# Optimized Complex Wavelet Transforms and Genetic Algorithm for Fusion of Images

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**Abstract:** The fusion of images is the process of combining two or more images into a single image retaining important features from each. Fusion is an important technique within many disparate fields such as remote sensing, robotics and medical applications. Wavelet based fusion techniques have been reasonably effective in combining perceptually important image features. Shift invariance of the wavelet transform is important in ensuring robust sub band fusion. Therefore, the novel application of the shift invariant and directionally selective Dual Tree Complex Wavelet Transform (DT-CWT) to image fusion, this novel technique provides improved qualitative and quantitative results compared to previous wavelet fusion methods. A perceptually based image fusion method is proposed that employs explicit luminance and contrast masking models. These models are combined to give the perceptual importance of each coefficient produced by the dual-tree complex wavelet transform of each input image. This combined model of perceptual importance is used to select which coefficients are retained and furthermore to determine how to present the retained information in the most effective way. Genetic Algorithm is used in order to find the optimized solution for the image fusion.

*IndexTerms:* ***Complex Wavelet, Contrast mask, Genetic Algorithm, Image fusion, Luminance, Perceptual importance, Optimization***

## I.Introduction

Image fusion is the process of combining relevant information from two or more images into a single image which contains more information than any of the input images. It has become a regulation which demands more general formal solutions to different applications. It can be implemented in either spatial or frequency domain methods. Every method that was proposed earlier had some advantages along with some challenges. Our main aim in this work is focussed at enhancing the quality of the fused image based on some performance measures such as Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE). Our proposed method is compared with the recent previous method and a comparative analysis is presented briefly in this paper.

Previously developed methods for Image fusion use direct pixel wise operations and various transformations, i.e. spatial domain and frequency domain methods. Spatial domain techniques include Simple Average, Simple Maximum and Principle Component Analysis (PCA). [6] The advantage of spatial domain based methods is the computational simplicity; however it suffers many disadvantages owing to the quality of image fusion. The disadvantages in the spatial domain methods are (i) Blurring which affects the contrast of the fused image.(ii) Produces spectral degradation.(iii) Lesser spatial resolution. Frequency domain methods include Discrete Cosine Transform, Discrete Fourier Transform and Discrete Wavelet Transform based approach. The entire frequency domain based methods offer better peak signal to noise ratio than pixel based spatial domain methods. [4] DCT based image fusion requires less energy of all the methods but it has unwanted blurring effects which decrease the quality of fused image. DWT based image fusion requires more number of calculations, slighter large amount of memory and little more time. [9] But the quality of the fused image is better. The disadvantage of existing methods is that they do not employ perceptual models of the Human Visual System (HVS) to decide which information to retain from each source. [1]

Contrast Masking: Contrast perception is also dependent on orientation of local content, Frequency Masking: The Contrast Sensitivity Function (CSF) gives a measure of the perceptual importance of spatial frequencies.[3] Dual Tree Complex Wavelet transform allows high directionality and they are free from oscillations and aliasing effects when compared to real wavelets. [11] Here maximum fusion rule is applied for performing image fusion. We modify the threshold equation by taking account into the coefficients produced by luminance and contrast masking known as Just Noticeable Difference (JND) [7] and use Genetic algorithm to optimize the JND Threshold. The advantage using this method is PSNR increases and MSE decreases and the obtained image is of better quality than DWT based image fusion. [10]

## II. PROPOSED METHOD

### II.1.DUAL TREE COMPLEX WAVELET TRANSFORM

The dual-tree complex wavelet transform (DT-CWT) is a relatively recent enhancement to the discrete wavelet transform (DWT), It includes shift invariant and directionally selective in two and higher dimensions. [3] It achieves this with a redundancy factor of only 2 d for d-dimensional signals, which is substantially lower than the undecimated DWT. The multidimensional (M-D) dual-tree CWT is non-separable but is based on a computationally efficient, separable filter bank (FB).The dual-tree complex DWT of a signal is implemented using two critically-sampled DWTs in parallel on the same data. If the filters in the upper and lower DWTs are the same, then no advantage is gained. The sub-band signals of the upper DWT can be interpreted as the real part of a complex wavelet transform, and sub-band signals of the lower DWT can be interpreted as the imaginary part. For filters, the wavelet associated with the upper DWT can be an approximate Hilbert transform of the wavelet associated with the lower DWT. When designed in this way, the dual-tree complex DWT is nearly shift-invariant, in contrast with the critically sampled DWT.

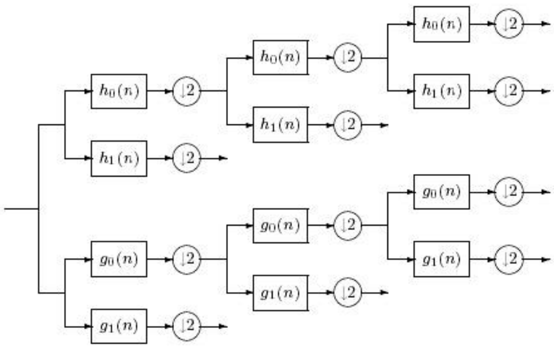


Fig.1 Dual tree wavelet using two critically-sampled DWTs in parallel on the same data

### II.II CONTRAST MASKING

Contrast masking quantifies how the visibility of an image component varies in the presence of other image components. Contrast masking is commonly defined as the variation of the JND threshold of a target signal as a function of the intensity of a masking. Within a fusion framework, the target signal can be defined as a transform coefficient and the masking signals as the neighbouring coefficients. A contrast mask allows reducing overall contrast, simultaneously bringing out more detail in highlights and shadows. The advantage of the contrast mask technique is that it allows much more precise control, and gives better results. The basic technique is to create a layer above the image that contains a B&W negative of the image. The images are combined in overlay mode: dark parts with light, light parts with dark. All the while the original image remains blissfully unchanged on its layer.

The measure of the contrast masking $a_c$ is defined and modelled using DT-CWT as

$$a_c(\lambda,\theta,i,j) = a_{c_{intra}}(\lambda,\theta,i,j)a_{c_{inter}}(\lambda,\theta,i,j) \quad \text{.........>Eq(1)}$$

Where $a_{c_{intra}}(\lambda,\theta,i,j)$ is the contrast masking effect due to the coefficients within the same subband as the target coefficient and $a_{c_{inter}}(\lambda,\theta,i,j)$ is the contrast masking effect due to the co-located coefficients within neighbouring subbands. The effect of contrast masking is only observed up to a relative frequency range of two octaves.

### II.III LUMINANCE MASKING

Lumi masking, also known as psycho visual enhancements or adaptive quantization, is a technique, which reduces quality in very bright or very dark areas of the picture, as quality loss in these areas is less likely to be visible. The reduction in quality in certain areas of the picture caused by using lumi masking allows more bits to be allocated, thus improving overall quality. The perception of contrast by the human visual system is dependent on the luminance context i.e. on the global and local background luminance levels. This is termed luminance adaptation. The Weber-Fechner law states that the ratio of the JND threshold T to the background luminance L is constant over a range of L. Modified versions of this law have been proposed where the ratio T/L is elevated for high and low background luminance values to take into account the human visual system's decrease in sensitivity within these background luminance regions

### II.IV GENETIC ALGORITHM

Genetic Algorithm (GA) is a search-based optimization technique based on the principles of Genetics and Natural Selection. It is frequently used to find optimal or near-optimal solutions to difficult problems which otherwise would take a lifetime to solve. It is frequently used to solve optimization problems, in research, and in machine learning.

## ALGORITH FOR PROPOSED SYSTEM

The proposed Image Fusion Algorithm is as follows:

1. First input image is loaded
2. Second input image is loaded.
3. Calculate Dual Tree Complex Wavelet transform for both the images.
4. Apply maximum fusion rule to find out wavelet coefficients.
5. Luminance masking coefficients are calculated for both the images.
6. Contrast masking coefficients are calculated for both the images.
7. Calculate JND threshold by using the information obtained in steps 5 & 6.
8. Optimize the value of JND threshold value using Genetic Algorithm.
9. Apply the optimized JND threshold to the fused wavelet coefficients.
10. Calculate inverse Dual Tree Complex Wavelet transform to obtain the fused image.

### III. RESULTS AND DISCUSSION

The entire Algorithm is implemented using MATLAB software, input images are loaded first, and then transformations of both the images are applied separately using DT-CWT. The relevant masking effects such as contrast and luminance masking are applied separately by using pixel information from each of the input image. Genetic Algorithm is used at the final stage to get optimized value of JND threshold with the help of Optimization Tool in the MATLAB. The resultant threshold obtained is applied at the complex wavelet transform coefficients. The inverse transform gives the final fused image as the output. PSNR and MSE are calculated separately for the fused image with respect to each input image to observe how much information was retained from each of them.

The proposed image fusion algorithm is now applied on different sets of images and the fusion metrics such as correlation, Peak Signal to Noise Ratio (PSNR), and Mean Square Error (MSE) are observed and compared with the previously existing method using Discrete Wavelet Transform (DWT).

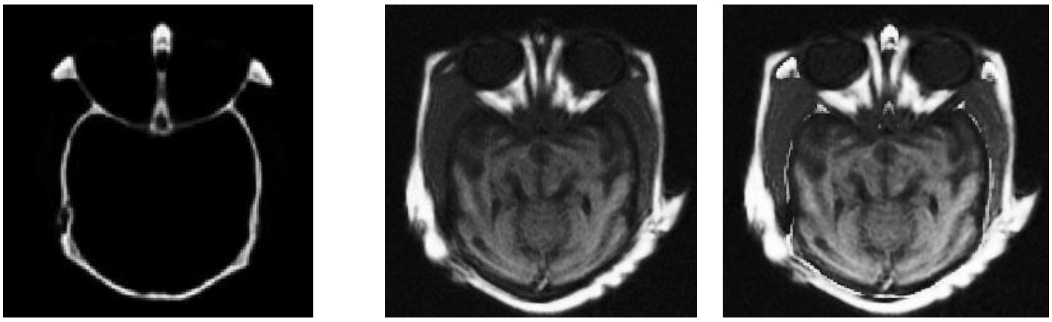

**Fig 2 Proposed methods for CT and MRI images**

Input image 1 Input image 2 Fused image

**Fig 3 Proposed method for house images**

| Fusion Metrics | Existing DWT method | Proposed method |
|---|---|---|
| PSNR between first input image and fused image | 16.02 dB | 16.04 dB |
| PSNR between second input image and fused image | 16.06 dB | 16.10 dB |
| Correlation between first input image and fused image | 0.568817 | 0.562924 |
| Correlation between second input image and fused image | 0.845537 | 0.852944 |
| MSE between first input image and fused image | 1616.81 | 1615.15 |
| MSE between second input image and fused image | 1611.53 | 1595.27 |

**Table 1 Comparison for CT and MRI images**

| Fusion Metrics | Existing DWT method | Proposed method |
|---|---|---|
| PSNR between first input image and fused image | 14.28 dB | 14.35 dB |
| PSNR between second input image and fused image | 14.34 dB | 14.40 dB |
| Correlation between first input image and fused image | 0.672145 | 0.691581 |
| Correlation between second input image and fused image | 0.142502 | 0.146088 |
| MSE between first input image and fused image | 2427.52 | 2338.62 |
| MSE between second input image and fused image | 2393.22 | 2361.74 |

**Table 2 Comparison for house images**

## IV. CONCLUSION

It is seen that the values of Peak Signal to Noise Ratio (PSNR) are increased and the values of Mean Square Error (MSE) are decreased using this technique compared to previously developed DWT based image fusion methods. This proves that our proposed system returns better quality of the fused image. Also the correlation between input images and the fused image is slightly increased in our proposed system which means that maximum information is retained from both the source images. The shift invariance property of DT-CWT plays a key role in transforming the images. Luminance and contrast masking effects provides the masking coefficients which in turn account for the JND threshold. Genetic Algorithm plays a significant role for optimizing the threshold obtained by coefficients of luminance and contrast masking. Further, this work can be extended to track remote objects under continuous monitoring for enhanced security.

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