ISSN (Print): 0974-6846 ISSN (Online): 0974-5645

Image Fusion of Multi-Modal Images using Region Consistency Check and Blocking in Contourlet Transform

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Abstract

Objectives: The purpose of medical image fusion is to obtain more useful content from different imaging modalities. Region consistency check fusion rule is applied in Contourlet Transform with blocking methodology for better diagnosis. **Methods:** Here, features of Contourlet Transform along with Wavelet transform have been studied. Simulation experiments have been done on multimodality images. Two source images are decomposed into multi-resolutions by applying concept of Contourlet transform. Transformed coefficients will be integrated with a fusion rules. After that, CT with blocking has been applied. In blocking process similarity between temporary fused image and original image has been find out. Lastly best result has been considered using sign matrix. **Finding:** CT, which provides a good directionality than the others transforms. Quantitative and qualitative analysis of our proposed algorithm shows that using blocking in CT with region consistency check fusion rule gives more informative image. **Novelty/Improvement:** The results show that it is useful for enhancing medical imaging for medical diagnostics and analysis.

Keywords: Blocking, Contourlet Transform (CT), Fusion, Region Consistency Check, Sign Matrix, Temporary Fused Image

1. Introduction

Now days various medical devices are available to take images but as these images are taken from different modality so to obtain one single image with more details which can help for better diagnosis image fusion is needed in field of data fusion. Here, the aim of fusion is to fix anatomical, functional images and allow recovered spatial localization of irregularity. Three distinguish levels of image fusion are pixel, feature, and decision based image fusion. It can be classified in two domains, first one is spatial domain and second one is transform domain. In a fused image spatial misrepresentation is given by spatial domain methods. Transform domain approach can able to resolve this problem. Spatial domain image fusion is

enduring by fusing source images directly. This technique had the shortcoming that, the fused image has low contrast than source image. To remove this shortcomings pyramid decomposition method is established. The pyramid decomposition provides good contrast which is sensitive to eye. It also provides good localization. Discrete wavelet is one of the examples of it. But the disadvantage of DWT is it agonized from shift variance⁴. Because of anisotropy and multi-directionality, CT represents image features like edges, lines, curves and contours well than DWT. When CT performed on image first Laplacian pyramid applied to find out point discontinuity, then directional filter bank applied to join point discontinuity. The image expansion is done using basic essentials like contour sections, therefore the name CT is being created⁵.

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2. Image Fusion In Frequency Domain

Transform domain processing techniques consists of 3 steps⁶:

- Decomposition of an image
- Formation of a source image for Re-composition.
- · Re-composition.

In following section DWT and CT has been discussed.

a. Discrete Wavelet Transform

The DWT^{2,8} can be able to capture temporal information at each different level². An oscillatory function of wavelet has zero average value. Due to good localization feature a wavelet works quite better than others for analysis of signals³. This signal has discontinuities. Wavelet has a two function, first is scaling function f (t) and second is wavelet function ψ (t). Wavelet function undergoes translation. Scaling function gives similar wavelet structure families. Both functions are described as in below equation³:

$$\varphi_{k,l}(t) = \frac{1}{\sqrt{k}} \varphi\left(\frac{t-l}{k}\right), (k, l \in R), k > 0$$
 (1)

Where, k = scale factor and l = translation factor. In DWT, an input source image will be partitioned in to low-pass filter and high-pass filter. It will perform down sampling at every step, to get estimate (LL) coefficient and the detail (LH, HL, and HH) coefficients. Using a smooth filter – low pass filter scaling function is fixed. Wavelet function is fixed with high-pass filtering³. Conversion of spatial coefficient to frequency coefficient is done by DWT as shown in Figure 1. Image is separated by horizontally and vertically which represents first order of DWT. The four

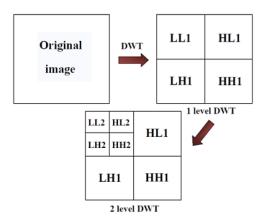


Figure 1. Frequency distribution in DWT 3 .

sections are obtained. The left-upper section is known as LL1, right-upper section is known as HL1, left-bottom section is known as LH1 and right-bottom section is known as HH1. Here LH1 section, HL1 section and HH1 section have additional specified information than LL1 section¹.

Some of DWT methods used here are

- Haar WT method
- Daubechies WT method.

In this paper to implement DWT image fusion, Daubechies wavelets (db5) are used.

b. Contourlet Transform

A novel multi-scale, directional selectivity transform known as Contourlet Transform (CT). It has 2D non separable filter bank who provides a elastic multi resolution, local and good directional ways for image processing ^{10,11}. It is having following properties ¹²:

- Multi-resolution: Image is successively divided from coarse to fine presentation of resolution in this transform.
- Localization: The Basic element should be localized in to both spatial as well as frequency domains.
- The Directionality: The basic element should orient at various directions than DWT.
- Critical sampling: In image, the representation should frame with less redundancy
- Anisotropy: The representation should have variety of elongated forms to capture smooth contours. The elongated forms are having different aspect ratios.

Treating with singularity of higher dimension CT works fairly better than DWT. It provides a copious directional selectivity. It can present a variety of direction for even contours in source images^{13,11}, as shown in Figure 2. Here it shows that contours are smoother in CT.

For multi-resolution CT has Laplacian Pyramid (LP). For multi directionality has Directional Filter Bank (DFB). Figure 3 shows the frame of CT decompo-

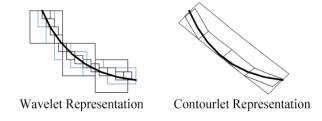


Figure 2. Comparison of Wavelet and Contourlet 12.

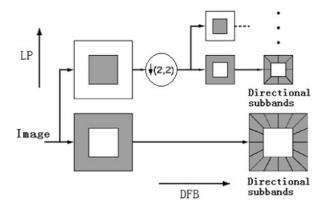


Figure 3. Framework of CT decomposion $\frac{14}{2}$.

sition. The first step of it is, decomposed images by LP into LF sub-band and various HF sub-bands. Succeeding HF bands are nourish into DFB and fragmented into numerous directional bands¹⁴.

CT is sparse because the greater part of CT coefficient is near to zero. Additionally, CT can offer specified information in any random direction. CT can achieve this due to the no. of directional sub-bands at every level is typically 2ⁿ, which is quite elastic when dissimilar n has been chosen¹⁴.

3. Proposed Algorithm

Here two fusion rules have been applied. The rules are Averaging and Region consistency check.

a. Fusion Rules

There are so many image fusion rule has been applied till date. Among them two fusion rule has been applied in simulation of multimodality image fusion using CT.

i. Averaging

For the coefficients of the LF, Fusion with spatial method –Averaging 15.16 has been performed. Averaging is performed using following equation:

$$IF{1} = {IA{1} + IB{1}}/2$$
 (2)

ii. Region Consistency Check

High frequency coefficient will be fused with Region consistency check¹⁷.

$$DFL_x(kk, ll) = \sum_{kk \le M, ll \le N} Y_X(kk, ll)^2, X = A, B$$

$$Y_{f}(kk, ll) = \begin{cases} Y_{A}(kk, ll), & DF_{A}(kk, ll) \ge DF_{B}(kk, ll) \\ Y_{B}(kk, ll), & DF_{A}(kk, ll) < DF_{B}(kk, ll) \end{cases}$$
(3)

b. Proposed Algorithm

Proposed algorithm includes image fusion of multi modal images in CT using Blocking. Here temporary fused image generated first and then blocking has been performed. Finally more informative fused image has been generated.

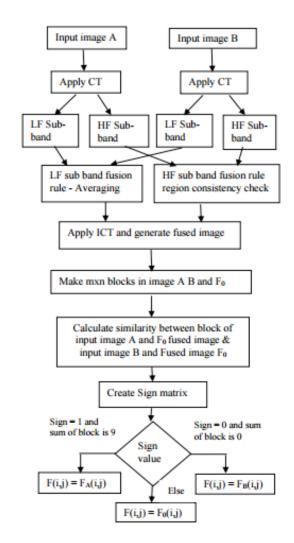


Figure 4. Proposed algorithm.

The steps are as mention below:

- Fuse the both input source image named I1 and I2 based on the Averaging fusion rule and Region consistency check fusion rule in CT to achieve the initial temporary fused image F0.
- Input source images I1 and I2 and provisional fused image F0 is divided into m x n sized block where m = n.
- SM Similarity measure values¹⁸ has been calculated for the consequent sub-blocks of I1, I2 and F0

respectively. If greater SM value then more similarities between that images. Here in equation 4 and 5, I1 represent with image A and I2 with B.

$$SM_{FoA}(r,c) = \frac{2 X \sum_{o=1}^{m} \sum_{s=1}^{m} F_o(o,s) X A(o,s)}{\sum_{o=1}^{m} \sum_{s=1}^{m} [F_o(o,s)^2 + A(o,s)^2]}$$

$$SM_{FoB}(r,c) = \frac{2 X \sum_{o=1}^{m} \sum_{s=1}^{m} F_o(o,s) X B(o,s)}{\sum_{o=1}^{m} \sum_{s=1}^{m} [F_o(o,s)^2 + B(o,s)^2]}$$
(4)

Create a sign matrix

$$Sign(r,c) = \begin{cases} 1 & SM_{FoA}(r,c) \ge SM_{FoB}(r,c) \\ 0 & otherwise \end{cases}$$
 (5)

Here r = 1, 2... M and c = 1, 2... N.

 To obtain final fused image, following condition will be checked:

In the defined 3x3 matrix sign (r,c) = 1 and summation of matrix is 9 then:

$$F(o, s) = F_{A}(o, s)$$

Other possibility is if Sign (r, c)=0 and summation of 3x3 matrix is 0 then:

$$F(o, s) = F_{p}(o, s)$$

Else

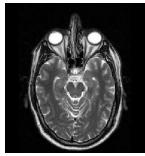
$$F(o, s) = F_o(o, s)$$

4. Result with Performance Analysis

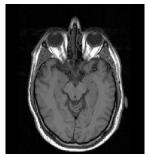
Here Image fusion is performing to obtain more information. The original purpose of image fusion is to boost information by performing merging of medical images like PET, CT, and MRI¹⁹. Here in this simulation we have used input Image A C3.jpg which is CT image and input Image B M3.jpg, which is MRI image. Both input image is shown in Figure 5. Qualitative analysis of simulation is clearly visualized in Figure 6. Five standard measuring parameter has been used to measure performance of fusion process, which are RMSE^{3,20}, PSNR^{15,21,22}, NCC¹⁵, Standard deviation (SD)^{3,11} and DD¹⁵. All fusion methods are implemented in MATLAB 13.

Figure 6 shows the result of CT using region consistency check and CT using region consistency check with blocking. Qualitative analysis shows that our proposed algorithm gives more informative result.

Here in Table 1 Existing algorithm is CT using Region consistency check and Proposed algorithm is CT using



Input Image A (Dataset 3)



Input image B (Dataset 3)

Figure 5. Input images 23 .

Contourlet

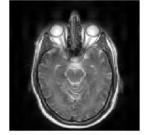


Image Fusion in CT with region consistency check fusion rule

Contourlet with blocking

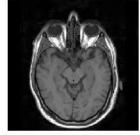


Image Fusion in CT with blocking using region consistency check fusion rule

Figure 6. Qualitative analysis of CT using region consistency check rule and proposed algorithm.

Table 1. Quantitative analysis of proposed algorithm

Dataset	Method	RMSE	PSNR	NCC	SD	DD
Dataset 1	Existing algorithm	5.478	33.35	0.755	71.22	27.78
	Proposed algorithm	1.308	45.79	0.823	64.71	1.45
Dataset 2	Existing algorithm	5.681	33.04	0.713	72.07	30.34
	Proposed algorithm	1.186	46.64	0.781	63.17	1.34
Dataset 3	Existing algorithm	4.780	34.54	0.922	59.79	13.43
	Proposed algorithm	0.974	48.35	0.967	54.66	0.68

Region consistency check with blocking. Dataset 1, 2 and 3 taken from²³ Table 1 shows the quantitative analysis of both. As per the quantitative analysis, it shows that proposed algorithm works better than existing algorithm.

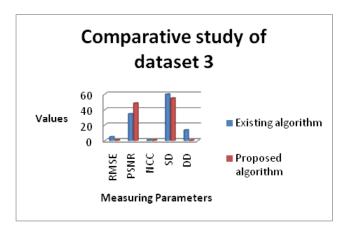


Figure 7. Comparative study of existing algorithm – method 1 with proposed algorithm method-2.

Here Figure 7 shows that Mean square error and Degree of Distortion is less while PSNR and NCC are greater value which shows the better quantitative result of proposed algorithm.

5. Conclusion

CT gives better directionality than other traditional transform. Here simulation result shows that after applying blocking on CT with region consistency check temporary fused image has been generated and resultant finalized fused image created by similarity check and sign matrix which gives quite good quantitative results and qualitative results. Here medical images are fused to perform the fusion operation. So fused image is having higher information than CT and MRI source images which can be helpful in medical diagnosis.

6. Acknowledgment

All kind of research work is made probable with the helping nature of parents, professors, family members, friends, and in spirit of, all sentient beings. Especially, please permit me to donate our acknowledgment of thankfulness toward the CHARUSAT University who provides platform for us to do the research on Image Fusion.

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