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Image Fusion Based On Wavelet Transform

Souparnika Jadhav
Department of Electronics and Communication Engineering, VTU,MMEC, Belgaum, Karnataka, India
Email: souparnika.j@gmail.com

Abstract— ***In various applications, image fusion plays an important role. Image fusion is nothing but combining two or more images into a single image by extracting important features from each of the images. The fusion of images is often required to fuse images that are captured from instrument .Complex Wavelet based fusion techniques have been used in combining perceptually important features. A novel image fusion technique based on dual-tree complex wavelet transform is presented in this paper. Dual tree CWT is an extension to discrete wavelet transform (DWT). Our approach is based on a gradient domain technique that preserves important local perceptual features which avoids many problems such as ghosting, aliasing and haloing.***

Keywords-Image fusion, DTCWT, gradient approach, wavelet based fusion, wavelet transforms.

I. Introduction

Image fusion is the process by which two or more images are combined to form single image retaining the important features from each of the original images. The fusion is required to fuse images captured from different instrument which may be multi-sensor, multi-focus and multi-modal images.

Fusion techniques include from simplest method of pixel averaging to more complicated methods such as principal component analysis and wavelet transform fusion. There are many methods to fuse images and can be classified, depending on whether the images to be fused in the spatial domain or in frequency domain.

In order to overcome short comings of DWT Kingsbury[1,7,8] introduced the DTCWT consisting of two trees of real-valued wavelet filters that operate in parallel, with the filters designed to produce the real and imaginary parts of the complex-valued coefficients. We can extend it to higher dimensions.

The image processing technology has grown tremendously both in terms of applications and requirements it need. The image fusion scheme is facing problem in fusing images acquired from different modalities, to fuse colour images, to fuse images of different resolution, size and images of different format, to create surreal (un-real) images. To ensure edges in the images that has to be included in the fused algorithm in order to minimize the effect of noise.

One of the most promising wavelet transform to overcome all these problems is Dual-tree complex wavelet transform (DT-CWT). DT-CWT method is able to retain edge information without significant ringing artefacts. It is also good at retaining textures from the input images. All these features contribute to the increased shift invariance and orientation selectivity of the DT-CWT.

The main objective of the project is to fuse the images that have been acquired from different instrument like multisensory, multifocal and multimodal images and even real time images. To fuse images of different size. To fuse colour images and also to fuse images of different formats (e.g.: JPEG and PNG, PNG and JPG). To create surreal (un-real) images .The use of gradient ensures two fold effects to minimize the noise .The motivation for using the Dual Tree Complex Wavelet Transform for image fusion is its shift invariance together with its improved directional selectivity.

In this paper, an image fusion algorithm based on wavelet transform is proposed. In the proposed scheme, the images to be processed are decomposed into sub-images with the same resolution at same levels and different resolution at different levels and then the information fusion is performed using high-frequency sub-images under the 'gradient' approach and finally these sub-images are reconstructed into a resultant image having plentiful information.

Section II discusses a point-based method of image registration adopted as a pre processing step prior to fusion. In Section III, we have given a brief introduction to Complex Wavelet transform based Image Fusion. The proposed scheme for fusion of images based on wavelet transform is described in Section IV. Concluding remarks are cited in Section V. Acknowledgement in section VI.

II. Image Registration

It is necessary to register the images to perform fusion. In general, different sensors capture scene characteristics in different ways. We can integrate or fuse images of multi-focus, multi-sensor and multi-resolution only if the images are registered or positioned with respect to a common coordinate system. Image registration (in case of fusing two images) is the process of determining correspondence between all points in two images of the same scene or object. There are no of techniques for registering multimodal images. Brown [2] gave a good survey on image registration. Some of which are area based while some are point based. Point-based methods [3, 4] are simpler and more common. Linear methods use either the affine transformation or the geometric transformation like translation, rotation and scaling so as to minimize the distance measure or to maximize the similarity between these points [5]. Finally, this transformation function is used to map points in one image to points in the other.

III Complex Wavelet Transform

Complex wavelet transform is a powerful mathematical tool used in the fields of signal and image processing. It divides the function or signal into different scale components where each scale component has a resolution that it matches. The Fourier transform is based on complex-value. Thus, we can imagine that there exists a Complex Wavelet Transform (CWT) based on the complex-valued scaling function and the complex-valued wavelet function. The complex wavelet function is defined as

$$\psi_c(t) = \psi_r(t) + j\psi_i(t) \qquad (2.1)$$

where $\psi_r(t)$ and $\psi_i(t)$ forms a Hilbert transform pair, or we can say that

$$\psi_i(t) = H\{\psi_r(t)\} \qquad (2.2)$$

On the other hand, $\psi_r(t)$ is real and even symmetric and $\psi_i(t)$ is odd symmetric. Since $\psi_c(t)$ is composed of the Hilbert

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transform pair and the phase of is ψ_i (t) shifted by π/2, it supports the positive part of the spectrum.

By means of this property, we can form the basis with more directionality in addition to the horizontal, vertical and diagonal directions. The reason why the basis contains more directionality is described as follows.

The basis ψ(x, y) is composed of two 1D complex wavelet bases along horizontal and vertical directions. That is

$$\psi(x, y) = \psi(x)\,\psi(y) \quad (2.3)$$
$$= [\psi_h(x) + j\psi_g(x)]\,[\psi_h(y) + j\psi_g(y)]$$
$$= [\psi_h(x)\,\psi_h(y) - \psi_g(x)\,\psi_g(y)]$$
$$+ j[\psi_g(x)\psi_h(y) + \psi_h(x)\,\psi_g(y)]$$

We can observe that only the high frequency sub-band supports in ($+\omega_x$, $+\omega_y$). If we preserve the real part only and discard the imaginary part of ψ (x, y) then from the symmetry property, we know that the sub-band in ($-\omega_x$, $-\omega y$) also supports. The complex wavelet transform (CWT) has two real-valued DWTs. The DWT is shift variant because of the decimation operation exploited in the transform .because of this, a small shift in the input signal can cause a very different set of coefficients produced at the output. For that, Kingsbury [1, 7, 8] introduced a new kind of wavelet transform, called the DT-CWT or CWT, for short, which exhibits approximate shift invariant property and improves directional resolution when compared with that of the DWT. At each scale, the DT-CWT produces six directional sub-bands, oriented at $\pm 15^o$, $\pm 45^0$, and $\pm 75^0$ while the DWT produces only three directional sub-band oriented at 0^o , 45^0 and 90^0 transform

.

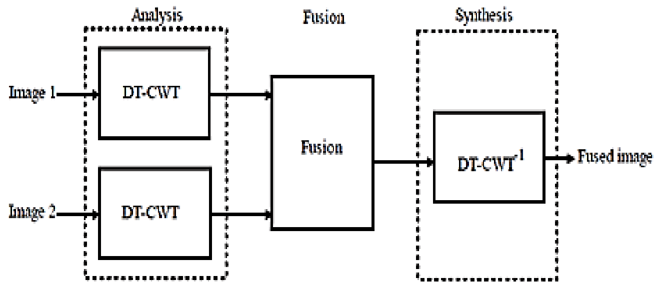

Fig 1: DTCWT

Complex transform uses complex wavelet filtering that decomposes the image into real and imaginary parts in transform domain. With the real and imaginary coefficients we can compute magnitude and phase information. The prime motivation for using the dual-tree complex wavelet transform was shift invariance. In many other wavelet decomposition small shifts of the input signal are able to move energy between output sub-bands. We can also achieve Shift invariance in DWT by doubling the sampling rate. This is affected in the DT-CWT by eliminating the down sampling by 2 after first level filter. Two fully decimated trees are then produced by down sampling, affected by taking first even and then odd samples after the first level of filters. To get uniform intervals between the two trees samples, the subsequent filters need half a sample different delay in one tree. Application to image can be achieved by separable complex filtering in two dimensions. The real 2-D dual-tree DWT of an image x is implemented using two critically-sampled separable 2-D DWTs in parallel. Then we take pair of sub-bands and compute sum and difference. The complex 2-D DT-DWT also gives rise to wavelets in six distinct directions. The complex 2-D dual-tree is implemented using four separable 2-D DWTs which operates in parallel as shown in figure (2). 2-D structure needs four trees for analysis and synthesis. The pair of conjugate filters applied to two dimensional images (x, y) can be expressed as:

$$(h_x + jg_x)(h_y + jg_y) = (h_x h_y - g_x g_y) + j(h_x g_y + g_x h_y)$$

.

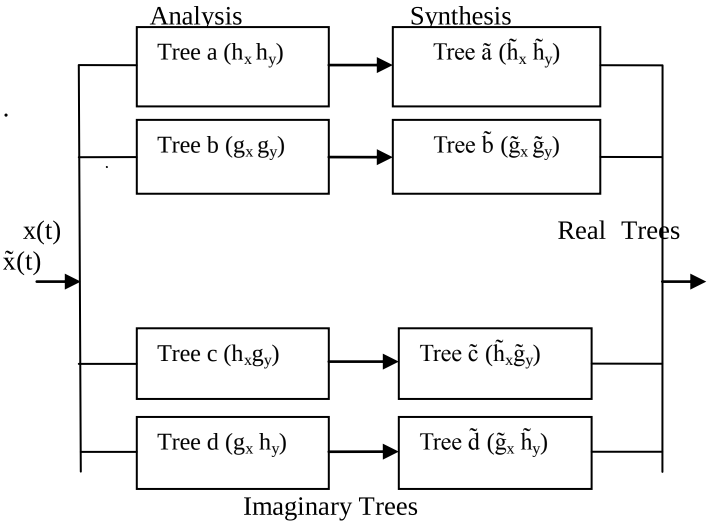

Fig 2: Filter bank structure for 2D DT-DWT

The complex wavelets are able to distinguish between positive and negative the diagonal sub-bands can be distinguished and horizontal and vertical sub-bands are divided giving six distinct sub-bands in each scale at orientations $\pm 15^0$, $\pm 45^0$, $\pm 75^0$. Thus DT-CWT improves the directional selectivity which is the prime concern in the application like image fusion.

IV. PROPOSED IMAGE FUSION ALGORITHM

We propose a scheme for fusion of images of same scene obtained through different modalities, real time or high definition images. The basic idea is to decompose each image into sub-images using complex wavelet transform. Information fusion is performed based on detailed coefficients of sub-images and resulting image is obtained using inverse dual tree wavelet transform. The proposed scheme is based on 'gradient' criterion.

A. The Gradient Criterion

For a gray image I(x, y), the gradient at any pixel location (x, y) is obtained by applying Roberts Cross Edge Detector.

The main reason for using Roberts Cross operator performs very quick operation. It examines only four input pixels and determine the value of each output pixel, it uses simple arithmetic subtractions and additions are used in the calculation. There are no additional parameters to set. The kernels are applied separately to the input image, to produce gradient component in each orientation (call these *Gx* and *Gy*).. The gradient magnitude is given by

$$|\mathbf{G}| = \sqrt{\mathbf{G}^2_x + \mathbf{G}^2_y}$$

Although typically, an approximate magnitude is computed using:

$$|\mathbf{G}| = |\mathbf{G}_x| + |\mathbf{G}_y|$$

This is much faster to compute.

B. Image fusion

Steps to perform fusion

1. Take Test Images

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2. Apply Dual Tree CWT to each of the test images
3. Set the decomposition level (Here we have considered 6 level decomposition)
4. Combine the complex wavelet coefficients (Magnitudes)
5. Applying inverse Dual Tree CWT (Reconstruction)
6. Generating Final fused images.
7. A refined image with high sharp edges is obtained by gradient approach

V. Experimental Results

After understanding the concept of DT-CWT, next step was to implement it. In order to accomplish this we use C language. This code was synthesized using MATLAB. The gradient criterion based fusion in Dual Tree Complex Wavelet domain has been performed using various images from a standard image database or real time images. The robustness of the proposed fusion technique is verified successfully with some images such as: multi sensor image, multispectral remote sensing images and medical images such as CT, MR images, Surreal images .We can also fuse real time images.
Steps to fuse the images, we have created a GUI as shown in fig3.We have created two list-box to store the selected images. Then we load the images which we want to fuse on the axis .The fused image is shown on the third axis shown in fig 5. The spatial gray level gradients of image 1 and image 2 are shown in fig 6. The spatial gradient computed by smoothing the average of two input images is shown in fig 7.

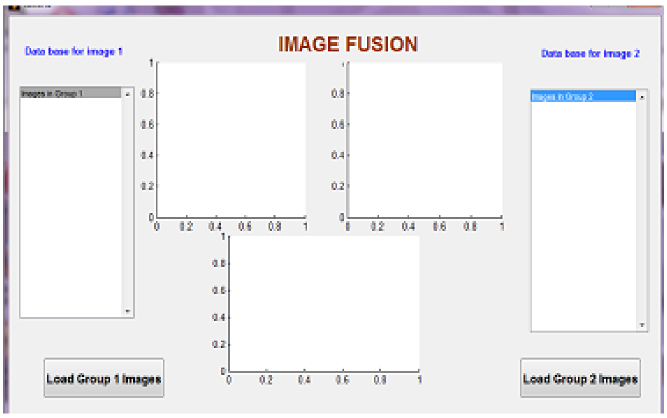

Fig 3: GUI created to fuse images

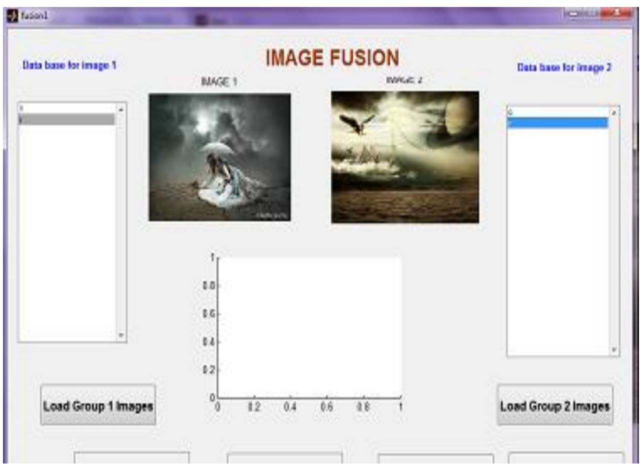

Fig 4: Two images which are to be fused

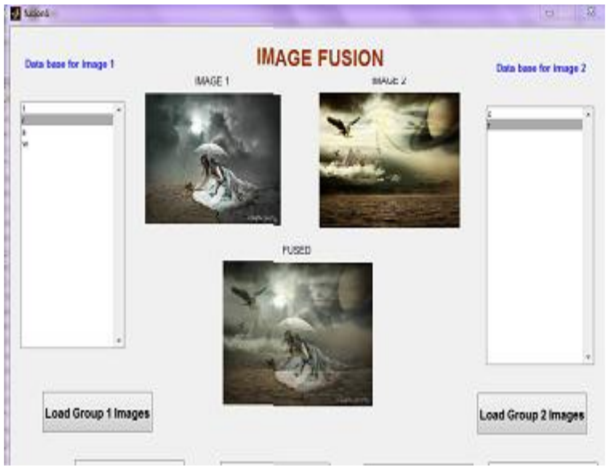

Fig5: The fused image in third axis

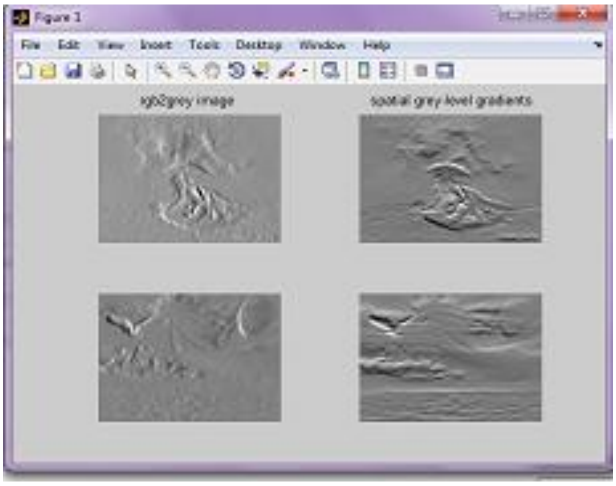

Fig 6: The spatial gray level gradients of image1 and image2

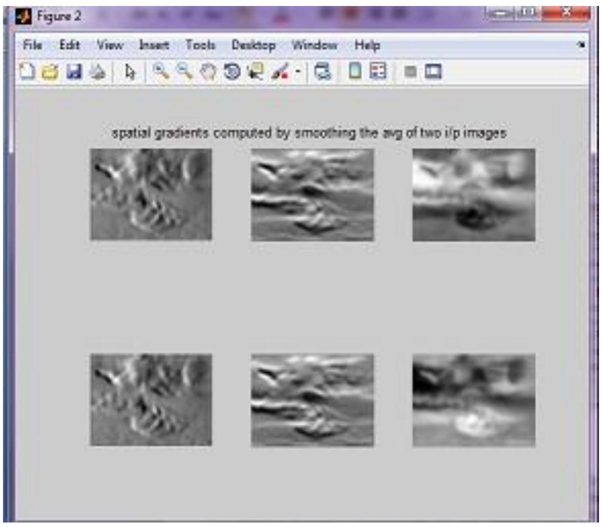

Fig 7: Spatial gradients computed by smoothing the average of two input images.

V. Conclusion

The proposed fusion technique compensates all the shortcomings of Discrete Wavelet Transform by the implementation of Q-shift DT-CWT. It also removes the ringing artefacts introduced in the fused image by assigning

suitable weighting schemes to high pass wavelet coefficients and low pass coefficients independently. The normalized maximum gradient-based sharpness criterion for low frequency coefficients enhances the background texture information as well as improves the quality of the blurred regions in the fusion
There are number of other advantages of proposed algorithm. We have used complex wavelet with approximate shift
invariance, good directional selectivity, PR, limited redundancy and efficient computation. Then, we carry out image fusion using CWT instead of classical DWT.

We use the complex wavelet decomposition to implement the multi resolution analysis, since it can decompose the image information in the localization of both spatial and frequency domains. Another advantage of the wavelet transform is that we can implement it with the use of extension of one-dimensional operator to compute the two-dimensional image decomposition. It will save the computational time.
Our proposed algorithm consists of two major steps similar to video matting: foreground extraction and background fusion. Robust foreground extraction in image space is difficult to achieve in practice, especially when dealing with low contrast and noisy images. Therefore we propose a gradient space algorithm. A gradient space method also allows us to simply state the constraints on the resultant image i.e. which parts of constituent images should be preserved.

We have presented gradient domain techniques to extract useful information from multiple images of scenes by exploiting their illumination-dependent properties. Our methods are useful as digital tools for artists to create surrealist images and videos. By providing context to dark or low quality images or videos, we can create more comprehensible images and generate information rich image. We show how the gradient space method can be used as artistic tool to produce surrealist effects.

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