Fusion of Medical Images based on Second Generation Wavelet Transform

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Abstract: The aim of the medical image fusion is to combine two or more medical images or some of their characteristics into one image, without introduction of any noise or artifacts. The medical images such as computed tomography (CT) and magnetic resonance imaging (MRI) are used widely for diagnosis and treatment. These images contain complementary information that needs to be combined in a single image for better quality and more information. Image fusion technique using wavelet transform gives good results to yield more information without reducing the contrast of the obtained image. The use traditional wavelet transform however involves high computational complexity and large storage requirements. The second generation wavelet transform i.e. lifting wavelets gives better results as compared to traditional wavelets

Keywords: image fusion, wavelet transform, multi-resolution, lifting wavelet transform, discrete wavelet transform

Introduction

Image fusion is the methodology of combining two or more images' complementary and redundant information in a solitary fused image. The fused images are useful for individuals and device opinion and in numerous applications for example remote sensing, medical pictures processing, object identification, target identification etc [1]. Fusion can be applied to single modality images or multimodality images. In the medical field, for various purposes such as researches, precise disease diagnosis, monitoring and treatment process like surgery planning, doctors or radiologists need high spatial and spectral data into a solitary image. This sort of information cannot be obtained using a single modality image, because in medical imaging every imaging instrument captures images with diverse radiation power [2]. For example, computer tomography (CT) provides detail cross-sectional pictures of bones, but does not provide information about delicate tissues or muscles. So, CT cannot distinguish tumours from scar tissues. Magnetic resonance imaging (MRI) pictures give data about delicate tissues, organs and blood vessels etc, but do not provide information about boundaries. So, by fusing CT and MRI clear information about both bones and soft tissues can be obtained in a single image, which is used for diagnosis and treatment [3] [4].
Manually combining images is possible but it takes a lot of time and is a tedious task. Many fusion techniques have been developed in past few years such as weighted average scheme, Gaussian pyramid, laplacian pyramid, and multi-resolution techniques including wavelet transforms [5]. An ideal image fusion algorithm collects the complementary information of source images and tends to prevent the introduction of artifacts or any other unexpected features.
Image fusion is done at three different levels:

- Pixel level: In this, the fusion of images is carried out by applying fusion rules to each pair of corresponding pixels to generate the corresponding pixel of the fused image.
- Feature level: In feature level image fusion techniques, the features like texture, brightness etc. are extracted and used to form the feature vector for fused image.
- Decision level: In decision level image fusion, decision algorithms are used.
- Image fusion methods are categorized into three groups:
- Mathematical methods like subtraction, addition, averaging etc.
- Substitution algorithms like PCA
- Multi-resolution analysis based fusion algorithms.

Wavelet transform multi-resolution techniques are most widely used in this area of image fusion [6]. The traditional wavelets are referred to as first generation wavelets and these have certain limitations in translation and dilution of a particular function. These limitations have been overcome by second generation wavelets named lifting wavelet transforms. Lifting transform is not a consequence of translation and dilution of single function. Lifting scheme [7] is the tool to build the second generation wavelets. The operations in this algorithm are done in spatial domain rather than fourier transform and frequency domain. Lifting wavelets are more efficient and have faster implementation as compared to traditional wavelets. The lifting wavelet transform (LWT) is discussed in section II, fusion algorithm using LWT is discussed in section III, section IV gives the experimental results and section V contains concluding remarks.

Lifting wavelet transform (LWT)

Lifting wavelet transform is divided into three phases i.e. split, predict and update.

- Split: In this step, the input image say I(n) is divided into two subsets, namely, an even subset and odd subset,

$$\text{Even subset } xe(n) = I(2n) \tag{1}$$

$$\text{Odd subset } xo(n) = I(2n=1) \tag{2}$$

- Prediction: In this step, the prediction coefficient is defined. The odd subset coefficient is defined from the prediction of even coefficients. The prediction difference is calculated as:

$$d(n) = xo(n) - P\,(xe(n)) \tag{3}$$

Here, P is the prediction operator and is linear combination of neighbouring even coefficients for each odd coefficient.

- Update: In this step, the odd subset is used to update the even subset in order to maintain the original characteristics. The update operator U is constructed by following equation:

Here, N indicates the number of wavelet coefficient point to attend weighting update and u(i) is the lifting factor.

This approximation coefficient a(n) is created by the process of prediction. The update process is performed using the following equation:

$$a(n) = xe(n) + U(d(n)) \tag{5}$$

The low frequency components are decomposed based on lifting wavelet continuously to create multilevel transformations. The lifting wavelet transforms can be inverted easily by reversing the above steps:

- Anti-Update:

$$xe(n) = a(n) - U(d(n)) \tag{6}$$

- Anti-Prediction:

$$xo(n) = d(n) + P\,(xe(n)) \tag{7}$$

- Merge:

$$I(n) = xo(n) + xe(n) \tag{8}$$

Fusion algorithm using Lifting Wavelet Transform

The input images to be fused must be registered images so as to obtain correct fusion results. The registered images are first decomposed by using LWT and then, a proper fusion rule is applied to merge the wavelet coefficients. The low and high frequency components have different properties, so they need different fusion rules to merge.

The steps used in this fusion process are:

- The source images i.e. a CT and MRI are decomposed into several levels using lifting wavelets to get different wavelet coefficients.
- Low frequency coefficients of source images are fused using averaging method.
- The high frequency coefficients are fused using weighted fusion rule. The weight is calculated using the ratio of corresponding part's spatial frequency.
- Inverse LWT is applied to the components of fused image.

Experimental Results

To evaluate the performance of the proposed fusion algorithm, experiments are conducted on two datasets of CT and MRI images. The size of all images is 256 X 256 [8-9]. Both the source images are already registered. The fusion results for first dataset are shown in Figure 1. By looking at the images, it can be easily determined that fusion is an efficient tool in gathering information from source images into a single fused image.

The second dataset contains CT and MRI pictures of brain and their fusion results are shown in Figure 2. It can be clearly observed from both the figures that the LWT methodology gives superior combination of CT and MRI pictures of first and second dataset. The images shown in Figure 1(d) and Figure 2(d) give clear information about bones which aids doctors in making accurate diagnosis. These images fused using LWT method provides clear information about CT and MRI images and have higher contrast than images fused using traditional wavelet method.

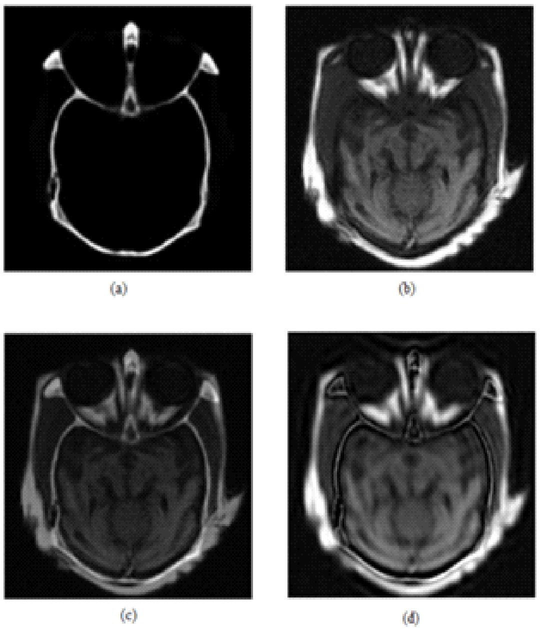

Figure 1: Fusion results of first dataset; (a) CT image (b) MRI image (c) traditional wavelet transform method (d) lifting wavelet transform method

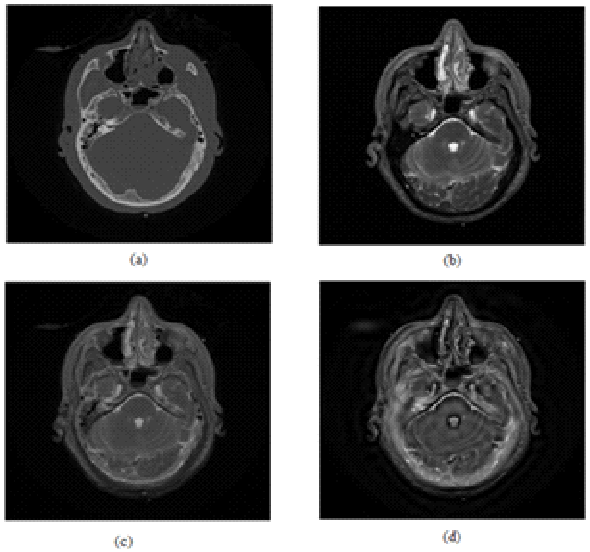

Figure 2: Fusion results of second dataset; (a) CT image (b) MRI image (c) traditional wavelet transform method (d) lifting wavelet transform method

Conclusion

MRI and CT are widely used imaging modalities in the field of medical science. Both imaging modalities contain different information related to tissues and bones. In medical imaging, the edges are quite important as the tissues and organs are presented by them. The fusion method using LWT gives significant results in preserving edge information in the fused image. The visual results clearly depict that the LWT method give superior results as compared to DWT.

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