

Medical Image Fusion

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Abstract-- Image Fusion is the process of generating better quality image from two or more input images. The resultant image should retain all important features of all input images. Various techniques are available for image fusion. Contourlet transform provides directionality and anisotropy which can be useful in generation of better quality fused image. This paper includes medical image fusion using contourlet transform. Region consistency check fusion rule is used to get fused image coefficient. New method of image fusion based on contourlet with image blocking is also presented. Various Qualitative parameters to measure effectiveness of fusion process are also presented. Comparison is presented in graphical as well as tabular form. Comparative study shows that by combining image fusion with image blocking better quality image can be obtained.

Index Terms — Image Fusion, Contourlet transform, Image Blocking, Directionality, Anisotropy

I. INTRODUCTION

Image fusion can be defined as the process of extracting the appropriate information from a set of images and then combining them intelligently to form a single composite image with extended information content in order to overcome the limitation of the type and resolution of the hardware sensors capturing images [3]. Image fusion technology can be applied to many areas dealing with images such as medical image analysis, remote sensing, military surveillance, etc [14].



Figure 1. CT Image

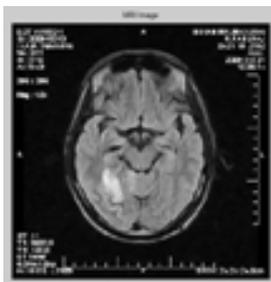


Figure 2. MRI Image



Figure 3. Fused Image

Two images from different image modalities are shown Fig 1 and Fig 2. First image is a Computed Tomography (CT) image which shows the hard structure of the body such as skeleton or bone. The second image is a Magnetic Resonance Imaging (MRI) which shows the soft tissue of body. Each image has its own limitation, which can be solved by creating the fused image from two different image modalities as shown Fig 3. This would lead to improved diagnosis, better surgical planning, more accurate radiation therapy and countless other medical benefits [14].

This paper is structured in the following way:

Section 1 gives introduction to image fusion. Section 2 provides details on Contourlet Transform. Section 3 contains Implementation of Medical Image Fusion using Contourlet Transform. Section 4 presents implementation of Medical Image Fusion using Contourlet Transform and Image Blocking. Section 5 defines a set of image fusion measures of effectiveness and performance evaluation. Section 6 provides conclusions.

II. THE CONTOURLET TRANSFORM

Minh N. Do and Martin Vetterli recently pioneered a new system of representations named contourlets which is a "true" two dimensional transform that can capture the intrinsic geometrical structures that are key features in visual information. The idea is to construct a discrete domain multiresolution and multi-direction expansion using non-separable filter banks, in much the same way that wavelets were derived from filter banks. Inspired by the painting scenario and studies related to the human visual system and natural image statistics, "wish list" [12] for image representations is as follow:

- A. *Multiresolution*: The representation should allow images to be successively approximated, from coarse to fine resolutions.
- B. *Localization*: The basic elements in the representation should be localized in both the spatial and the frequency domains.
- C. *Critical sampling*: For some applications (e.g., compression), the representation should form a basis, or a frame with small redundancy.
- D. *Directionality*: The representation should contain basis elements oriented at a variety of directions, much more than the few directions that are offered by separable wavelets.
- E. *Anisotropy*: To capture smooth contours in images, the representation should contain basis elements using a variety of elongated shapes with different aspect ratios.

Among these features multiresolution, localization and critical sampling is provided by wavelet but it does not provide directionality and anisotropy. Contourlet provides all the features listed above. Figure 4 illustrates the difference between working of discrete wavelet transform and contourlet transform. Here task is to draw a curve. DWT can use only square shaped basic element and can capture limited directional information. On the other hand contourlet can use basic element which can be of any size. Contourlet exploits effectively the smoothness of the contour by making brush strokes with different elongated shapes and in a variety of directions following the contour.

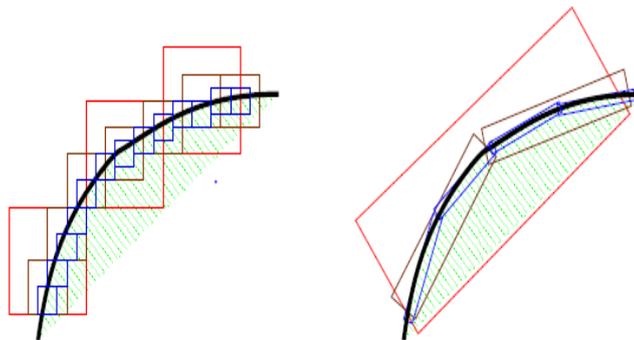


Figure 4. DWT versus Contourlet scheme [12]

Contourlet transform is a multi-scale and multi-direction framework of discrete image. In the transform, the multiscale analysis and the multi-direction analysis are separated in a serial way. The Laplacian pyramid (LP) is first used to capture the point discontinuities, and then followed by a directional filter bank (DFB) to link point discontinuities into linear structures. The overall result is an image expansion using basic elements like contour segments. The framework [7] of contourlet transform is shown in Figure 5.

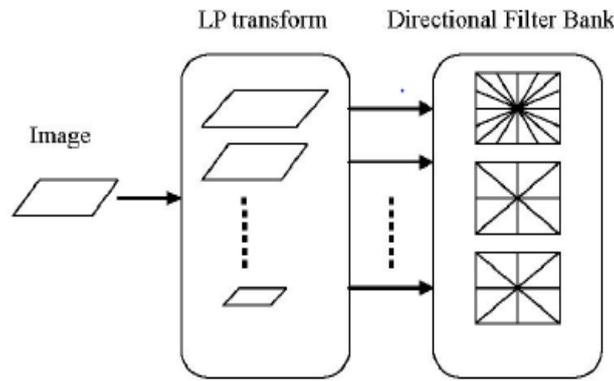


Figure 5. Framework of Contourlet Transform [14]

Laplacian pyramid and a directional filter bank is a double filter bank structure. In contourlet transform, the multi-scale decomposition is done firstly. One way to obtain a multi-scale decomposition is to use the Laplacian pyramid. The LP decomposition at each level generates a downsampled lowpass version of the original and the difference between the original and the prediction could be calculated. The difference is the prediction error. The process can be iterated on the coarse (downsampled lowpass) signal. The DFB is designed to capture the high frequency components of images. Therefore, low frequency components are handled poorly by DFB. The low frequency component should be removed before DFB. Through the multi-resolution of LP, the low frequency subimage is removed, and DFB can be used only to process the high frequency components.

Figure 6 is the contourlet decomposition [7] framework using LP and DFB. The bandpass images, output of the LP, are fed into a DFB. Directional information can be captured efficiently when using PDFB. The scheme can be iterated repeatedly on the coarse image. The final result is a double iterated filter bank structure, which decomposes images into directional subbands at multiple scales. The scheme is flexible since it allows for a different number of directions at each scale.

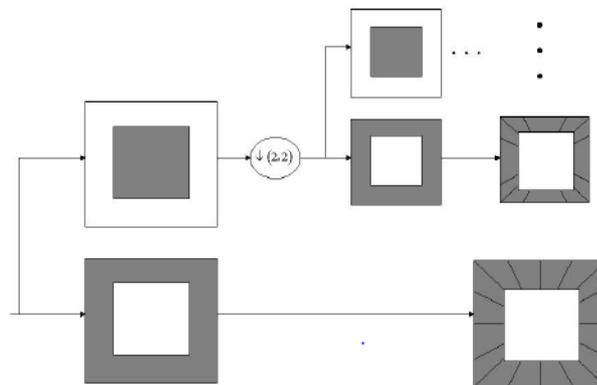


Figure 6. Contourlet decomposition framework[12]

Contourlet transform is more appropriate for the analysis of the signals which have line or hyper-plane singularity than wavelet, and it has better approximation precision and sparsity description. When introducing contourlet transform to image fusion, we can take the features of original images well and provide more information for fusion. The ability of noise restraint is also better than wavelet transform. The fused image with the proposed contourlet-based fusion method could represent better detail from original image because contourlet represent edges better than wavelets. Therefore, this new method is an optimal method for image fusion [8].

III. MEDICAL IMAGE FUSION USING CONTOURLET TRANSFORM

For Image Fusion using Contourlet Transform following steps are required.:

Step 1: Images are decomposed into various subbands. The transformed images include one low frequency subbands and other high frequency subbands.

Step 2: Apply different Fusion Rules to high frequency and low frequency coefficients. It gives coefficients for fused image.

Step 3: Construct Fused Image by reconstructing fused image coefficients obtained in step 2. For the coefficients of the low frequency, Fusion is carried out with the average rule:

$$Y_F\{1\} = \{Y_A\{1\} + Y_B\{1\}\} / 2 \quad (1)$$

Here $Y_A\{1\}$ and $Y_B\{1\}$ are low Frequency subbands of MRI image and CT image respectively.

And $Y_F\{1\}$ is low frequency subband of Fused image. For the coefficients of the high frequency, Fusion with region consistency check:

$$D_x(i, j) = \sum_{i \leq M, j \leq N} Y_X(i, j)^2, X = A, B \quad (2)$$

$$Y_F(i, j) = \begin{cases} Y_A(i, j), & D_A(i, j) \geq D_B(i, j) \\ Y_B(i, j), & D_A(i, j) < D_B(i, j) \end{cases} \quad (3)$$

Here region consistency is calculated based on equation(2) and region with highest value of region consistency is selected as fused region.

IV. MEDICAL IMAGE FUSION USING CONTOURLET WITH IMAGE BLOCKING

Following step are required to perform medical image fusion using image blocking and contourlet transform:

Step 1: Decompose source images CT and MRI using Contourlet Transform.

Step 2: Get fused image coefficients using fusion rule explained in section III.

Step 3: Reconstruct Fused image F_0 from Fused image coefficients obtained in step2.

Step 4: Divide the input images CT, MRI and the initial fused image F_0 into equi-sized square blocks whose size are $m \times n$. Calculate the similarity measure SM values of the corresponding subblocks of A ,B and F_0 respectively using following equations.

$$SM_{F_0CT} = \frac{2 \times \sum_{i=1}^m \sum_{j=1}^n F_0(i, j) \times CT(i, j)}{\sum_{i=1}^m \sum_{j=1}^n [F_0(i, j)^2 + CT(i, j)^2]} \quad (4)$$

$$SM_{F_0MRI} = \frac{2 \times \sum_{i=1}^m \sum_{j=1}^n F_0(i, j) \times MRI(i, j)}{\sum_{i=1}^m \sum_{j=1}^n [F_0(i, j)^2 + MRI(i, j)^2]} \quad (5)$$

Step 5: Construct map using following equation:

$$Map(r, c) = \begin{cases} 1 & SM_{F_0CT}(r, c) \geq SM_{F_0MRI}(r, c) \\ 0 & \text{Otherwise} \end{cases} \quad (6)$$

Step 6: Get the final fused image F by the following calculation:

If $Map(r, c) = 1$ and the sum of each element in the Map entered at (r, c) of 3×3 neighborhood is equal to 9, then:

$$F(i, j) = CT(i, j) \quad (7)$$

Else if: $Map(r,c)=0$ and the sum of each element in the map centered at (r,c) of 3×3 neighborhood is equal to 0, then:

$$F(i, j) = MRI(i, j) \quad (8)$$

Else

$$F(i, j) = F_0(i, j) \quad (9)$$

V. PERFORMANCE EVALUATION

There are several quality measures which are used to measure quality of image fusion process. From these we have discussed Root Mean Square Error(RMSE), Peak Signal to Noise Ratio(PSNR), and Normalized Cross Correlation.

A. *Root Mean Square Error*: The root mean square error [14] given by:

$$\sqrt{\frac{\sum_{i=1}^m \sum_{j=1}^n [R(i, j) - F(i, j)]^2}{M * N}} \quad (10)$$

Where, $R(i, j)$ is original image (or one of the source images) and $F(i, j)$ is the fused image. m and n are the dimensions of the images. Smaller value of the RMSE indicates better fusion performance.

B. *Peak signal to noise ratio*: Peak signal to noise ratio [14] can be given as follow:

$$PSNR = 10 * \log_{10}\left(\frac{fmax^2}{MSE}\right) \quad (11)$$

Where, $fmax$ is maximum gray scale value of the pixels in fused image, the higher the value of the PSNR, the better the fusion result.

C. *Entropy*: Entropy [14] gives a statistical measure of randomness that can be used to characterize the texture of the input image. Entropy is defined as

$$E = - \sum_{i=0}^{L-1} P_i \log_2 P_i \quad (12)$$

Where, p contains the histogram counts of an output image.

D. *Normalized Cross Correlation*: It used to find out similarities between fused image and registered image is given by the following equation [14]

$$NCC = \frac{\sum_{i=1}^m \sum_{j=1}^n (F_{ij} * R_{ij})}{\sqrt{\sum_{i=1}^m \sum_{j=1}^n (F_{ij})^2}} \quad (13)$$

Where, R is original image (or one of the source images) and F is the fused image. m and n are the dimensions of the images.

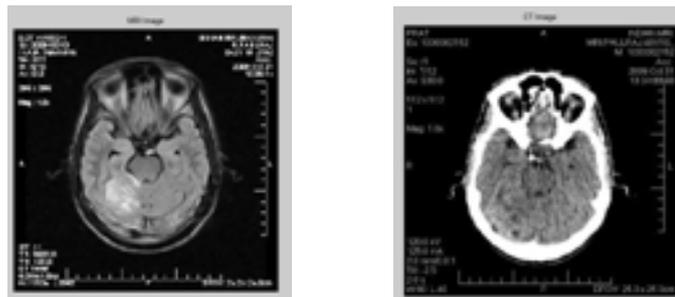


Figure 7. MRI Image

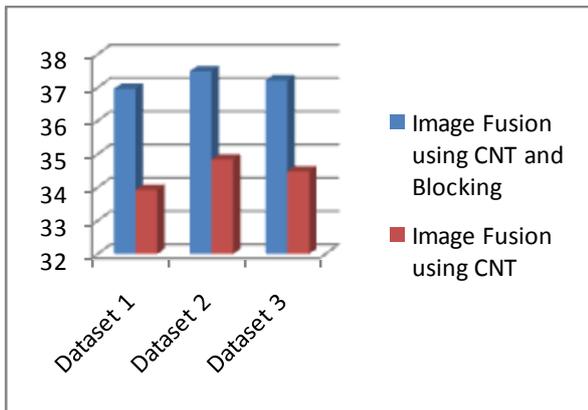
Figure 8. CT Image



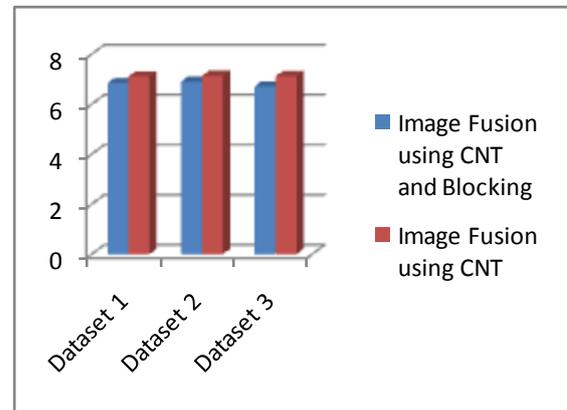
Figure 9. Fused Image – CNT

Figure 10. Fused Image – CNT and Image Blocking

Fig. 7 and Fig. 8 shows input images MRI and CT respectively. These are brain images taken by different sensors. Contourlet and Contourlet with Image Blocking methods of Image Fusion are applied on input images. Resultant image are shown below. Fig. 9 shows result of medical image fusion using contourlet transform and Fig. 10 shows resultant image using contourlet transform and image blocking. Experiment is carried out on several datasets. Quantitative analysis is presented in Table 1. Graph 1, Graph 2, Graph 3 shows PSNR, Entropy and NCC values respectively.



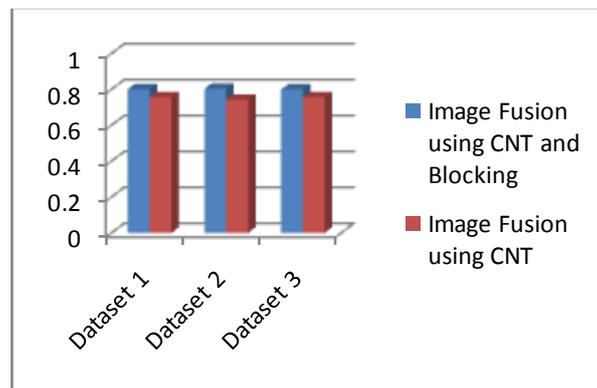
Graph 1. PSNR Calculation



Graph 2. Entropy Calculation

Input Parameters	Dataset 1		Dataset 2		Dataset 3	
	Contourlet	Contourlet with Image Blocking	Contourlet	Contourlet with Image Blocking	Contourlet	Contourlet with Image Blocking
PSNR	33.92	36.96	34.84	37.49	34.48	37.22
ENTROPY	7.1019	6.8425	7.1280	6.8977	7.1015	6.7002
NCC	0.7552	0.8007	0.7428	0.8031	0.7555	0.7996

Table 1. Quantitative analysis of CNT and CNT with Image Blocking Fusion Methods



Graph 3. NCC Calculation

VI. CONCLUSION

There are several methods for Image Fusion. Here medical Image Fusion is carried out using two methods namely Contourlet transform and Contourlet Transform with Image Blocking. Various Quantitative parameters such as PSNR, Entropy, and NCC are used for performance evaluation. By combining Contourlet Transform and Image blocking PSNR and NCC values are increases. As each block of Fused image is original block of any of the input image visual Quality is also improved.

VII. REFERENCES

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