Medical Image Fusion And Denoising Using Butterworth And Cross Bilateral Filters

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Abstract *— This paper presents the architecture and implementation of a system that aims at integrating information from multiple source images in to a single fused image. Medical image fusion conglomerate all the significant visual informations from multiple input medical images by retaining the more accurate and stable information than the individual source images without introducing any artifacts. Usually medical images are often noise affected due to the imperfections in the image capturing device. Noise distorts the useful characters of the image and thus reduces the fusion rate significantly. Hence, denoising is a challenge for medical image fusion techniques. In order to avoid this problem a new technique is introduced, initially a multi scale alternating sequential filter is used to extract the useful characters (region of interest) from the input images. Then, a combination of butterworth and cross bilateral filters is used to guide the image fusion. From the experimental results, it is proved that the proposed system works well on both noisy and normal medical images.*

Keywords **—** *Medical image fusion and denoising, Multi scale alternating sequential filter, Region of interest, Cross bilateral filter*

I. INTRODUCTION

Medical image fusion is becoming an important tool to enhance the visual interpretation of the medical images. Medical image fusion is the process of registering or combining multiple images from single or multiple imaging modalities. Main objective of medical image fusion is to automatically transfer the useful information contained in the multiple source images to a single fused image without any information loss. This technique increases the clinical applicability of medical images for diagnosis. Medical image fusion is based on the fact that each imaging modality provides information in limited domains. For example, computed tomography(CT) image provides good results on dense structures like bones and implants. While magnetic resonance imaging (MRI) provides better information on soft tissues. By integrating relevant information from CT/MRI scans,it is easy for the radiologists to effectively report CT/MRI studies. But most of the medical images are prone to noise due to imperfections in the image capturing devices. Noise distorts the useful characters of the image and finally reduces the fusion rate. So due to the presence of noise, traditional image fusion techniques fails. In the proposed system, input images are subjected to denoising prior to image fusion. Since noise is high frequency component, generally concentrates in the high frequency region of the image, making the extraction of edge features and image details difficult. Hence, medical image fusion and denoising is a challenging problem. The proposed system makes use of multi scale alternating sequential filter, to effectively extract the region of interest from the noisy input images. Also butterworth and cross bilateral filters are used to efficiently carry out the fusion.

II. METHODOLOGY

Proposed system, integrates the information from multiple source images to obtain a more complete and accurate description of the same object with reduced noise. The proposed system make use of multiscale alternating sequential filter, butterworth filters and cross bilateral filters. Goal of medical image fusion is to integrate noisy medical images in to one image which preserves details (like dense structures, soft tissues, and blood flow) of the input images by reducing the noise. Joint fusion and denoising is done by cross bilateral filters. Image fusion has many applications, medical image fusion is one among .Medical image fusion can be done in brain, prostate, bone marrow, lungs etc. Inputs of Image fusion algorithm can be a computed tomography (CT) image/magnetic resonance (MR) image/ultrasonic scan/positron emission tomography (PET) image. Different scan images of same organ are taken as the input to fusion algorithm.

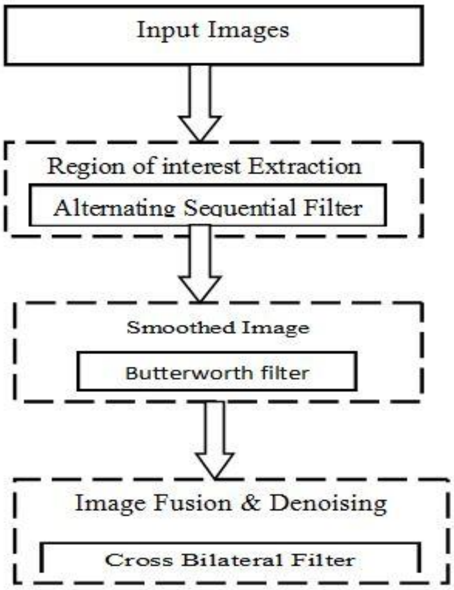


Fig:1. Flow chart of the proposed medical image fusion and denoising framework

A. *Multiscale Alternating Sequential Filter*

Noise and the features of the image have similar characteristics in spatial and frequency domains thus, making the extraction process difficult. Region of interest is extracted from the input noisy images by using multi scale alternating sequential filter. Mathematical operations like opening, closing, dilation, erosion etc are used for edge detection. Dilation and erosion, denoted by $f \oplus B$ and $f \ominus B$ is defined as follows:

$$f \oplus B = \max_{u,v} (f(x-u, y-v)+B(u,v))$$
$$f \ominus B = \min_{u,v} (f(x+u, y+v)-B(u,v))$$

Other significant operations are opening and closing, denoted by $f \circ B$ and $f \bullet B$ is defined as follows:

$$f \circ B = (f \ominus B) \oplus B$$
$$f \bullet B = (f \oplus B) \ominus B.$$

Where B is the structuring element and f is the input image. Closing can eliminate small holes and fill gaps on the contour. Opening eliminates glitches and scatters of the object edge. Thus by alternatively operating opening and closing, alternate sequential filter can be realized. The shape and size of the structuring elements are the two important parameters in alternate sequential filter. Shape of structuring element should be similar to object boundary. Proposed system assumes that various boundaries can be constituted by a series of horizontal vertical or inclined lines. Four different directions are selected: 0◦, 45 ◦, 90 ◦, and 135◦. The structuring element of 3×3 used for closing operation to reduce noise and the structuring element of 5×5 used for opening operation to fill the holes generated by closing operations.

0	0	0	0	0	1	0	1	0	1	0	0
1	1	1	0	1	0	0	1	0	0	1	0
0	0	0	1	0	0	0	1	0	0	0	1
(a)			(b)			(c)			(d)		

Fig: .2 Structuring element of 3×3 in 0^o, 45^o, 90^o, and 135^o

0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
1	1	1	1	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0
0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
(a)					(b)					(c)					(d)				

Fig: 3. Structuring element of 5×5 in 0^o, 45, $90^{o,}$ and 135^o

B. *Butterworth Filter*

Image filtering is useful for the removal of noise and the enhancement of image details such as edges or lines. Low pass filter (LPF) leads to the smoothing of image by removing the high frequency components, and High pass filter (HPF) used for the sharpening purposes. For sharpening purposes, ideal HPF has the sharp discontinuity which produces the unwanted ringing effect. BHPF(butterworth high pass filter) does not have sharp discontinuity, thus not having much ringing artifacts. It has maximal flat phase delay. BHPF is the transition between the IHPF and GHPF(Gaussian high pass filter). BHPF has the gradual attenuation profile, in which the cut off and slope are to be adjusted independently. The transfer function of BHPF is given as:

$$H(f)= 1/1+(f_0/f)^{2n}$$

Where f_o is a certain cut off frequency, n is the order of the filter. It passes the frequency above f_o and rejects the lower frequencies. In BHPF, both cut off frequency and order can be changed to yield variety of results. As the cut off frequency increases, the filter becomes smoother, and the resultant filtered images are milder. The effect is not much pronounced due to the order, which can be controlled independently to get the sharper images. But in GHPF, order cannot be changed, and thus increase in cut off frequency results in more smoothness. Hence, images filtered from BHPF are superior in quality.

C. *Cross Bilateral Filter*

Image fusion and denoising are effectively done using cross bilateral filter. This image fusion algorithm directly fuses two source images of a same organ using weighted average. The weights are computed by measuring the strength of details in a detail image that is obtained by subtracting CBF output from the original image. The weights thus obtained are directly multiplied with the original source images followed by weight normalization. Cross bilateral filter is combination of low-pass filter with an edge-stopping function that attenuates the filter kernel, when the intensity difference between pixels is large. The block diagram of the proposed scheme is shown in Fig.4. for two source images A and B. The advantage of the filter is that it smoothes the image by preserving the edges using neighbouring pixels. The detail image, obtained by subtracting CBF output from the respective original image, for image A and B is given by :

$$AD = A - A_{CBF}$$
$$BD = B - B_{CBF}$$

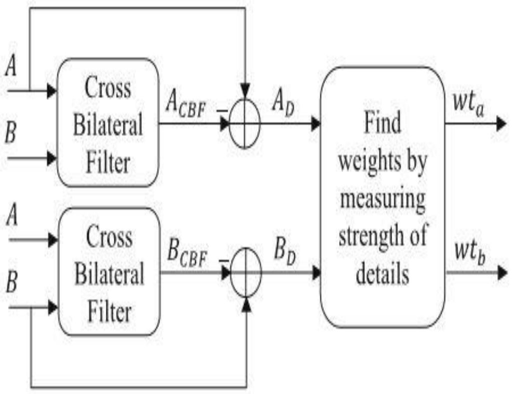


Fig: 4. Weight Calculation

From the obtained detail images the average weights of the input images A and B are calculated by the given formula:

$$Wt(i,j) = \text{Hdetail strength}(i,j) + \text{Vdetail strength}(i,j)$$

Where, Hdetail strength(i,j) is the horizontal detail strength of the horizontal direction, Vdetail strength is the vertical detail strength of the vertical direction. Mathematically they are defined as:

$$\text{Hdetail strength}(i.j) = \sum_{k=1}^{w} \text{eigen}_k \text{ of } C_h^{i,j}$$
$$\text{Vdetail strength}(i.j) = \sum_{k=1}^{w} \text{eigen}_k \text{ of } C_v^{i,j}$$

Where $C_h^{i,j}$ is the covariance estimate along the horizontal direction and $C_v^{i,j}$ is the covariance estimate along the vertical direction. After computing the weights from the detailed images ,image fusion is done. If Wta and Wtb are the weights for the detail coefficients AD and BD belonging to the respective source images A and B, then the weighted average of both is computed as the fused image using pixel based fusion rule;

$$F(i,j) = A(i,j)Wta(i,j) + B(i,j)Wtb(i,j) / Wta(i,j)+Wtb(i,j)$$

Hence, fused image is obtained using pixel based fusion rule.

III. PERFORMANCE EVALUATION PARAMETERS

In order to judge the medical image fusion performance of different methods, four quality evaluation metrics are adopted.

A. Signal To Noise Ratio

High SNR value indicates better performance of fusion and denoising.

$$SNR = 10\log_{10}\left[\sum_{i=1}^{X}\sum_{j=1}^{Y}(Rij)^2 / \sum_{i=1}^{X}\sum_{j=1}^{Y}(Rij - Fij)^2\right]$$

where X and Y represents the number rows and columns of the image respectively ,and Rij and Fij denotes the pixel values in (i,j)of the reference image and fused image .

B. Root -Mean Square Error

Smaller RMSE value shows better fusion.

$$RMSE = \sqrt{\sum_{i=1}^{X}\sum_{j=1}^{Y}(Rij - Fij)^2 / (X \times Y)}$$

C. Entropy

A larger entropy value means the fused image contains more information thus denoting a better fusion rate. Entropy is given as:

$$En = -\sum_{i=0}^{L-1} Pi \log Pi$$

where Pi stands for ratio of pixel number Ni of gray value i and the total pixel number N.

D. Gradient Based Index

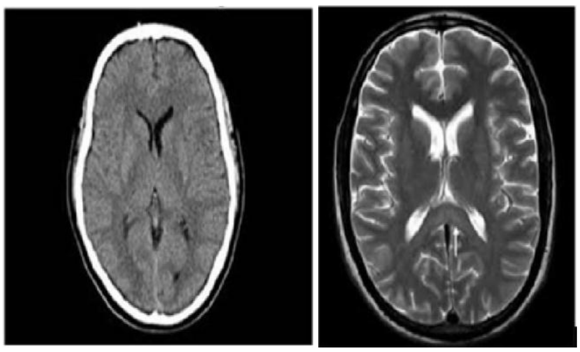
It is given by:

$$QG = \sum_{I=1}^{X}\sum_{J=1}^{Y}(Q^{AF}(I,J)\,T^{A}(I,J) + Q^{BF}(I,J)\,T^{B}(I,J)) / \sum_{I=1}^{X}\sum_{J=1}^{Y}(T^{A}(I,J) + T^{B}(I,J))$$

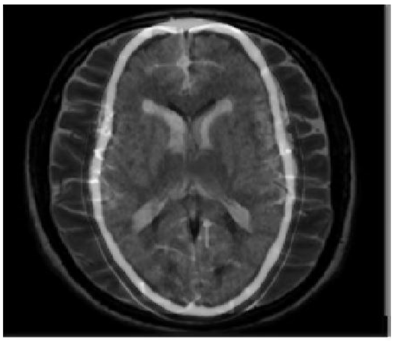
where, $Q^{AF} = Q_g^{AF}\ Q_o^{AF}$, $Q_g^{AF}(i,j)$ and $Q_o^{AF}(i,j)$ are edge strength and orientation preservation values at location (i,j) respectively

IV.. EXPERIMENTAL RESULTS

The proposed method works well on both noisy as well as normal medical images. Let the inputs given to the image fusion algorithms be CT image and MRI scan image. The fused image provides better information than the individual scan images. The fusion algorithm combines the significant information from CT and MRI in to single fused output.



Inputs: a) MRI brain Scan b) CT brainScan



c) Fused Output image

By this method the clinical applicability of medical images increases. Medical image fusion is an important technology that will help in easier detection of diseases.

The performance of the medical image fusion using cross bilateral filters are evaluated using the above discussed parameters. A graph is obtained for each performance evaluation parameters. The proposed system is compared with other two methods like combination of block matching with 3D filtering + guided filtering fusion (BM3D+GFF) and adaptive fractional order total variation method (AFOTV).Below four graphs shows the comparison graphs of the proposed system using cross bilateral filter with other two methods. From the below graphs it is evident that medical image fusion using cross bilateral filter is efficient than other traditional fusion methods.

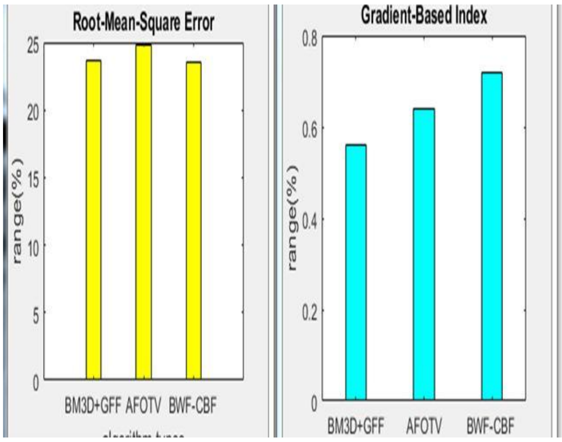


Fig: 5. Screen shot of graph of RMSE and Gradient Based Index

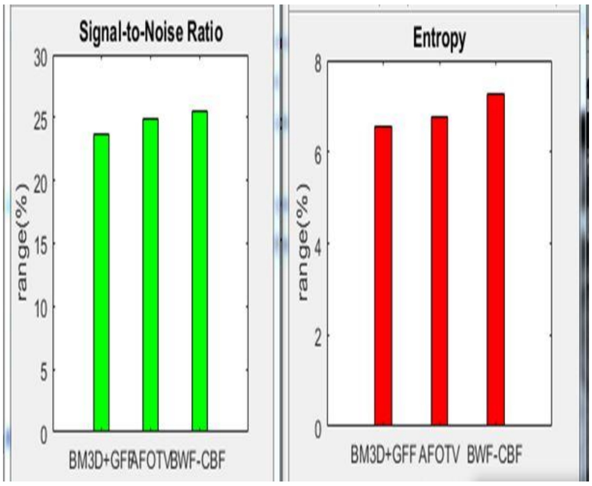


Fig: 6. Screen shots of graph of SNR and Entropy

V. Conclusions

Thus it is proved that the proposed method can greatly suppress noise while well preserving the complementary information and main features of noisy input medical images.The proposed fusion algorithm is efficient compared to the traditional fusion algorithms.

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