International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-04, Issue-04, July 2018

Analysis of Image Fusion Using Optimized Complex Wavelet Transforms

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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.

Keywords- 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.

II. BACKGROUND

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. All the 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]

III. PROPOSED SYSTEM

The perception of contrast relevant to image fusion has therefore been found to be dependent on a range of masking effects. [2] The relevant masking effects employed in this work are: Luminance Masking: The dependence of contrast perception on local luminance,

 DOI : 10.18231/2454-9150.2018.0468 © 2018, IJREAM All Rights Reserved.

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]

IV. METHODS USED IN THE PROPOSED SYSTEM

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. [11]

Contrast Masking: A contrast mask allows reducing overall contrast, simultaneously bringing out more detail in highlights and shadows. [3] The advantage of the contrast mask technique is that it allows much more precise control, and gives better results. [6] 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.

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. [8] 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. Lumi masking is not perfect, however, and in some cases the degradation in quality it causes is visible. [5]

Genetic Algorithm: Genetic Algorithm (GA) is a search-based optimization technique based on the principles of Genetics and Natural Selection. [12] It is frequently used to solve optimization problems, in research, and in machine learning. In GAs, we have a pool or a population of possible solutions to the given problem. These solutions then undergo recombination and mutation (like in natural genetics), producing new children, and the process is repeated over various generations. Each individual (or candidate solution) is assigned a fitness value (based on its objective function value) and the fitter individuals are given a higher chance to mate and yield more "fitter" individuals.

V. ALGORITHM FOR PROPOSED SYSTEM

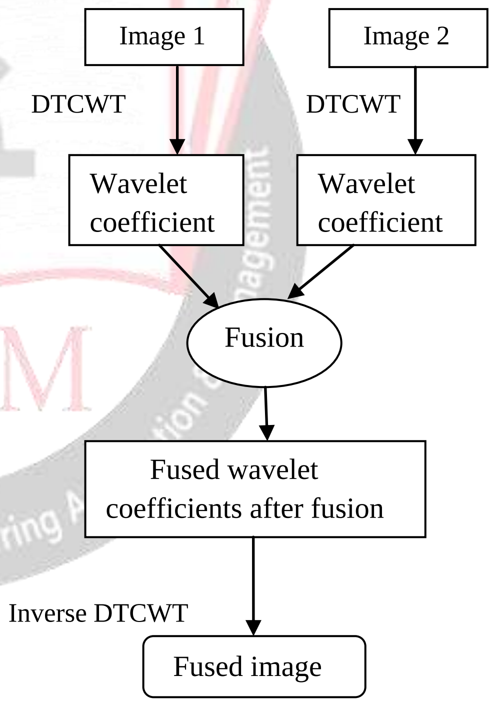

Fig 1: Flowchart of the proposed system

1. Load the first image
2. Load the second image.
3. Compute Dual Tree Complex Wavelet transform for both the images.
4. Apply maximum fusion rule and obtain wavelet coefficients.
5. Calculate coefficient for luminance masking for both the images.

 DOI : 10.18231/2454-9150.2018.0468 © 2018, IJREAM All Rights Reserved.

ISSN : 2454-9150 Vol-04, Issue-04, July 2018

6. Calculate coefficient for contrast masking for both the images.
7. Calculate JND threshold by using the information obtained in steps 6 &7.
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.

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.

VI. RESULTS

We now present the result of our proposed system for different examples and compare with the previously employed fusion methods.

Example 1: Solenoid image

Fig 2.1 First input image

Fig 2.2 Second input image

Fig 2.3 Fused output image

Fusion metrics	Existing DWT method	Proposed method
PSNR between first input image and fused image	29.91 dB	30.33 dB
PSNR between second input image and fused image	29.74 dB	29.41 dB
Correlation between first input image and fused image	0.976805	0.978943
Correlation between second input image and fused image	0.971112	0.977780
MSE between first input image and fused image	66.41	60.30
MSE between second input image and fused image	69.10	71.23

Table 1: Comparison of fusion for solenoid image

Example 2: CT and MRI images

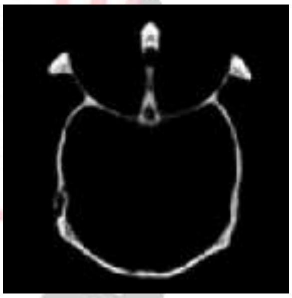

Fig 3.1 CT image

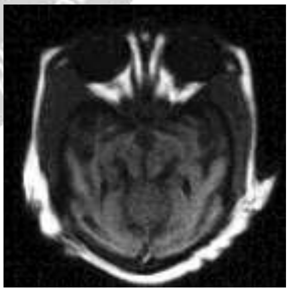

Fig 3.2 MRI image

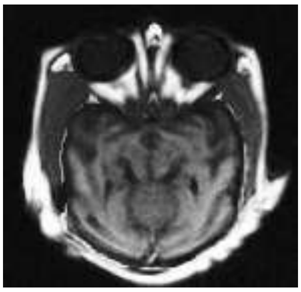

Fig 3.3 Fused output image

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CT and MRI images fusion has been widely used in biomedical applications for detection of tumour cells and also to differentiate carcinogenic cells from normal cells. Diagnosis and treatment have become simple due to recent advancements in the fusion methods.

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 CT and MRI images

Example 3: Person standing near house

Fig 4.1 Input image house

Fig 4.2 Person standing near house

Fig 4.3 Fused image

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 3: Comparison for house images

VII. 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 project can be extended to track remote objects under continuous monitoring for enhanced security. If we consider a military base under strict video surveillance,

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ISSN : 2454-9150 Vol-04, Issue-04, July 2018

every second will be monitored and a suspicious flying object above it can be easily traced if each and every frame of the video is fused with the successive frame. Since our project deals with developing HVS models, fusion is directly associated with human perception.

ACKNOWLEDGEMENT

We express our deep gratitude to Prof .B.N.Srinivasa Rao, Head of the Department of ECE, Dadi Institute of Engineering and Technology for his constant guidance and support to our work. Also we thank Prof. Dr. Ch.S..Naga Prasad, Principal, Dadi Institute of Engineering and Technology for his encouragement.

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