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Hybrid Image Fusion implemented in DTCWT

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ABSTRACT

Acquiring a perfect perception and clarity in image resolution by applying prevailing fusion techniques is one of the challenging and advancing focus of research work. The multisensory fusion of images is having tremendous benefits in various sensitive applications like medical diagnosis for treatment, military and defence applications, computer perceptions, remote sensing, etc. This paper focuses on the emolument of the Hybrid Image fusion technique in recently developed, one of the most advanced wavelet fusion techniques - DTCWT (Dual Tree Complex Wavelet Transform) technique. As proved by various qualitative and quantitative analysis DTCWT is an improved fusion method than DWT (Discrete Wavelet transform) having presence of phase information in coefficients of complex wavelet, appreciable directionality, shift invariance and better resolution fused results.

Key Words: Discrete Wavelet Transform, Dual Tree Complex Wavelet Transform, Hybrid Fusion, Image Fusion, MSE, PSNR, Wavelet filters.

1. INTRODUCTION:

Image Fusion is defined as process of combining two or more different images into a new single image and producing a better resolution image as this process the new single image so formed retain all its important features from each its result. In image with extended information content and better visual perception. Image fusion is a powerful key to enhance the quality of image. Image fusion technique is classified into two categories – Direct Image Fusion and Multi resolution Image Fusion. Here, we focus on Multi resolution Image Fusion techniques inspired of wavelet based fusion methods. Earlier various fusion techniques like: Maxima fusion method, Minima fusion method, etc. have been applied to DWT (Discrete wavelet transform) and DTCWT (Dual tree complex wavelet transform. Here, this paper approaches the implementation of 'Hybrid Image Fusion' in DTCWT to produce even better results that simple fusion techniques. Image fusion is to integrate complementary information from multimodality images such that the new image is more suitable for the purpose of human perception and computer processing tasks such as segmentation, feature extraction and object recognition.

2. Objectives of Research Work:

1.) Obtaining better quality image by extracting the results of various image fusion techniques and combining it in a Hybrid image fusion technique.

2.) Various complex wavelet filters with required coefficients are used to extract the best results of DTCWT (Dual Tree Complex Wavelet Transform).

3.) Proposed methodology of Hybrid Image Fusion , has minimized errors and much better resolution images as compared to DWT technique.

3. Platform:

The MATLAB package offered a significant advantage as it has provided access to the Image Processing Toolbox that offers a comprehensive suite of standard algorithms and graphical tools for image processing, analysis and visualization. However, using the Image Processing Toolbox in MATLAB would enable instant access to standard image processing algorithms and would also allow the application to be easily ported to any environment that is supported by MATLAB, so MATLAB was chosen as the computational package that would be used to develop the application.

4. Basics of DTCWT:

Dual Tree Complex Wavelet Transform, a form of discrete wavelet transform which generates complex coefficients by using a dual tree of wavelet filters to obtain their real and imaginary parts. Nick Kingsbury has introduced DTCWT, which has the following properties:

1. Approximate shift invariance
2. Good directional selectivity in 2-dimensions (2-D) with Gabor-like filters also true for higher dimensionality: m-D)

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3. Perfect reconstruction (PR) using short linear-phase filters
4. Limited redundancy: independent of the number of scales: 2:1 for 1-D (2m:1 for m-D);
5. Efficient order -N computation - only.

DWT suffers with two main disadvantages:

1. Lack of shift invariance. This means that small shifts in the input signal can cause major variations in the distribution of energy between DWT coefficients at different scales.
2. Poor directional selectivity for diagonal features, because the wavelet features are separable and real.

DTCWT introduces limited redundancy (2m: 1 for m-dimensional signals) and allows the transform to provide approximate shift invariance and directionally selective filters (properties lacking in the traditional wavelet transform) while preserving the usual properties of perfect reconstruction and computational efficiency with well-balanced frequency responses.

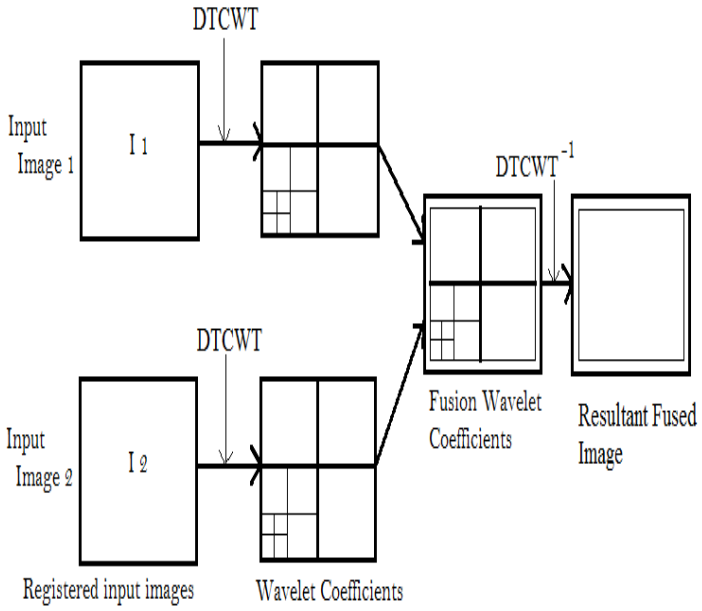

Figure 1: Schematic diagram for Dual Tree Complex wavelet based basic image fusion, I1 and I2 are input images and F is the resultant fused image.

The drawbacks of DWT i.e. shift sensitivity poor directionality and lack of phase information is removed with the use of Dual Tree Complex Wavelet Transform (DTCWT). DTCWT provides shift invariance and better directional information in 2-D by using Gabor like filters. This directional information in 2-D is given by dividing sub bands into six spatial orientation which are ±150, ±450, ±750. Also use of short linear phase filters leads to perfect reconstruction in DTCWT by introducing limited redundancy 2:1 for 1-D (2m: 1 for m-D). It requires more computation (twice of DWT for 1-D and 2m: 1 for m-D). The imaginary coefficients of DTCWT provide phase information of signals. We know that most of the structural information of images is contained in the phase. So this property of DTCWT is useful in fusion in order to obtain salient information from source images.

The Dual Tree Complex Wavelet Transform (DTCWT) provides all these properties by replacing the tree structure of the wavelet transform with a dual tree as shown in figure 2. Two fully decimated trees are produced, one for the odd samples and one form the even samples i.e. at each scale one tree produce the real part of the complex wavelet coefficients and other produces the imaginary parts. All the filters in DTCWT are real and imaginary coefficients are obtained only when the two trees are combined. Although DTCWT has increased memory requirements and high computational cost, it is much beneficial than DWT and provides improved fusion results over DWT with high directionality, shift invariance and availability of phase information.

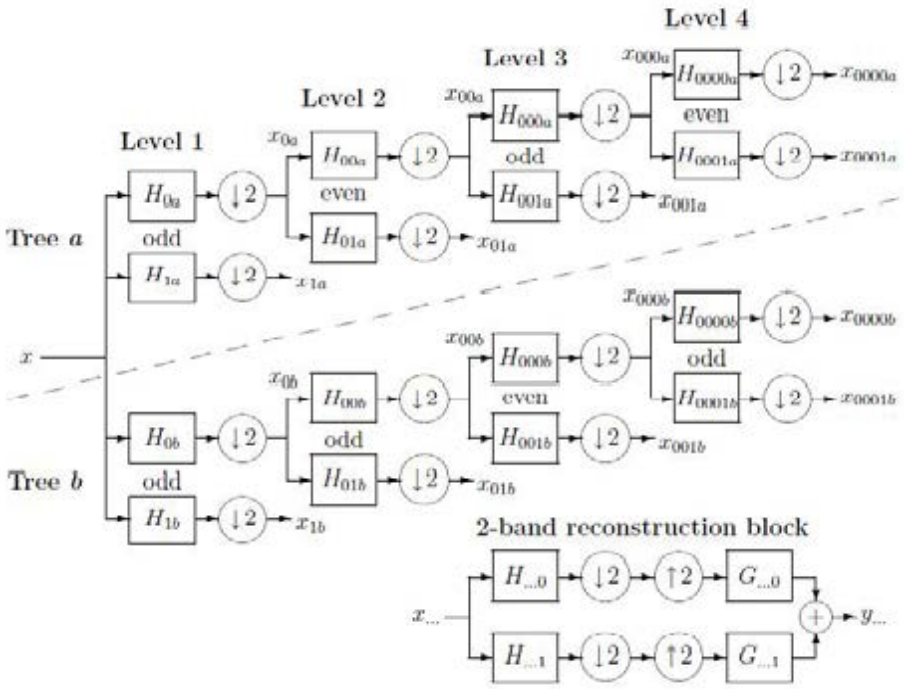

Figure 2: Dual tree of the real filters for the complex wavelet transform (DTCWT), giving real and imaginary parts of the complex coefficients (Image Courtesy Dr. N. Kingsbury)

5. Proposed Method: Hybrid Image Fusion:

The proposed Hybrid fusion method integrates various pixel level fusion rules in a single fused image with the DTCWT wavelet transformation. Pixel based rules operate on individual pixels in the image, but does not take into account some important details like edges, boundaries and salient features larger than a single pixel. Pixel level rules may reduce the contrast in some images and does not always succeed in effectively removing ringing artefacts and noise in source images. The inadequacies of these types of fusion rules point to the importance of developing a Hybrid algorithm to improve the visual quality by combining the advantages of two or three pixel based methods.

Combination of various fusion rules is done to get better quality final fused image. Here the image fusion techniques used are based on wavelet transformation. First level and second level decomposition of original image is based on Dual Tree Complex Wavelet Transformation (DTCWT). In this hybrid method, first wavelet decomposition of the input source images is performed up to level N. The low pass and high pass sub-bands are then fused using different pixel level fusion methods. Then the inverse (IDTCWT) wavelet transformation is performed to get full size fused images. The results of pixel level minima , pixel level maxima , and pixel level averaging are fused together to get the final fused image.

As DTCWT is a dual tree complex wavelet transform so it uses output of two filters with complex coefficients such as FS farass filter and Dual filt filter to get the best results. Hence the result so obtained not only have better quality of image as compare to the traditional methods, but also removes the drawbacks of traditional methods.

6. Results and Discussions:

In this section some of experimental results of our work on wavelet based Image Fusion are discussed. Input image database is taken in different environment through a digital camera; the multi focused environment is generated using different light effects. In the proposed hybrid method, first wavelet decomposition of the input source images is performed up to level second level using discrete wavelet transform.

In the first stage the results of the different wavelet filters for an simplest and specific fusion technique Pixel Level Method are presented. The performance of the wavelet filters are compared using mean square error and Peak Signal to noise ratio for different kind of simple fusion techniques and then the results for the Hybrid image fusion simulated as :

- If I1 and I2 are the two distorted images then we first obtain results of simple fusion techniques and calculate the PSNR values for the distorted images and resultant fused image for the corresponding fusion techniques :

i. Maxima Fusion Method: In this simple pixel level fusion technique , resultant fused image (F) is obtained by :

$$F = \max (I1 , I2)$$

ii. Minima Fusion Method: In this simple pixel level fusion technique , resultant fused image (F) is obtained by :

$$F = \min (I1 , I2)$$

iii. Averaging Method : In this simple pixel level fusion technique , resultant fused image (F) is obtained by :

$$F = (I1 , I2) / 2$$

- **Hybrid Image fusion :** And finally our proposed Hybrid Image Fusion Technique is implemented by combining all these three method and then fusing the two distorted images using that hybrid image fusion technique implemented as:

$$F = (\max (I1 , I2) + \min (I1 , I2)) / 2 ;$$

Figure 3: Shows the example of Hybrid Image Fusion applied on one of the images. As seen the distorted images (a.) and (b.) does not have the complete information and the missing information is complementary in both the images. Thus on applying our Hybrid image fusion to these two images, we finally get the resultant fused image (c.) , which is complete in its information and better in quality and resolution.

The **Table 1.1** below shows the fusion results and hence proves that Hybrid Image Fusion in DTCWT is much better fusion technique an produced image having better quality and resolution has a very less difference with the original image .

Figure 3: Shows the (a.), (b.) : Two distorted image (c.) Resultant Fused image

Name of the Image	Fusion Technique used	PSNR values for		
		Image 1(I1) and Fused image (F1)	Image 2(I2) and Fused Image (F1)	Fused image (F1) and Original Image
Aircraft	Hybrid Image fusion (max(I1,I2)+min(I1,I2))/2	30.5322	30.5322	4.8894
	Maxima Image Fusion Method	26.5412	28.1411	6.8668
	Minima Image Fusion Method	28.1411	26.5412	6.8701
	Averaging Method	24.2804	19.4348	6.7079
Flora girl	Hybrid Image fusion (max(I1,I2)+min(I1,I2))/2	12.9116	12.9116	1.4135
	Maxima Image Fusion Method	10.8517	10.3229	2.4711
	Minima Image Fusion Method	10.3229	10.8517	2.8446
	Averaging Method	11.1381	8.8734	2.7474
Clock	Hybrid Image fusion (max(I1,I2)+min(I1,I2))/2	12.6809	12.6809	2.8133
	Maxima Image Fusion Method	9.995	9.995	3.206
	Minima Image Fusion Method	9.995	9.995	2.2069
	Averaging Method	11.5076	11.3842	2.5187

Flowers	Hybrid Image fusion (max(I1,I2)+min(I1,I2))/2	**25.4304**	**25.4304**	**5.399**
	Maxima Image Fusion Method	**20.3517**	**19.7989**	**5.3085**
	Minima Image Fusion Method	**19.7989**	**20.3517**	**5.2823**
	Averaging Method	**16.1189**	**17.7148**	**4.3255**
Baby	Hybrid Image fusion (max(I1,I2)+min(I1,I2))/2	**19.5241**	**19.5241**	**4.2971**
	Maxima Image Fusion Method	**16.09**	**15.9223**	**8.4046**
	Minima Image Fusion Method	**15.9223**	**16.09**	**9.2589**
	Averaging Method	**12.0064**	**11.7715**	**7.8573**
Tiger	Hybrid Image fusion (max(I1,I2)+min(I1,I2))/2	**15.8912**	**15.8912**	**2.3638**
	Maxima Image Fusion Method	**8.266**	**8.5235**	**5.2321**
	Minima Image Fusion Method	**8.5235**	**8.266**	**5.1531**
	Averaging Method	**13.9749**	**10.8289**	**5.8165**

Table 1.1: Showing PSNR values for distorted images, fused images and Original images

7. CONCLUSION:

The fusion method is selected according to the physical characteristics of sensors, the performance measure, and the interpretation of image. Various fusion rules for the selection and combination of sub band coefficients increases the quality (perceptual/quantitative measures) of image fusion in specific applications. The developed Hybrid Fusion Technique based on DTCWT fusion technique provides better quantitative and qualitative results than the DWT at the expense of increased computation. The DTCWT method is able to retain edge information without significant ringing artefacts. It also faithfully retains textures from the input images. All of these features can be attributed to the increased shift invariance and orientation selectivity of the DTCWT when compared to the DWT. Proposed method is based upon assumption that images are fully registered but in practical scenario they may be unregistered. So, registering multi sensor images is another research area.

In the current research work, Secondly, implementation is being done on Pixel Level Fusion rules such as Pixel Level Maxima, Pixel Level Minima and Pixel Level Averaging. As the results of averaging method show better features comparatively, but with maximum MSE and minimum SNR value. Hence our target was to achieve better features of an image with minimum MSE and maximum SNR. To achieve the desired target an algorithm is proposed in the second stage of the current work. In the third stage various stimulated images such as aircraft.jpg, and flowers.png, images are taken. The results showed that proposed Hybrid fusion method has minimized MSE and has maximized SNR with respect to averaging method and other images for stimulated images also. The results obtained from proposed hybrid fusion algorithm can further be applied to other pixel level method to segment the features of the input images either jointly or separately, to produce a region map as a future research work. Visual Representation and quantitative assessment of fusion results implies that the proposed fusion method using Hybrid Image Fusion based on DTCWT is better than those of Simple Fusion Techniques for normal and blurred image data sets.

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