International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 8, October - 2012

An Image Fusion Technique For Colour Images Using Dual-Tree Complex Wavelet Transform.

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Abstract:

Noise elimination in images is one of the important tasks in pre-processing of images and analysis. Fusion is used as a chief technique in many different fields such as study of distant universe, denoising, biomedical, remote sensing, robotics etc. for elimination of noise. In this paper DT-CWT is used in denoising of colour images. CDWT is a form of DWT in which complex coefficients (real and imaginary parts) are generated by using a dual tree of wavelet transform. Experiments on a number of standard colour images carried out to evaluate performance of the proposed method. Results shows that the DT-CWT method is better than that of DWT method in terms of image visual quality.

1. Introduction

As colour images are best suited for representation and analysis, and these images may be corrupted by addition of noise by any means, that may be caused by an imaging system or may due to effects of environment. So, noise must be eliminated for better representation and analysis.

Fusion is used as a chief technique in many different fields for the elimination of noise. In Image fusion two or more images which are not more suitable for analysis are taken and these are converted into a single image, in which noise is eliminated but retaining important features from each of the source image , so is more suitable for analysis. Fusion of colour-images can be carried in two ways (a) first convert colour images into gray images and apply fusion for the gray images and then convert fused grey image back to colour image (b) Decompose the color image into three components then apply fusion to red components of the input images individually and then fuse green components, and then blue (or simultaneously). After fusion combine all the three colours to form the final image as shown in fig.4. But the problem involved in the process (a) is while converting image first from colour to gray before fusion, gray to colour after fusion the final image colour characteristics may change because of approximations involved in this process. So, direct fusion of colour images is preferred where colours of the images have the at most importance.

2. Wavelet based De-noising

The wavelet transform is generally termed as mathematical microscope in which big wavelets give an approximate image of the signal, while the smaller wavelets zoom in on the smaller details [3]. The basic idea of the wavelet transform is to represent the signal to be analyzed as a superposition of wavelets.

In this de-noising process two or more spatial domain images of same scene are taken, in which it is assumed that each image is corrupted at different locations due to noise. These images are now translated into wavelet domain and are fused using any fusion rule. Now, this fused image is converted back into spatial domain using inverse wavelet transform. Noise in the resultant image will much less when compared to the input images.

$$\mathbf{I(x, y) = W_{-1}(Ø (W (I_1 (x, y)), W (I_2 (x, y)))}$$

Where $\mathbf{I_1}$, $\mathbf{I_2}$ are source images, **W** represents wavelet transform, Ø represents fusion, $\mathbf{W_{-1}}$ represents inverse wavelet transform, and **I** is the fused image.

3. Discrete Wavelet Transform

A real continuous function f (t) is mapped into another real continuous signal **W**f (a, b) by the standard wavelet transform, where 'a' is scaling parameter and' b' is the shift parameter. The major disadvantages of standard wavelet (C_OWT) are redundancy (complexity due to large number of samples) and due to very large number of samples (as f (t) is continuous) it is impracticable to evaluate with computers. A discretized version of wavelet transform provides decomposition of the original signal based on constant-Q (equal BW on a logarithmic scale) basis functions with better multi-resolution characteristics in the time frequency plane. The discretization is carried out in such a way that the orthogonality is still satisfied and the transform is done on a grid within the continuous (a, b) plane.

4. Two Dimensional Discrete Wavelet Transform (2-D DWT)

Implementation of 2-D DWT is also known as 'multi-dimensional' wavelet transform. 2-D DWT is only an extension of 1-D DWT applied separately on rows and columns of an image as shown in fig1.
Colour image-processing applications require two-dimensional implementation of wavelet transform as a colour image is represented as 3- 2dimentional data matrixes (3D), one for red, one for green, one for blue.

The implementation of an analysis filter bank for a single level 2-D DWT is shown in figure [2- fig 3]. This structure produces a lower resolution sub-image LL and three detailed sub-images (HL, HL, HH) corresponding to 3 different directional-orientations (Horizontal, Vertical and Diagonal). The filter bank structure can be further iterated in a similar manner on the LL channel to produce multilevel decomposition. Multilevel decomposition hierarchy of an image is illustrated in figure2.

5. Complex Wavelet Transforms (CWT)

Standard wavelet transform and its extensions mainly consist of the following limitations. Due to these limitations standard DWT may not be preferred to use in some applications of image and signal processing.

1: SHIFT VARIANCE
A transform is said to be shift sensitive, if the time shifted input-signal causes an unpredictable change in coefficients of the transformed domain. Shift sensitivity in the standard DWT is arises from down samplers in the DWT implementation [8, 9]. Shift sensitivity is an unnecessary property, because, due to this DWT coefficients may fail to distinguish between shifts in the input-signals.

2: ALIASING
There will be substantial aliasing, as the coefficients of wavelets are calculated via iterated discrete-time down sampling operations that spread with non-ideal low-pass and high-pass filters. If the wavelet and scaling coefficients are not changed, then aliasing may be cancelled by the inverse DWT. But any processing of wavelet coefficient (thresholding, filtering, and quantization), leading to distortion in the reconstructed signal by upsetting the delicate relation in between forward and inverse wavelet transforms.

3: LACK OF DIRECTIONALITY
As number of smooth regions and edges with random orientations are contained by the natural images, but as 2-D DWT can only determine three spatial-domain feature orientations: horizontal (HL), vertical (LH) and diagonal (HH), optimal representation of natural images couldn't be achieved with the separable standard 2-D DWT.

4: ABSENCE OF PHASE INFORMATION:
Digital images are represented as a 2-D matrix by the computers. The size of this data is increased and phase distortion is also added when filtering the images with 2-D DWT. But human visual system is sensitive to phase distortion.
Generally real -valued approximations and details are obtained by most DWT implementations (including standard DWT, WP and SWT), as they uses filters with real coefficients, which are associated with real wavelets. Such DWT implementations is not able provide the information about the phase. So that, to provide the local phase information, complex-valued filtering is required [10, 11]

In complex domain there is another way for reducing these limitations with a limited redundant representation. The required phase information, more orientations [fig.3], and reduced shift-sensitivity are obtained by the formulation of complex-valued 'analytic wavelets'. Different approaches of filter bank realization using analytic filters associated with analytic wavelets are commonly termed as 'Complex Wavelet Transforms (CWT).

Real and imaginary coefficients are developed in the transformed domain by the complex valued filters from the real/complex source signals. These complex coefficients are used to determine the information (amplitude and phase), that is used for accurately describing the localization of energy of oscillating functions.

The filter banks (analysis and synthesis filter banks) that are used in DT-DWT are seems to be identical to those that are used in standard DWT. But the main difference is analytic filters replaces the real filters to obtain complex solutions and with twice the complexity. The structure of analytic filters appears as parallel operation of two standard DWT filters. These CWTs are termed as Dual-Tree DWT, as both Analysis as well as Synthesis operations are carried out on two parallel trees in which one tree is called as a real tree and the second one is called as an imaginary tree.

6. Experimental results

Experiments are carried out on number of colour images to compare the performances of DT-CWT fusion method with DWT fusion method. The results concerning on the experiments that have been conducted on different images, viz. toys, yellow butterfly, outdoor images. The first, third images are provided in [7]. The Visual quality comparison is demonstrated in figure 5(a, b, c).

7. Conclusion

Noisy colour image fusion technique using DT-DWT provides better results than DWT at the expense of increased computation. The DT-DWT method is able to retain edge information without significant ringing artifacts. DT-DWT Provides increased shift-invariance and increased orientation selectivity when compared to the DWT. This is proved by practical experiments.

8. Acknowledgement

The Author would like to thank Mrs. Padma Vasavi, Associate Professor, S.V.C.W., Bhimavaram, and Mr.T.J.V.Subrahamanyeswara Rao, former H.O.D., SITE, Tadepalligudem for their great support and suggestions throughout the project also grateful for the anonymous reviewers who made constructive comments. The author very thankful to one and all who helps to complete this work successfully.

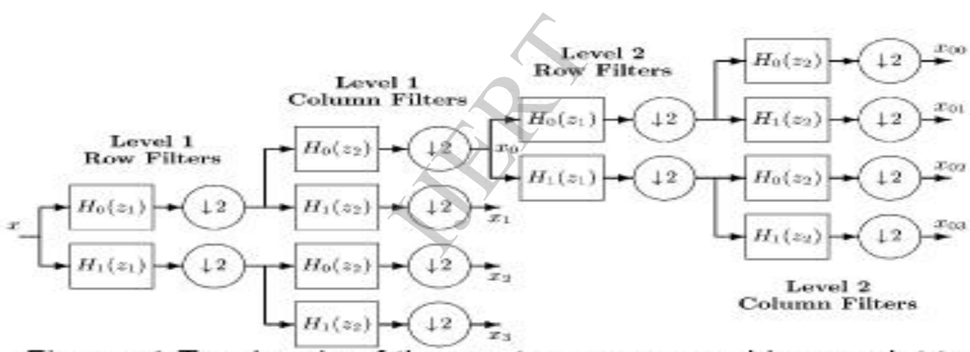


Figure: 1 Two levels of the quaternary separable wavelet tree, normally used for 2-D signal. Row filtering is denoted by the Z-transform parameter Z1 and column filtering by Z2.

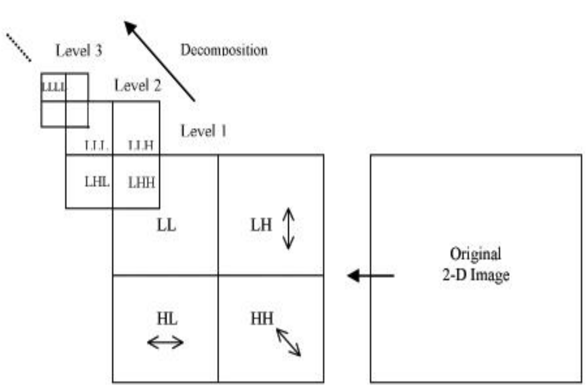


Figure: 2 multilevel decomposition hierarchy of an image with 2-D DWT

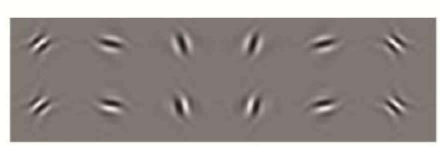


Figure:3 Directionality of 2-D DT-DWT

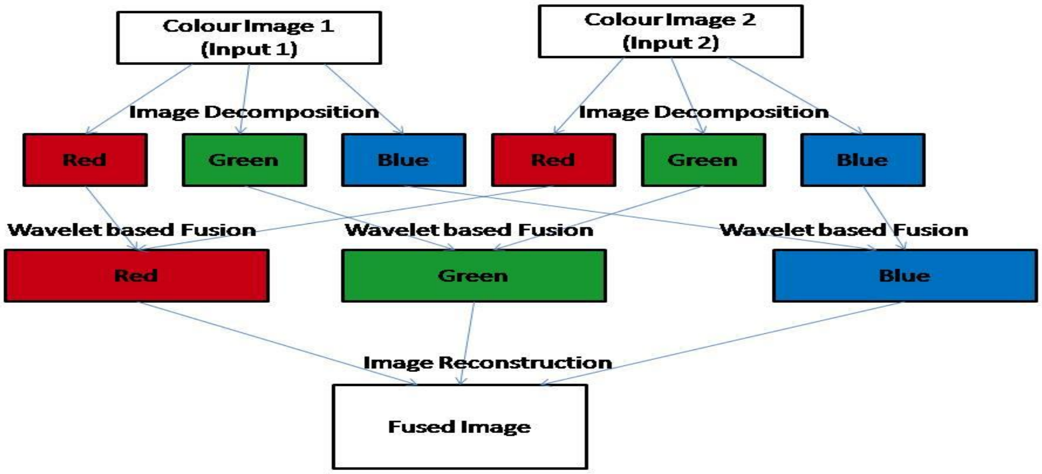
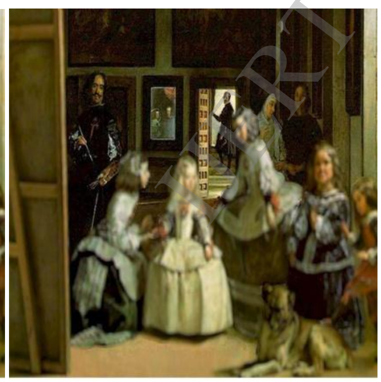


Figure: 4 Block Diagram of colour image Fusion

(a)

toys left blur



toys middle blur

toys right blur

toys standard DWT output

toys complex DWT output

(b)

(C)

Figure: 5 Visual comparison of some test images (a) toys image (b) yellow butterfly image(c) outdoor scene image

ISSN: 2278-0181
Vol. 1 Issue 8, October - 2012

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