International Journal of Scientific & Engineering Research, Volume 4, Issue 7, July-2013 129
ISSN 2229-5518

An Overview of Different Image Fusion Methods for Medical Applications

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Abstract— Image fusion is an important research topic in many related areas such as computer vision, remote sensing, robotics, and medical imaging etc. Image fusion is the process of combining relevant information from several images into single image. The final output image can provide more information than any of the single image. Now-a-days, almost all areas of medical diagnosis are impacted by the digital image processing. For medical diagnosis, MRI and CT images are of main concern, both images give special sophisticated characteristics of the organ to be imaged. Computed Tomography (CT) provides the best information on denser tissue like bones. Magnetic Resonance Image (MRI) provides better information on soft tissues. With more available multimodality medical images in clinical applications, the idea of combining images from different modalities become very important and medical image fusion has emerged as a new promising research field that help physicians in the diagnosis process. More research has been done for fusion of MRI and CT images using traditional wavelet transform and few attempts using curvelet transform. This paper provides an overview of different image fusion methods for medical applications in brief and to improve the fusion results proposed method is described shortly.

Index Terms— CT image, Curvelet Transform, Fast discrete curvelet transform (FDCT), Image fusion, MRI image, Wavelet Transfor

1 INTRODUCTION

Image fusion is a tool to combine multimodal images by using image processing techniques. Specifically it aims at the integration of disparate and complementary data in order to enhance the information apparent in the images, as well as to increase the reliability of the interpretation [1],[2]. Due to the advent of new diseases complementary information are required from different modalities. When sensitive organs like brain are scanned, both magnetic resonance imaging and computed tomography scans are preferred. CT provides best information about denser tissue and MRI offers better information on soft tissue [2],[3],[4]. These complementarities have led to idea that combining images acquired with different medical devices will generate an image that can offer more information than individual image. So, it is expected that fusion of MRI and CT images of the same organ would result in an integrated image of much more details [3]. Image fusion is deeply related to many different image processing fields such as satellite imaging, remote sensing and medical imaging. The study in the field of image fusion has evolved to serve the advance in satellite imaging and then, it has been extended to the field of medical imaging. Several fusion algorithms have been proposed extending from the simple averaging to the curvelet transform [1],[3].

Literature Survey reveals that, Shih-Gu Huang [1] proposed different image fusion methods that have been developed to perform image fusion. Wavelet transform used for image fusion produced superior results than different methods. S. Vasuki, S. Gandhimathi et al. [2] proposed integration of wavelets and PCA for fusion of medical images. Comparative analysis is done with different types of wavelets. The results obtained are suitable for medical image fusion. Smt. G. Mamatha, L. Gayatri [3] proposed wavelet and curvelet transform for image fusion and comparison was done between these two transform. The results show superiority of curvelet transform than wavelet transform. A. Soma Sekhar, Dr. M. N. Giri Prasad [4] proposed integration of wavelet transform and PCA based image fusion for medical images and compare results with different types of wavelets, which gives better fusion results. Bharat and E.S Karthik Kumar [5] proposed implementation of 2-G curvelet transform for image fusion which is fast and simpler than 1-G curvelet transform. Researchers have made lot of work on wavelet and curvelet transform for image denoising, image contrast enhancement, fusion of satellite images, image retrieval, texture analysis and object recognition. Few attempts were made for fusion of the MR and CT images using curvelet transform. This paper focuses more on image fusion for medical images. It was found that more work is done using wavelet transform for fusion of MRI and CT application. The traditional wavelets perform well only at representing point singularities since they ignore the geometric properties of structures and do not exploit the regularity of edges.

The curvelet transform has evolved as a tool for the representation of curved shapes and regularity of edges. The wavelet transform applied to these two images preserve both spectral and spatial information and gives image details but it has limited directionality to deal with curved shapes. The solution to this is curvelet transform which has ability to deal with

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ISSN 2229-5518

curved shapes.

To fuse MRI and CT images there are many fusion algorithms based on Wavelet. Now in this paper, a new fusion method is proposed based on both wavelet and Second generation Curvelet Transform. Since using Wavelet Transform edge information can't be extracted clearly. In Medical Image Fusion the edge information is most important so a new method can be used to fuse these images. It's a combination of Wavelet and Curvelet based algorithm which is used for fusion to extract edge information and the process is simple to analyze the fusion of the images. The performance of proposed method can be compare with different types of wavelets used in image fusion.

2 Wavelet Theory Used In Image Fusion

2.1 Wavelet Theory

Wavelets are finite duration oscillatory functions with zero average value. The irregularity and good localization properties make them better basis for analysis of signals with discontinuities. Wavelets can be described by using two functions viz. the scaling function f (t), also known as father wavelet and the wavelet function or mother wavelet. Mother wavelet ψ (t) undergoes translation and scaling operations to give self-similar wavelet families as in (1).

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right), (a, b \varepsilon R), a > 0 \qquad (1)$$

Where, a is the scale parameter and b the translation parameter. Practical implementation of wavelet transforms requires discretization of its translation and scale parameters by taking,

$$a = a_0^j, b = ma_0^j b_0 \quad j, m \varepsilon Z \qquad (2)$$

Thus, the wavelet family can be defined as:

$$\psi_{j,m}(t) = a_0^{-j/2}\psi(a_0^{-j}t - mb_0) \;\; j, m \varepsilon Z \qquad (3)$$

.

2.2 Types of Wavelets

The wavelets used in image fusion can be classified into three categories Orthogonal, Bi-orthogonal and A'trous wavelet. Although these wavelets share some common properties, each wavelet has a unique image decompression and reconstruction characteristics that lead to different fusion results [2],[6], [13].

1. Orthogonal Wavelet

The dilations and translation of the scaling function ϕj, k(x) constitute a basis for Vj, and Similarly Ψj, k(x) for Wj, if the ϕj, k(x) and Ψj, k(x) are orthonormal, they include the following property.

$$\mathbf{Vj} \perp \mathbf{Wj} \qquad (4)$$

These results in a representation of a single image, containing multiscale detail information from all component images involved. This representation leads to multiple applications ranging from multispectral image fusion to color and multivalued image enhancement, denoising and segmentation.

2. Bi-orthogonal Wavelet

For biorthogonal transform, perfect reconstruction is available. Orthogonal wavelets give orthogonal matrices and unitary transforms; biorthogonal wavelets give invertible matrices and perfect reconstruction. For biorthogonal wavelet filter, the Low-pass and high-pass filters do not the same length. The low-pass filter is always Symmetrical, while high pass filter could be either symmetric or anti-symmetric. The method allows unusual flexibility in choosing a filter for any task involving the multiresolution analysis and synthesis.

3. A'trous (Non-orthogonal) Wavelet

A'trous is a kind of non–orthogonal wavelet that is different from orthogonal and biorthogonal. It is a stationary or redundant transform, i.e. decimation is not implemented during the process of wavelet transform, while the orthogonal or biorthogonal wavelet can be carried out using either decimation or undecimation mode. The enhancement of the spatial information often leads to the distortion of the information in the spectral domain.

3 Existing Methods

3.1 Wavelet Transform

The most common form of transform type image fusion algorithms is the wavelet fusion algorithm due to its simplicity and its ability to preserve the time and frequency details of the images to be fused. Wavelet transform fusion is more formally defined by considering the wavelet transforms of the two registered input images together with the fusion rule .Then, the inverse wavelet transform is computed, and the fused image is reconstructed [1], [3], [5], [6] . 2-D DWT is very useful for image processing because the image data are discrete and the spatial and spectral resolution is dependent on the frequency. The DWT has the property that the spatial resolution is small in low-frequency bands but large in high frequency bands.

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ISSN 2229-5518

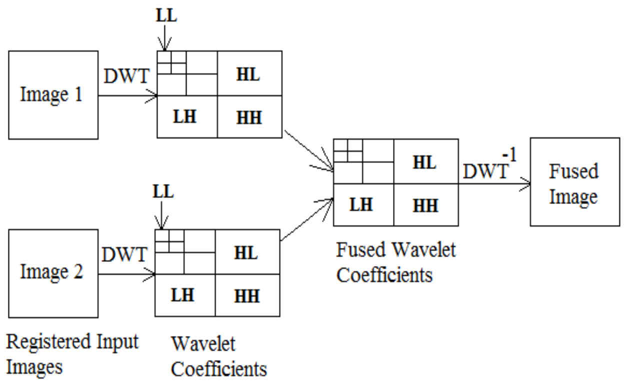

Fig.1 Block diagram of Discrete Wavelet transform

A schematic diagram of the wavelet fusion algorithm of two registered images $I_1(X_1, X_2)$ and $I_2(X_1, X_2)$ is depicted in fig.1. It can be represented by the following equation,

$$I(X_1, X2) = W^{-1}\{\Psi[W(I_1(X_1, X_2)), W(I_2(X_1, X_2))]\} \quad (5)$$

Where W, $W^{-1}$and ψ are the wavelet transform operator, the inverse wavelet transform operator and the fusion rule, respectively. There are several wavelet fusion rules that can be used for the selection of wavelet coefficients from the wavelet transforms of the images to be fused. The most frequently used rule is the maximum frequency rule which selects the coefficients that have the maximum absolute values. The wavelet transform concentrates on representing the image in multi-scale and it is appropriate to represent linear edges. For curved edges, the accuracy of edge localization in the wavelet transform is low. So, there is a need for an alternative approach which has a high accuracy of curve localization such as the curvelet transform.

3.2 Curvelet Transform

Candes and Donoho justifies that ,though wavelet transform exhibits time frequency localization and yields acceptable fused output, the edges and singularities are not well represented. Also it suffers from limited directionality. The point singularity is better suited for wavelets in 1 dimensional signals ,but 2 dimensional signals like images have curve or line singularities where wavelets fails to approximate. Hence to process images of sparse nature, Fast Discrete curvelet transform is recommended by the researchers. E. J. Candes and D. L. Donoho put forward curvelet transform theory in 2005[7]. The curvelet transform is a multiscale directional transform that allows an almost optimal nonadaptive sparse representation of objects with edges. Curvelet transform consisted of special filtering process and multiscale Ridgelet transform. Curvelet transform is anisotropy, which can represent the contour of image more sparsely and provide more information for image processing. The curvelet transform has gone through two major revisions. The first generation curvelet transform used a complex series of steps involving the ridgelet analysis of radon transform of an image. In this curvelet approach, input image is first decomposed into a set of sub bands each of which is then partitioned into several blocks for ridgelet analysis. The ridgelet transform is implemented using the Radon transform and the 1-D wavelet transform. During the ridgelet transform, one of the processes is the spatial partitioning which involves overlapping of windows to avoid blocking effects. It results in a large amount of redundancy. The Curvelet Co-efficient has taken and depending upon the maximum value the fusion between the images takes place. It is used to extract the edge information, the ridgelet transform is complicated so the process is very time consuming and the performance was exceeding slow.

The second generation curvelet transform discarded the use of the ridgelet transform, thus reduced the amount of redundancy in the transform and increased the speed considerably. Two fast discrete curvelet transform (FDCT) algorithm were introduced. The first algorithm is based on unequally-spaced FFT while the second is based on the wrapping of specially selected Fourier samples. In this paper, we focus on the "wrapping" version of the curvelet transform.

The algorithm can be summarized as follows-

1. Apply the 2D FFT and obtain Fourier samples $\hat{f}[n_1, n_2],\ -n/2 \leq n_1, n_2 < n/2.$
2. For each scale j and angle l form the product $\tilde{U}_{j,\ell}[n_1, n_2]\hat{f}[n_1, n_2].$
3. Wrap this product around the origin and obtain

$$\tilde{f}_{j,\ell}[n_1, n_2] = W(\tilde{U}_{j,\ell}\hat{f})[n_1, n_2]$$

Where, the range for n1 and n2 is now $0 \leq n1 < L1,j$ and $0 \leq n2 < L2,j$ (for θ in the range $(-\pi/4, \pi/4)$).

4. Apply the inverse 2D FFT to each ˜ fj,l, hence collecting the discrete coefficients $c^D(j, l, k)$.

It is clear that this algorithm has computational complexity O (n2 log n).

3.3 Problem Statement

The wavelet transform concentrates on representing the image in multi-scale and it is appropriate to represent linear edges. For curved edges, the accuracy of edge localization in the wavelet transform is low. Normally, when a wavelet transformation alone is applied the results are not so useful for analysis. For medical applications, MRI and CT images plays very important role. Since medical images have several objects and curved shapes. So, there is a need for an alternative approach which has a high accuracy of curve localization, it is expected that the curvelet transform would be better in their fusion.

4 Proposed Image Fusion Method

Wavelet transform is useful for objects with point singularities and analyses the feature of images in detailed, but it does not provide information about edges clearly. While curvelet transform is more useful for the analysis of images having curved shape edges. So, in this paper, a new image fusion technique based on the combination of wavelet and a fast discrete curvelet transform is proposed, which describe the curved shapes of images and analyses feature of images better. In medical image fusion, edges play a very important role. This new fusion technique is used to fuse the MRI and CT images. These two images contain complementary information. The Flow of proposed image fusion method can be given as follows:

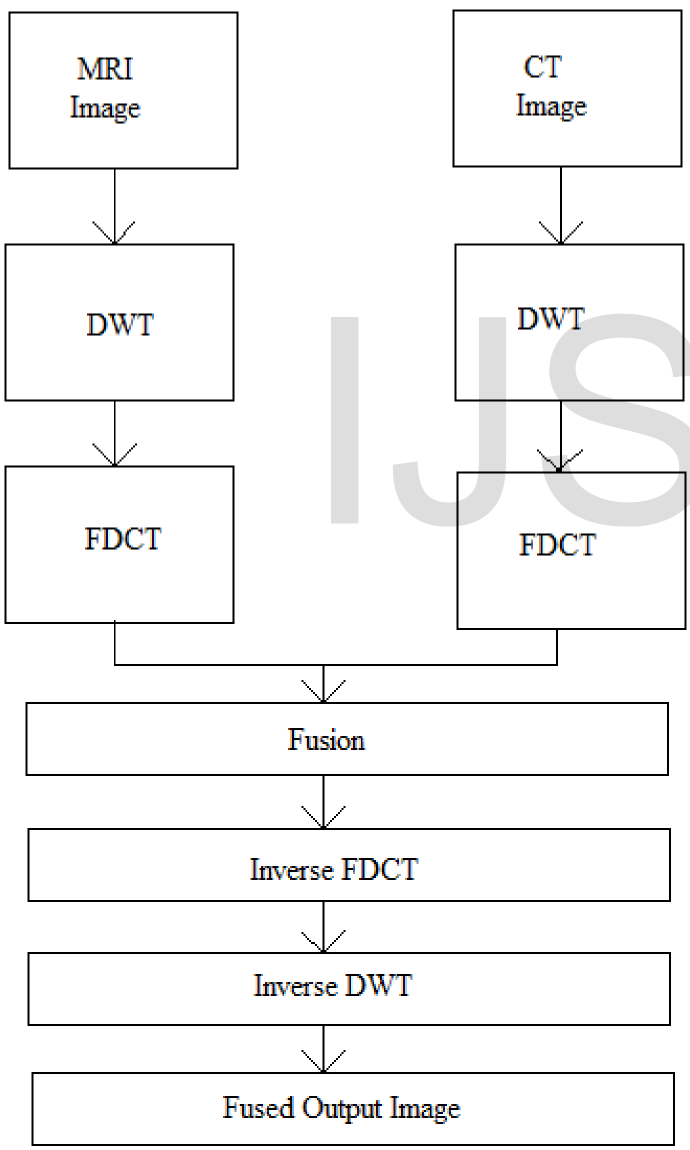

Fig. 2 Flow of proposed image fusion method

4 Conclusion

In many important imaging applications, images exhibit edges and discontinuities across curves. In biological imagery, this occurs whenever two organs or tissue structures meet. Especially in image fusion the edge preservation is important in obtaining the complementary details of the input images. As edge representation in curvelet transform is better and wavelet transform gives image details. The combination of wavelet and fast discrete curvelet transform applied to medical images may give better fusion results useful for diagnosis. This can be used to give the edge information clearly and speed of computation will be high compare to other methods. The proposed method may be useful for researchers for further research work on image fusion.

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