Comparison of Fusion Algorithms for Fusion of CT and MRI Images

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ABSTRACT
This paper presents combination of wavelet and curvelet based approach for the fusion of magnetic resonance (MR) and computed tomography (CT) images. The objective of the fusion of an MR image and a CT image of the same organ is to obtain a single image containing as much information as possible about that organ for diagnosis.

In this paper some attempts have been proposed for the fusion of MR and CT images using the wavelet transform. Since medical images have several objects and curved shapes, it is expected that the curvelet transform would be better in their fusion. The simulation results show better result than the fusion using wavelet algorithm. Proposed method is combination of wavelet and curvelet transform is used for fusion the medical images. In vision, the fusion algorithm proposed in this project acquires the best fusion result compare to other two methods. In objective evaluation criteria, its fusion characteristic is superior to traditional wavelet transform and curvelet transform. The simulation results show superiority of the combination of wavelet and curvelet transform to the only wavelet transform and only curvelet transform in the fusion of MR and CT images from the visual quality, the peak signal to noise ratio (PSNR) and Root Mean Square Error (RMSE) points of view. It includes multiresolution analysis ability, edge direction of images and analyzes feature of images better.

General Terms
Image fusion, Wavelet algorithm, Curvelet algorithm, Wrapping algorithm, Combination of wavelet and curvelet algorithm

Keywords
Computed Tomography, Magnetic Resonance Imaging, Fusion Technique, Wavelet Transform, Curvelet Transform

1. INTRODUCTION
Image fusion is a data fusion technology which keeps images as main research contents. It refers to the techniques that integrate multi-images of the same scene from multiple image sensor data or integrate multi-images of the same scene at different times from one image sensor. The image fusion algorithm based on Wavelet Transform is faster developed multi-resolution analysis image fusion method. Wavelet Transform has good time-frequency characteristics. It was applied successfully in image processing field. But problem with it is more suitable for one dimension rather then multi dimensions, it is not suitable for edge information as well as for curve shapes

To overcome the limitations of wavelet transform Curvelet Transform is useful. Curvelet Transform consisted of special filtering process and multi-scale Ridgelet Transform. It could fit image properties well. However, Curvelet transform had complicated digital realization, includes sub-band division, smoothing block, normalization, Ridgelet analysis and so on [1]. Curvelet deomposition brought immense data redundancy.Fast Curvelet Transform (FCT) was the Curvelet Transform which was simpler and easily understanding. Its fast algorithm was easily understood. Li Huihui's researched multi-focus image fusion based on the Curvelet Transform. This paper introduces wavelet transform, curvelet transform and uses it to fuse images, different kinds of fusion methods are compared at last. The experiments show that the method could extract useful information from source images to fused images so that clear images are obtained.

Fused image that help physicians in the diagnosis process. Today, there are many medical modalities that give important information about different diseases. These equipments are accompanied by software programs which offer image processing facilities. Complementary information is offered by these modalities. For example, CT provides best information about denser tissue and MRI (Magnetic Resonance Imaging) offers better information regarding soft tissue, [2]. These complementarities have led to idea that combining images acquired with different medical devices will generate an image that can offer more information than each other separate. In this way, the obtained image can be very useful in the diagnosis process, and due to this reason the image fusion has become an important research field.

There are some important requirements for the image fusion process, [5]:

• The fused image should preserve all relevant information from the input images

• The image fusion should not introduce artifacts which can lead to a wrong diagnosis

2. FUSION USING WAVELET ALGORITHM

The most common form of image fusion algorithms is the wavelet fusion algorithm. It is very simple and it has ability to preserve the time and frequency details of the images to be fused [11].

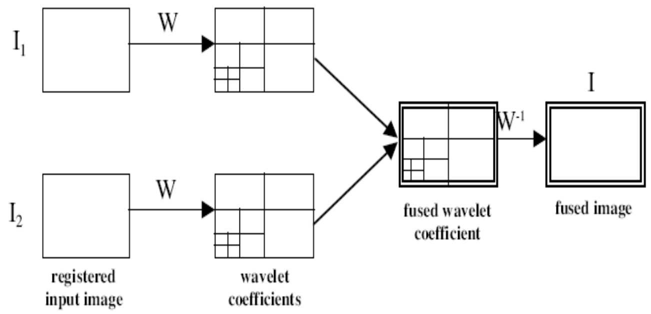


Fig 1: Wavelet fusion of two images.

When constructing each wavelet coefficient for the fused image. We will have to determine which source image describes this coefficient better. This information will be kept in the fusion decision map. The fusion decision map has the same size as the original image. Each value is the index of the source image which may be more informative on the corresponding wavelet coefficient. Thus, we will actually make decision on each coefficient. There are two frequently used methods in the previous research. In order to make the decision on one of the coefficients of the fused image, one way is to consider the corresponding coefficients in the source images as illustrated by the red pixels. This is called pixel-based fusion rule. The other way is to consider not only the corresponding coefficients, but also their close neighbors. This is called window-based fusion rules. This method considered the fact that there usually has high correlation among neighboring pixels.

Objects carry the information of interest, each pixel or a small neighboring pixel is just one part of an object. Thus, we proposed a region-based fusion scheme. When make the decision on each coefficient, we consider not only the corresponding coefficients and their closing neighborhood, but also the regions the coefficients are in a schematic diagram of the wavelet fusion algorithm of two images I1(x1, x2) and I2(x1, x2) is depicted in Fig. 1. It can be represented by the following equation:

$$I(x1, x2) = W^{-1} (\varphi (W (I1(x1, x2)), W (I2(x1, x2))))\text{......} \quad (1)$$

Where W, W^{-1} and φ are respectively the wavelet transform operator, the inverse wavelet transform operator and the fusion rule, respectively. There are several wavelet fusion rules that can be used for the selection of the wavelet coefficients from the wavelet transforms of the images to be fused. The most frequently used rule is the maximum frequency rule which selects the coefficients that have the maximum absolute values [4, 5, 11].
The wavelet transform concentrates on representing the image in multi-scale and it is appropriate to represent linear edges. For curved edges, the accuracy of edge localization in the wavelet transform is low. So, there is a need for an alternative approach which has a high accuracy of curve localization such as the curvelet transform.

3. FUSION USING CURVELET ALGORITHM

It is known that different imaging modalities are employed to depict different anatomical morphologies. CT images are mainly employed to visualize dense structures such as bones. So, they give the general shapes of objects and few details. On the other hand, MR images are used to depict the morphology of soft tissues. So, they are rich in details [12–16]. Since these two modalities are of a complementary nature, our objective is to merge both images to obtain as much information as possible. A curvelet based algorithm is introduced for this purpose. This algorithm is summarized as follows:

(1)The curvelet transform steps are performed on both CT and MRI images.

(2) The maximum frequency fusion rule is used for the fusion of the ridgelet transforms of the subbands Δ1 and Δ2 of both images.

(3) An inverse curvelet transform step is performed on P3 of the MR image and the fused subbands Δ1 and Δ2.

These steps are expected to merge the details in both images into a single image with much more details.

3.1 Wrapping Algorithm (In frequency domain):

1) Perform FFT on the original image.

2) Divide FFT into collection of tiles

3) For each tile apply

a) Translate tile to the origin.

b) Wrap parallelogram shaped support of tile around the rectangle with center as the origin as shown in Figure 2.

\ c) Take inverse FFT of wrapped one

d) Add curvelet array to collection of curvelet coefficients.

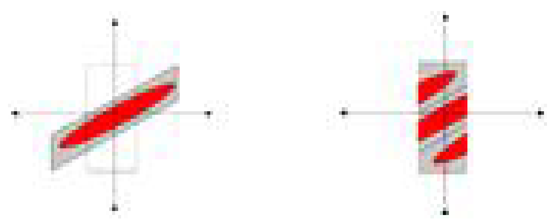


Fig 2: Support of wedge before (left) wrapping and after wrapping

3.2 Inverse Wrapping Algorithm:

1. For each curvelet coefficient array

a) Take FFT of the array.

b)Unwrap rectangular support to original orientationshape.

c) Translate it back to the original position

d) Store the translated array

2. Add all the translated curvelet arrays

3. Take inverse FFT to reconstruct the image.

4. IMAGE FUSION USING COMBINATION OF WAVELET AND CURVELET ALGORITHM

Fusing the medical images (CT & MRI) with the combination of Wavelet & Curvelet

- Using Wavelet Transform to decompose original images into proper levels. One low-frequency approximate component and three high-frequency detail components will be acquired in each level.
- Curvelet Transform of individual acquired low frequency approximate component and high frequency detail components from both of images, neighborhood interpolation method is used and the details of gray can't be changed.
- According to definite standard to fuse images, local area variance is chose to measure definition for low frequency component.
- Inverse Transformation is taken to get Original Image

5. FUSION TECHNIQUE

The most important issue concerning image fusion is to determine how to combine the sensor images. In recent years, several image fusion techniques have been proposed. The primitive fusion schemes perform the fusion right on the source images. One of the simplest of these image fusion methods just takes the pixel-by-pixel gray level average of the source images. This simplistic approach often has serious side effects such as reducing the contrast.

With the introduction of pyramid transform, some more sophisticated approaches began to emerge. It was found that better results were obtained if the fusion was performed in the transform domain. The pyramid transform appears to be very useful for this purpose. The basic idea is to perform a multiresolution decomposition on each source image, then integrate all these decompositions to form a composite representation, and finally reconstruct the fused image by performing an inverse multi-resolution transform.

Actually, the wavelet transform can be considered to be one special type of pyramid decompositions. It retains most of the advantages for image fusion but has much more complete theoretical support.

6. RESULT AND DISCUSSION

The root mean square error of the fusion result is given by:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left[I(i,j)-F(i,j)\right]^2}{N.M}} \quad \ldots\ldots (2)$$

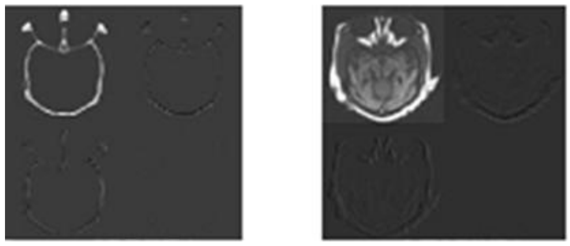
Where I (i, j) is either the MR or the CT image and F (i, j) is the fusion result. M and N are the dimensions of the images to be fused. The smaller the value of the RMSE, better the performance of the fusion algorithm.

The Peak Signal to Noise Ratio of the fusion result is defined as follows:

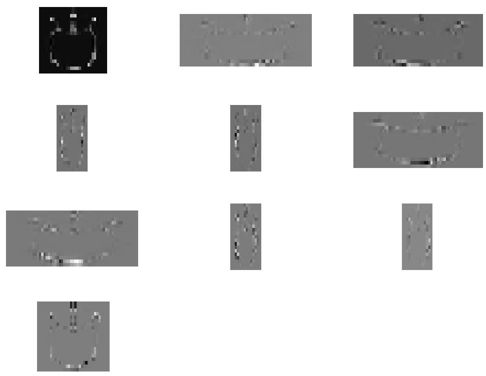
$$PSNR = 10 \times \log\left((f\ max)^2 / RMSE^2\right) \quad \ldots\ldots\ldots (3)$$

f max is the maximum gray scale value of the pixels in the fused image. The higher the value of the PSNR, better the performance of the fusion algorithm

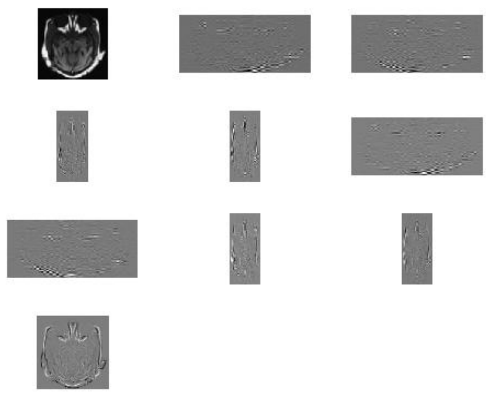
6.1 Result of Wavelet Transform and Curvelet Transform



(a) (b)



(c)



(d)

Fig 3: (a) Discrete Wavelet Transform output of CT image (b) DWT output of MRI image (c) Curvelete output of CT image (d) Curvelet output of MRI image

Above figure shows the result of DWT and Curvelet transform.

In DWT When one-level 2-D DWT is applied to an image, four transform coefficient sets are created. As depicted in Fig 3 (a) and (b) the four sets are LL, HL, LH, and HH, where the first letter corresponds to applying either a low pass or high pass filter to the rows and the second letter refers to the filter applied to the columns.

In Curvelet Transform output fig 3 (c) and (d)has 10 windows in which first is the original image next eight is wrapped output and last is inverse FFT output

6.2 Fusion Result Comparison for Three Different Algorithm

In medicine, CT and MRI image both are tomography scanning images. They have different features. In CT image brightness related to tissue density, brightness of bones is higher, and some soft tissue can't be seen in CT images. In MRI image brightness related to amount of hydrogen atom in tissue, thus brightness of soft tissue is higher, and bones can't be seen. There are complementary information in these images. Three methods use of fusion in medical images, and adopt the same fusion standards. Here shows simulation experiments by above fusion methods in comparison. The results are expressed as Fig. three algorithms all acquire good fusion results, in which the results of combination of wavelet and curvelet algorithm method in this paper have more detail information.

From the comparison chart and fusion outputs in fig it is clear that the curvelet fusion result has a better visual quality than the wavelet fusion result and Combination of wavelet and curvelet fusion have superior visual quality then other two. The PSNR and RMSE values of these results are for wavelet fusion, curvelet fusion and combination of both. These values reflect the ability of the Wavelet and curvelet transform to capture features from both the MR and the CT images. From these results, it is clear that the proposed combination of wavelet and curvelet fusion algorithm has succeeded in obtaining better results than the wavelet fusion algorithm and curvelet fusion algorithm from both the visual quality and the RMSE, PSNR points of view

7. CONCLUSION

Image fusion seeks to combine information from different images. It integrates complementary information to give a better visual picture of a scenario, suitable for processing. Image Fusion produces a single image from a set of input images. It is widely recognized as an efficient tool for improving overall performance in image based application. Wavelet transforms provide a framework in which an image decomposed, with each level corresponding to a coarser resolution band. The wavelet sharpened images have a very good spectral quality. The wavelet transform suffers from noise and artifacts and has low accuracy for curved edges. In imaging applications, images exhibit edges & discontinuities across curves. In image fusion the edge preservation is important in obtaining complementary details of input images. So, curvelet based image fusion is suited for medical images.

Image fusion algorithm based on Wavelet and Curvelet transform includes multi resolution analysis ability in Wavelet Transform, also has better direction identification ability for the edge feature of awaiting describing images in the Curvelet Transform. This method could better describe the edge direction of images, and analyzes feature of images better.

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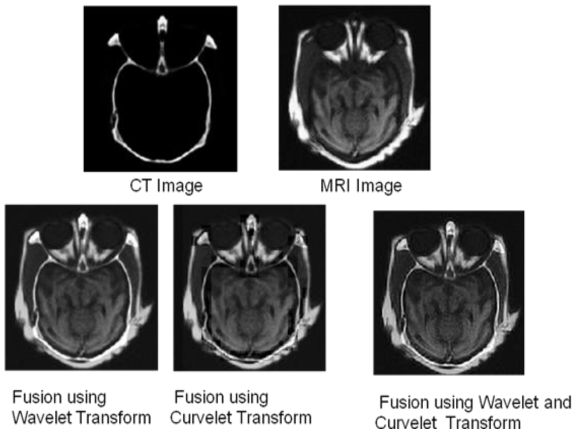

Fig 4: Fusion result of three different algorithms

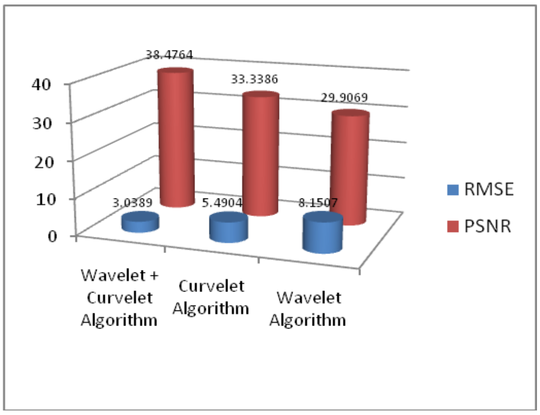

Fig 5: Comparision chart of PSNR and RSME value of three algorithms

From the above comparison chart and fusion outputs in fig 5 it is clear that the curvelet fusion result has a better visual quality than the wavelet fusion result and Combination of wavelet and curvelet fusion have superior visual quality then other two. The PSNR and RMSE values of these results are for wavelet fusion, curvelet fusion and combination of both. These values reflect the ability of the Wavelet and curvelet transform to capture features from both the MR and the CT images. From these results, it is clear that the proposed combination of wavelet and curvelet fusion algorithm has succeeded in obtaining better results than the wavelet fusion algorithm and curvelet fusion algorithm from both the visual quality and the RMSE, PSNR points of view.

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