two dimensional transformation used to bring the moving image in alignment with the reference image is specified by the transformation type [15]. The Figure-3 shows the flow of intensity based automatic image registration [15].

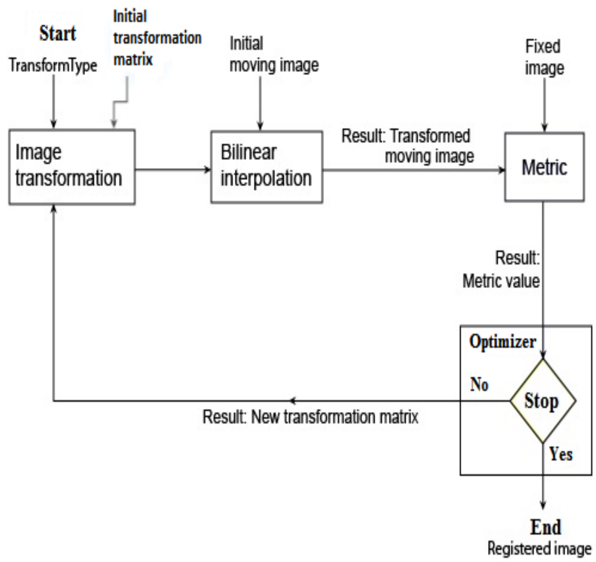

Figure-3. Intensity based image registration.

6. IMAGE REGISTRATION USING MUTUAL INFORMATION

Image registration methods based on mutual information criteria have been widely used in Multimodal medical image registration and have shown hopeful results. Although the information Content of the images being registered is constant, the information content of the portion of each image that overlaps with other image will change with each change estimated registration transformation [18]. Therefore a suitable technique for measuring joint entropy is to measure with respect to marginal entropy. This measure is known as Mutual Information / (A, B) [17]. It can be independently and simultaneously proposed for multimodal image registration.

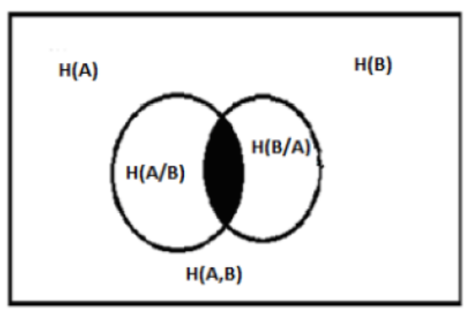

Figure-4. Mutual information.

$$/ (A(B) = H(A) + H(B) - H(A,B)$$

Where H (A, B) is joint entropy and H(A/B) & H(B/A) are conditional entropy.

Mutual information is a direct measure of the amount of information common between the two images as shown in Figure-4. During image registration, however, different transformation estimates are evaluated, and these

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transformation estimates will result in varying degree of overlap between images, though it is better than joint entropy [18]. The problem has been addressed by proposing various normalized form of mutual information that is more overlap independent [18]. Mutual information can be considered as a measure of how one image explains the other; it is maximized at the optimal alignment. In this method, first read reference main image and image to be registered. Then use mutual information as similarity criteria. Now calculate the angle of rotation and scale. Finally rotate the image with calculated angle of rotation and scale image accordingly.

7. RESULTS AND DISCUSIONS

The performance of the proposed fusion algorithm is evaluated in the pairs of CT and MR images obtained from patients in comparison with primitive fusion techniques such as maximum rule, minimum rule and mean rule. The performance is evaluated by using two metrics; Peak Signal to Noise ratio (PSNR) and edge based similarity measure ($Q^{AB/F}$).

The PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation [16]. The PSNR is most commonly used as a measure of quality of reconstruction in image enhancement. The PSNR is defined as:

$$PSNR = 20.\log_{10} \frac{(peak\ to\ peak\ value\ of\ the\ referenced\ image)^2}{\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left[\hat{f}(x,y) - f(x,y)\right]^2} \quad (1)$$

where $f(x,y)$ and $\hat{f}(x,y)$ are the input image and fused image respectively and peak to peak value of the referenced image is the maximum pixel value in the image. Table-1 shows the performance of the proposed fusion algorithm in comparison with existing algorithms by using Peak Signal to Noise ratio (PSNR).

Table-1. Performance evaluation of the fusion methods based on PSNR using intensity based image registration.

Image	DWT	FDCT	DTCWT
The PSNR performance w.r.t. MRI			
Image 1	26.43	27.30	46.99
Image 2	29.30	29.80	42.59
Image 3	34.62	37.26	46.29
The PSNR performance w.r.t. CT			
Image 1	36.05	36.90	48.85
Image 2	30.05	30.69	41.66
Image 3	26.14	26.37	43.62

Table-2. Performance evaluation of the fusion algorithm based on PSNR using mutual information based image registration.

Image	DWT	FDCT	DTCWT
The PSNR performance w.r.t. MRI			
Image 1	25.63	28.70	46.49
Image 2	28.76	28.98	43.46
Image 3	34.26	38.15	47.92
The PSNR performance w.r.t. CT			
Image 1	36.45	35.94	48.85
Image 2	30.75	30.18	41.25
Image 3	26.94	25.86	43.13

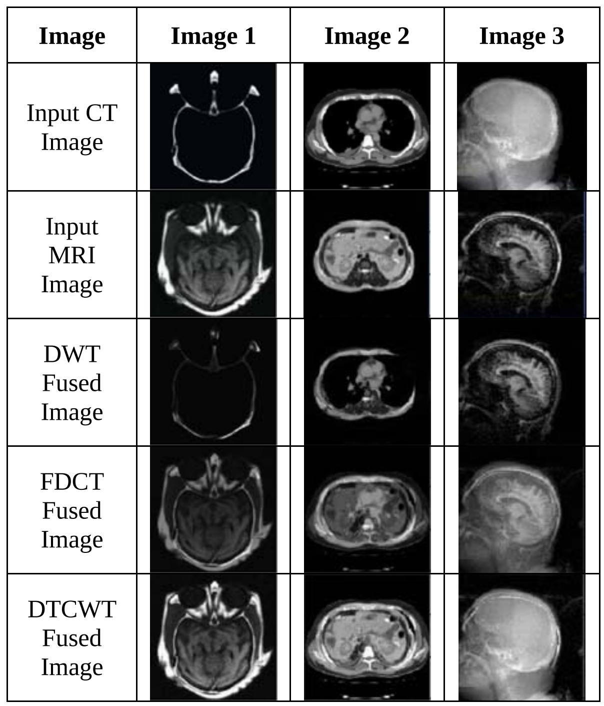

Figure-5. CT image, MR image and Fused images.

8. CONCLUSIONS

From the results of Table-1 and Table-2, fusion of medical images using DWT, FDCT and DTCWT fusion methods are suited for both intensity based image registration and mutual information based image registration. This work has offered taxonomy of existing image registration techniques and a framework to aid in the selection of the appropriate technique for a specific problem. Image registration is one of the most important tasks when integrating and analyzing information from various sources. It is a key stage in medical image fusion. The performance is evaluated by using quantitative measures such as PSNR values. From the experimental results, it is concluded that the fusion algorithms can preserve more useful information of CT and MR images on a single image using Intensity and Mutual Information based image registration schemes.

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