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Directive Contrast based Multimodal Image Fusion in UWT and NSCT Domain

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Abstract

Objectives: The purpose of image fusion is to provide information integrated from different images to eliminate redundancy and contradiction between images. This paper presents medical image fusion using pixel level fusion with multi-level wavelet transform to obtain low frequency and high frequency subbands. This involves a pixel level averaging rule for appropriate fusion to integrate the decomposed image coefficients subbands. **Methods:** A two-stage multimodal fusion framework uses the cascaded combination of Un-decimated Wavelet Transform (UWT) and Non Sub-sampled Contour let Transform (NSCT) domains are used. **Findings:** This is to improve upon the shift variance, directionality, and phase information in the finally fused image. **Applications/Improvements:** A mathematical analysis of fused images is done using dedicated fusion metrics. The system performance is evaluated by using the parameters such as Peak signal to noise ratio, correlation and entropy.

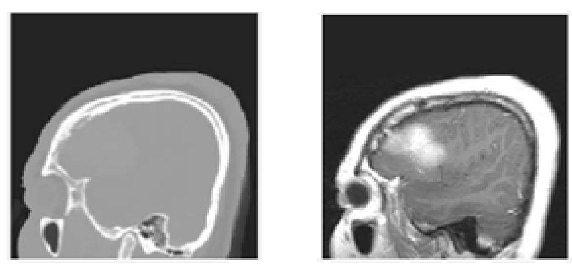
Keywords: Directive Contrast, Image Fusion, Multimodal Images, NSCT, UWT

1. Introduction

Medical image fusion has been a popular research topic. Computed Tomography can clearly reflect the anatomical structure of bone tissues whereas Magnetic Resonance Imaging can clearly reflect the anatomical structure of bone tissues, organs and blood vessels. In the medical diagnosis and management, the use of fused images can provide more valuable information[1–3]. It is significant for lesion location, diagnosis, constructing treatment and pathological study. CT, MRI and other modes of medical images reflect the human information from various viewpoints. In the medical diagnosis and treatment, the problems about the comparison and synthesis between image CT and MRI were frequently encountered[4].

Computed Tomography refers to the cross-sectional imaging of an object from either transmission or reflection data collected by illuminating the object from many different directions. The impact of this technique in diagnostic medicine has been revolutionary, since it has enabled doctors to view internal organs with unprecedented precision and safety to the patient[4].

Magnetic Resonance Imaging (MRI) uses the magnetic properties of hydrogen and its interaction with both a large external magnetic field and radio waves to produce highly detailed images of the human body[4]. Figure 1 shows the sample CT and MRI images.



(a) (b)

Figure 1. (a) CT image. (b) MRI image.

The actual fusion process can take place at different levels of information. A generic classification is to study the different levels sorted in ascending order of abstraction[5]. It focuses on the pixel level fusion process, where a composite image has to be built with several input images. Temporal stability and consistency[6–8] are the problems

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which arise with image sequence fusion. Temporal stability is one in which gray level changes in the fused sequence must only be caused by gray level changes in the input sequences. Temporal consistency is a problem where gray level changes occurring in the input sequences must be present in the fused sequence without any delay or contrast change[9,10]. The fusion process should be shift and rotational invariant.

1.1 Wavelet Transform

Wavelets are mathematical functions defined over a finite interval and having an average value of zero that transform data into different frequency components, representing each component with a resolution matched to its scale[11].

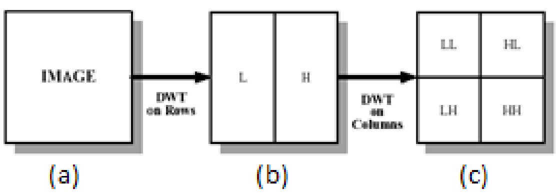

Figure 2. Block diagram of DWT.

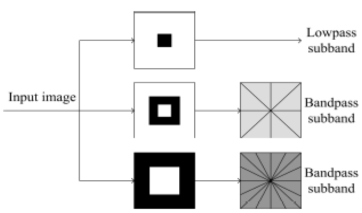

Figure 3. The non sub-sampled filter bank structure implementing NSCT.

Figure 2(a) depicts an Original Image, Figure 2(b) shows the output image after the 1-D is applied on column input and Figure 2(c) represents the output image after the second 1-D is applied on row input. The basic idea of the wavelet transform is to represent any arbitrary function as a superposition of a set of such wavelets or basis functions[12]. The baby wavelets are obtained from a single prototype wavelet called the mother wavelet, by dilations/contractions (scaling) and translations (shifts).

1.2 Undecimated Wavelet Transform

Fusion framework is based on undecimated wavelet transforms with spectral factorization which includes information about the presence of targets within the Infrared (IR) image to the fusion process[13].

1.3 Undecimated Wavelet Transform and Non Orthogonal Filter Banks

Multi scale image fusion framework utilizes a new class of Non-orthogonal filter banks[14]. This minimizes unwanted spreading of coefficient values around overlapping image singularities, usually complicating the feature selection process[15]. Furthermore, the introduction of blocking artifacts in the fused reconstruction is avoided. The combination of the undecimated Wavelet Transform with such filter banks leads to a fusion framework which is able to significantly outperform Multi scale fusion approaches for a large group of images, derived from different sensor modalities[16–18].

1.4 Non-Sub sampled Contourlet Transform

Zhouetal. (2006) proposed non-subsampled Contourlet Transform based on non-subsampled pyramid decomposition and non-subsampled filter banks[19].

Figure 3 shows the structure implementing NSCT that is built upon iterated non-separable two-channel Non-Subsampled Filter Bank (NSFB) to obtain the shift-invariance. The NSCT provides not only multi-resolution analysis, but also geometric and directional representation. The multiresolution decomposition step of NSCT is realized by the shift-invariant filter banks. Because of no decimation in the pyramid decomposition, the low pass subband does not bring frequency aliasing. The band width of the lowpass filter is larger than π/2.

2. Fusion Process

2.1 Low Frequency Fusion Process

Considering the images, approximate information is constructed by the low-frequency coefficients. Average rule is adopted for low-frequency coefficients. Suppose $B_F(x,y)$ is the fused low-frequency coefficients, then

$$B_F(x,y) = \frac{B_1(x,y) + B_2(x,y)}{2} \quad (1)$$

Where $B_1(x,y)$ and $B_2(x,y)$ denote the low-frequency coefficients of source images[20,21].

2.2 Fusion of High-Frequency Coefficients

High-frequency coefficients always contain edge and texture features. In order to make full use of information in the neighborhood and cousin coefficients in NSCT[22–24] domain a combination of region energy of NSCT coefficients and correlation of the cousin coefficients are used.

$$E_l^k(x,y) = \sum_{m,n \in S_{MXN}} (C_l^k(x+m, y+n))^2 \qquad (2)$$

Figure 4(a) shows NSCT fused image, Figure 4(b) shows the UWT fused image and Figure 4(c) shows NSCT fused image combined with the UWT fused image.

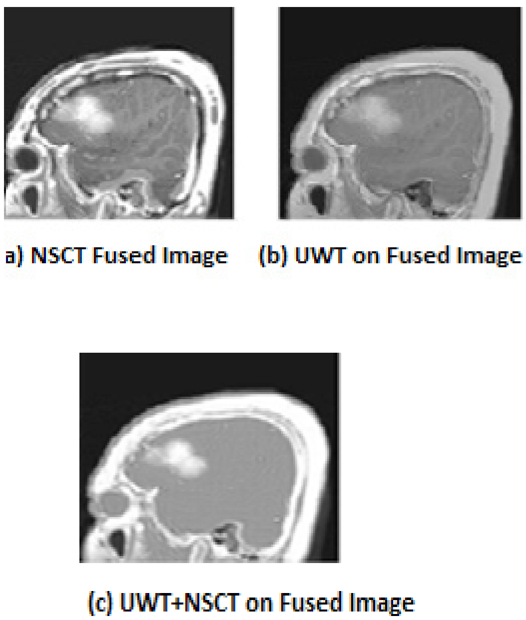

Figure 4. Fused images. (a) NSCT fused image. (b) UWT on fused image. (c) UWT+NSCT on fused image.

3. Performance Analysis

The digital image quality is assessed using the Peak Signal to Noise Ratio (PSNR) and is defined in Equation 3.

$$PSNR = 10 * \log_{10} 255^2 / MSE \qquad (3)$$

Where MSE is the Mean Square Error represents the difference between the cover-image and the fused image. The mathematical definition for MSE is defined in Equation 4.

$$MSE = \left(\frac{1}{M*N}\right) \sum_{i=1}^{M} \sum_{j=1}^{N} (a_{ij} - b_{ij})^2 \qquad (4)$$

In the above Equation a_{ij} means the pixel value at position (i,j) in the input image and b_{ij} is the pixel value at the same position in the output image. Larger the PSNR, higher will be the image quality. On the contrary, smaller the PSNR, greater is the distortion between the input-image and the fused-image[25,26].

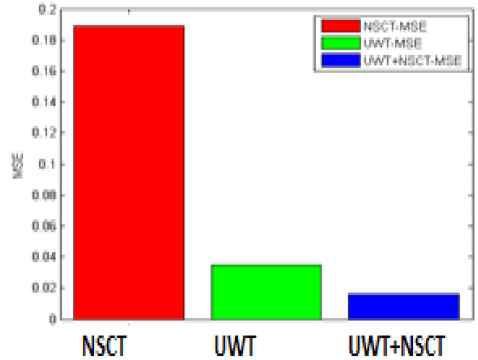

Figure 5. Different transform methods.

Figure 5 shows the Comparison of MSE values with various Image Fusion Techniques. The combination of NSCT and UWT produces a reduced error rate.

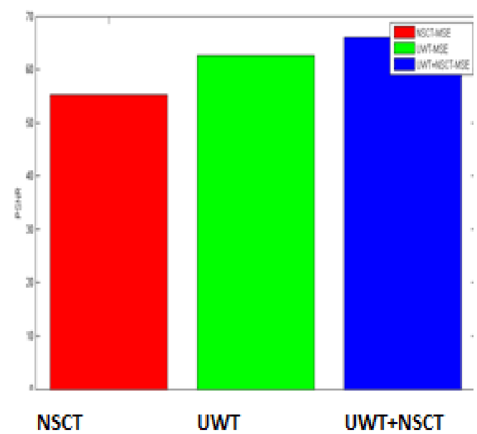

Figure 6. Comparison of PSNR.

Figure 6 clearly depicts that the combination of NSCT and UWT has higher PSNR which states that the quality of the image is increased.

4. Conclusion

The paper presented a Multispectral image enhancement where the images are fused effectively based on NSCT and UWT. The proposed technique has given better visual perception on processed multispectral images rather than prior approaches. The system can be further enhanced with better flexible algorithm to reduce the computational complexity.

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