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A Review on Multilevel Image Fusion Using Wavelet and Curvelet Transform

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Abstract— ***Image fusion is widely used term in different applications namely satellite imaging, remote sensing, multifocus imaging and medical imaging. This paper presents a literature review on multi-level image fusion in which fusion is carried out in two stages. Firstly, discrete wavelet or Fast Discrete Curvelet transform is applied on both source images and secondly image fusion is carried out with either spatial domain method like Averaging. Further, comparative analysis of fused image obtained from both Discrete Wavelet and Fast Discrete Curvelet transform is done which proves effective image fusion using proposed Curvelet transform than Wavelet transform through enhanced visual quality of fused image and by analysis of 7 quality metrics parameters. The proposed method is very innovative which can be applied to medical and multifocus imaging applications in real time. These analyses can be useful for further research work in image fusion.***
Keywords— ***Discrete Wavelet Transform, Fast Discrete Curvelet Transform, Image fusion, multifocus image, entropy, PSNR***

I. INTRODUCTION

This document is a template. With the continuous development of sensor technology, people have more and more ways to obtain images, and the image fusion types are also increasingly rich, such as the Image fusion of same sensor, the multi-spectral image fusion of single-sensor, the image fusion of the sensors with different types, and the fusion of image and non-image. Traditional data fusion can be divided into three levels, which are pixel-level fusion, feature-level fusion and decision level fusion. The different fusion levels use different fusion algorithms and have different applications, generally, we all research the pixel-level fusion. Classical fusion algorithms include computing the average pixel- pixel gray level value of the source images, Laplacian pyramid, Contrast pyramid, Ratio pyramid and Discrete Wavelet Transform (DWT). However, computing the average pixel-pixel gray level value of the source images method leads to undesirable side effects such as contrast reduction. Wavelet-based image fusion method provides high spectral quality of the fused satellite images. However, the fused image by Wavelets has much less spatial information than those by the Brovey, IHS, and PCA methods. The spatial information of fused image is an important factor as much as the spectral information in many remote sensing applications. In particular, this improves the efficiency of the image fusion application, such as unsupervised image classification. In other words, it is necessary to develop advanced image fusion method so that the fused images have the same spectral resolution as the multispectral images and the same spatial resolution as the panchromatic image with minimum artifacts.
The basic idea of DWT based methods is to perform decompositions on each source image, and then combine all these decompositions to obtain composite representation, from which the fused image can be recovered by finding inverse transform. This method is shown to be effective. However, wavelets transform can only reflect "through" edge characteristics, but cannot express "along" edge characteristics. At the same time, the wavelet transform cannot precisely show the edge direction since it adopts isotropy. According to the limitation of the wavelet transform, Donoho et al. was proposed the concept of Curvelet transform, which uses edges as basic elements, possesses maturity, and can adapt well to the image characteristics. Moreover, Curvelet Transform has anisotropy and has better direction, can provide more information to image processing. Through the principle of Curvelet transform we know that: Curvelet transform has direction characteristic, and its base supporting session satisfies content anisotropy relation, except have multi scale wavelet transform and local characteristics. Curvelet transform can represent appropriately the edge of image and smoothness area in the same precision of inverse transform. Image fusion is a useful technique for merging similar sensor and multi-sensor images to enhance the information content present in the images. Image fusion has several applications in various areas such as Medical Imaging, Satellite Imaging, Remote sensing, Robotics, Military applications and so on [1-4]. Image fusion has the following advantages:-
It improves the reliability by taking care of the redundant information.
It improves the capability as it keeps complementary information.
Image fusion is a sequel to data fusion. The basic limitation of the wavelet fusion algorithm is in fusion of curved shapes and this can be accurated by the application of the Curvelet transform, would result in the better fusion efficiency. Curvelet transform involves the segmentation of the whole image into small overlapping tiles. Then the ridgelet transform is itself a 1-D wavelet transform applied on the Radon transform of each tile, which itself is a shape detection tool. The purpose of the

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segmentation process is to approximate curved lines by small straight lines. The overlapping of tiles aims at avoiding edge effects. Initially, Curvelet transform was proposed for image denoising [5,6]. It is expected that the Curvelet transform would produce better fusion results than those obtained using the Wavelet transform. We have selected wavelet here, because of its features such as orthogonality, short support, symmetry, and high degree of vanishing moments and another curvelet, which deals with the curved shapes.

This paper is organized as follows. Section II gives detail about discrete wavelet transform. In section III, Curvelet transform is presented. Parameters evaluation is discussed in Section IV. The conclusion is described in Section V.

II. DISCRETE 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 transfer of the wavelet fusion algorithm of two registered images P1 ($x1$, $x2$) and P2 ($x1$, $x2$). It can be represented by the following equation:

$$I(x1, x2) = W-1(\psi(W(P1\ (x1, x2)), W(P2\ (x1, x2))))$$

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 averaging rule. 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. Algorithm for wavelet transform is:

The two input images are registered initially.

The wavelet transform steps are performed for both images (each input image is analyzed and a set of wavelet Coefficients are generated).

The maximum frequency fusion rule or any other rule is used for the fusion of the wavelet coefficients.

The inverse wavelet transform step is performed (The fused coefficients are subjected to the inverse wavelet transform) to obtain the fused image.

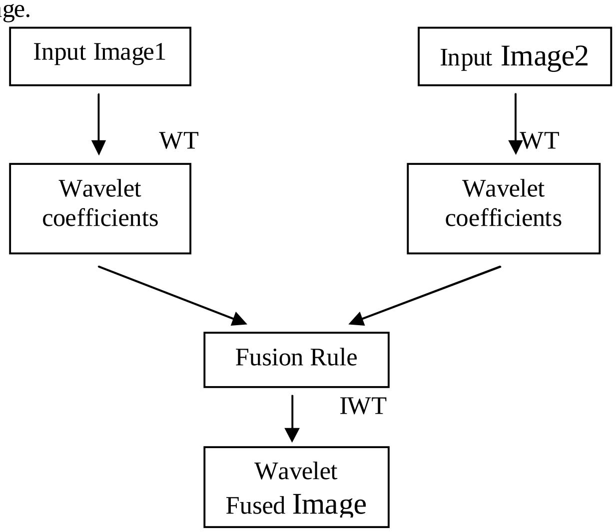

Fig 1. Image Fusion based on Wavelet Transform

Discrete wavelet transform with Haar based fusion scheme is discussed herewith**.** The Haar wavelet is the first known wavelet. The Haar wavelet ψ(t) can be described as and its scaling function φ(t) can be described as

$$\Psi(t) = \begin{cases} 1 & 0 \le t \le 1/2 \\ -1 & 1/2 \le t \le 1 \\ 0 & \text{otherwise} \end{cases}$$

The 2x2 Haar matrix is associated with

H2 = [1 1, 1   −1]

The filters, thus, considered here would be

F1 = [∗ 0.5 ∗ 0.5 ∗]

F2 = [∗ 0.5 ∗ 0.5 ∗]

The couple of filters, when applied on the input images matrices, would produce 4 resultant matrices. The fourth matrix, which would consist of all the high frequencies, would act as the input matrix for the next level of decomposition. The other three matrices, consisting of the low frequencies, are used to produce 3 pyramids at each level. The pyramids are produced as in pyramidal method. The re-composition process is performed with the help of the three pyramids formed at each level of decomposition.

III.DISCRETE CURVELET TRANSFORM

The Curvelet transform (CVT) is a multi-scale transform proposed by Candes and Donoho and is derived from the Ridgelet transform. The Curvelet transform is suited for objects which are smooth away from discontinuities across curves. Fourier Transform does not handle point's discontinuities well because a discontinuity point affects all the Fourier Coefficients in the domain. Moreover, Wavelet transform handles point discontinuities well and doesn't handle curve discontinuities well. Curvelet transform handles curve discontinuities well as they are designed to handle curves using only a small number of coefficients. Curvelet transform has several applications in various areas such as image denoising, image fusion, Seismic exploration, Turbulence analysis in fluid mechanics and so on [14-16].

The algorithm is as:

The image P is split up into three subbands P1,P2 and P3 using the additive wavelet transform.

Tiling is performed on the subbands P1 and P2.

The discrete Ridgelet transform is performed on each tile of the subbands P1 and P2.

It has the following steps:

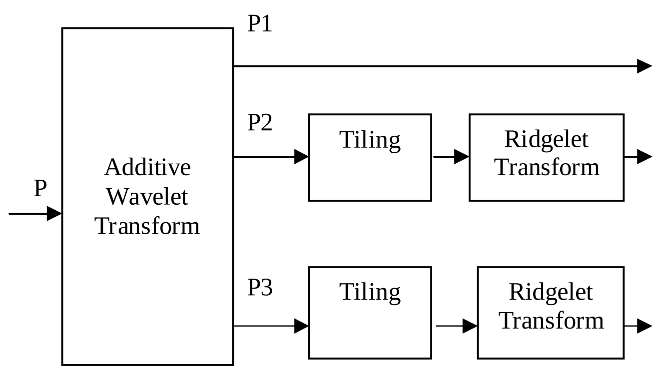

Fig 2. Image Fusion based on Curvelet Transform

A. Subband Filtering

The purpose of this step is to decompose the image into additive components; each of which is a Subband of that image. This step isolates the different frequency components of the image into different planes without down sampling as in the traditional wavelet transform.

B. Tilting

Tiling is the process by which the image is divided into overlapping tiles. These tiles are small in dimensions to transform curved lines into small straight lines in the subbands P1 and P2. The tiling improves the ability of the curvelet transform to handle curved edges.

C. Ridgelet Transform

The ridgelet transform belongs to the family of discrete transforms employing basis functions. To facilitate its mathematical representation, it can be viewed as a wavelet analysis in the Radon domain. The Radon transform itself is a tool of shape detection. So, the ridgelet transform is primarily a tool of ridge detection or shape detection of the objects in an image.

IV. QUALITY METRICS

Image Quality is a characteristic of an image that measures the perceived image degradation (typically, compared to an ideal or perfect image). Imaging systems like the fusion algorithm may introduce some amounts of distortion or artifacts in the signal, so the quality assessment is an important problem. Image Quality assessment methods can be broadly classified into two categories:

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Full Reference Methods (FR) and No Reference Method (NR). In FR, the quality of an image is measure in comparison with a reference image which is assumed to be perfect in quality.

NR methods do not employ a reference image. The image qualities metrics considered and implemented here fall in the FR category. In the following subsections, we discuss the SSIM and some other image quality metrics implemented to assess the quality of our fused image.

A. Structural Similarity Index Measure (SSIM)

The Structural similarity index measures follows that a measure of structural information change can provide a good approximation to perceived image distortion. The SSIM compares local patterns of pixel intensities that have been normalized such as luminance and contrast. It is an improved version of traditional methods like PSNR and MSE. The SSIM index is a decimal value between 0 and 1. A value of 0 would mean zero correlation with the original image, and 1 means the exact same image

B. Entropy

Entropy is used to measure the information content of an image. Entropy is sensitive to noise and other unwanted rapid fluctuations. An image with high information content would have high entropy.

C. RMSE

It is computed as the root mean square error of the corresponding pixels in the reference image and the fused image.

D. Quality Index

This measures how much of the salient information contained in reference image has been transformed into the fused image. The range of this metric is -1 to 1 and the best value 1 would be achieved if and only if reference and fused images are alike.

E. PSNR

This metric will be high when the reference and fused images are alike. Higher value implies better fusion.

V. CONCLUSION

Selection of proper fusion technique depends on the specific application. Spatial domain provides high spatial resolution. But in spatial domain spectral distortion is the main drawback therefore transform domain image fusion is done. Based on the analysis done on various transform domain techniques such as, wavelet transform, discrete wavelet transform, curvelet transform. It has been concluded that each technique it meant for specific application and one technique has an edge over the other in terms of particular application. Finally the image quality assessment parameters have been reviewed and determine the role of individual image quality assessment parameter to determine the quality of the fused image.

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