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Wavelet Based Image Fusion for Detection of Brain Tumor

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***Abstract*—** Brain tumor, is one of the major causes for the increase in mortality among children and adults. Detecting the regions of brain is the major challenge in tumor detection. In the field of medical image processing, multi sensor images are widely being used as potential sources to detect brain tumor. In this paper, a wavelet based image fusion algorithm is applied on the Magnetic Resonance (MR) images and Computed Tomography (CT) images which are used as primary sources to extract the redundant and complementary information in order to enhance the tumor detection in the resultant fused image. The main features taken into account for detection of brain tumor are location of tumor and size of the tumor, which is further optimized through fusion of images using various wavelet transforms parameters. We discuss and enforce the principle of evaluating and comparing the performance of the algorithm applied to the images with respect to various wavelets type used for the wavelet analysis. The performance efficiency of the algorithm is evaluated on the basis of PSNR values. The obtained results are compared on the basis of PSNR with gradient vector field and big bang optimization. The algorithms are analyzed in terms of performance with respect to accuracy in estimation of tumor region and computational efficiency of the algorithms.

***Index Terms*—** Tumor detection, Segmentation, Magnetic resonance image, Computed tomography image, Image fusion

I. INTRODUCTION

In the last two decades medical science has seen a revolutionary development [1] in the field of biomedical diagnostic imaging. The current advancement in the field of artificial intelligence and computer vision technologies [2] have been very effectively put into practice in applications such as diagnosis of diseases like cancer through medical imaging [3]. Latest research in biomedical imaging also finds potential applications in the fields of 3-D tissue harmonics [4], extended field of view and new contrast agents [5]. The main emphasis of the latest developments in medical imaging is to develop more reliable and capable algorithms which can be used in real time diagnosis of tumors. Brain tumor is caused due to uncontrolled growth of a mass of tissue, which can be fatal among children and adults. The National Brain Tumor Foundation (NBTF) for research in United States estimates the death of 13000 patients while 29000 undergo primary brain tumor diagnosis every year [5]. Depending on the origin and growth, brain tumor can be classified into two types: 1) primary brain tumor is developed at the original site of the tumor 2) secondary brain tumor is the cancer which spreads to the other parts of the body. The detection of brain tissue and tumor in MR images and CT scan images has been an active research area [6]. Segmenting and detection of specific regions of brain containing the tumor cells is considered to be the fundamental problem in image analysis related to tumor detection. Many segmentation algorithms are implemented based on edge detection on the grey scale images. Schendra et al [7] proposed a method based on multi scale image segmentation using hierarchical self-organizing map for the segmentation of brain tumor, which uses high speed parallel fuzzy c-mean algorithm. Another improved algorithm based on neuro fuzzy technique [8] while Chunyan et al. [9] designed a method for 3D variational segmentation for processes because of the high diversity in appearance of tumor from various patients. This paper seeks to bring out the advantages of segmentation of CT scan images and MR images through image fusion.

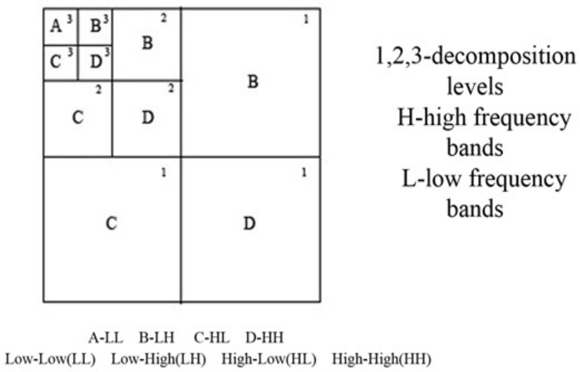

Fig. 1. Pyramid hierarchy of 2-D DWT

The paper uses wavelet based image fusion technique for brain tumor detection. Wavelet analysis is widely used method for solving difficult problems in mathematics, physics and engineering in the modern times. It has diverse applications in the fields of wave propagation, data compression, signal processing, image processing, pattern recognition and medical imaging technologies. Wavelet analysis decomposes complex information to elementary forms at different positions and scales, which can be easily reconstructed with high precision. Wavelet transform is a powerful tool in the analysis of signals compared to Fourier transform, because the later method fails in the analysis of non stationary signals. The first recorded mention of what we now call a “wavelet” seems to be in 1909, in a thesis by Alfred Haar [10]. Wavelet transforms is a new area of technology, replacing the Fourier transform in various fields of application like image processing, heart-rate and ECG analyses, DNA analysis, protein analysis, climatology, general signal processing, speech recognition, computer graphics and multi fractal analysis [11]. In this paper, our main goal is to exploit the advantages of wavelet transform compared to most widely used Fourier transform, in case of image fusion algorithm for the detection of brain tumor. Image Fusion technique is effectively used to the detect tumor in various complex backgrounds. Image Fusion is applied by merging multiple images resulting into precise information about the size, shape and location of the tumor. In this paper, the MRI and CT image (Fig. 5(a) and (b)) are processed using wavelet analysis. Before applying image fusion, the source images must be pre-processed through various Image enhancement techniques. The Image enhancement techniques involve point operations, mask operations, and global operations which sharpen image features for efficient analysis. In the proposed algorithm mask operations were used for the enhancement of brain tumor detection efficiency. These techniques improve the efficiency of the image fusion algorithm through elimination of ambient elements from the source images. In this paper various results are obtained by changing the wavelet used for decomposition. The paper further discusses the variation in result on changing the parameters of wavelet transforms used for the decomposition.

The results obtained help us in determining the performance efficiency of the algorithms to various wavelets, and helps us in deciding the most suitable wavelet for tumor detection. The paper is further divided into the following sections. Section II explains the Wavelet analysis and Image fusion used to detect the brain tumor. Section III presents the proposed algorithm used to detect the brain tumor. Section IV explains the results obtained by the using the proposed algorithm on MR Image and CT scan Image. The Section V elaborates the summary and conclusion in respective fields.

II. Basic Algorithms

A. *MRI and CT Analysis*

The paper forms fused images from CT and MRI images to detect tumor. Fused images can be created [12] by combining information from multiple modalities, such as magnetic resonance image (MRI) and computed tomography (CT). Both types of images play specific important roles in medical image processing. CT images are used more often to ascertain differences in tissue density depending upon their ability to block X-rays while MRI provides good contrast between the different soft tissues of the body, which make it especially useful in detecting brain tissues, and cancers [5]. The fused image from multiple images produce an image which contains combined complementary and redundant information provided by both the source images i.e. the size of the tumor, the location through the various pixel values of the gray scale images, hence resulting into better visibility of tumor.

B. *Wavelet analysis*

The concept of wavelets in its present theoretical form was first proposed by Jean Morlet and the team at the Marseille Theoretical Physics Centre working under Alex Grossmann in France [13]. Wavelet analysis is an effective methodology capable of revealing aspects of data which other signal analysis techniques overlook like trends, breakdown points, discontinuities in higher derivatives, and self-similarity. In addition, wavelet analysis is capable of compressing or de-noising a signal without appreciable degradation. In wavelet analysis, wavelet transform divides the image signal into wavelets representing each pixel of the original image as coefficients. The integral wavelet transform for all the pixels is defined as:

$$[W_\psi f](a,b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} \overline{\psi\left(\frac{x-b}{a}\right)} f(x)dx \tag{1}$$

The wavelet coefficients, for the pixel c_{jk} is then given by

$$c_{jk} = \left[W_\psi f\right]\left(2^{-j}, k2^{-j}\right) \tag{2}$$

The 2D image signals are broken down by a layer by layer decomposition process. Four frequency bands, namely (A) Low-Low (B) Low-High (C) High-Low (D) high-High are obtained after first level of decomposition. The next level of de-composition is obtained by applying a recursive decomposition procedure applied to the Low-Low band of the current decomposition stage. Thus, N-level decomposition will finally result into 3N+1 different frequency bands including 3N high frequency bands and one Low-Low frequency band. The frequency bands in higher decomposition levels will have smaller size. In this paper 1st level decomposition is used to get optimum results. Fig. 1 shows the structures of 2-D DWT with 3 decomposition levels.

C. Image Fusion

The principle of image fusion [14] using wavelets was first introduced by H. Li. in which image fusion was used for the fusion of synthetic aperture radar and multispectral image data. Image fusion can be defined as combining various signal sources from different sensors and multi-modality images. Simple image fusion can be achieved through taking pixel by pixel average of the source images. This process may lead to undesired side effects or distortions in the fused image. In order to avoid unnecessary distortions, the principle of pyramid transform is used to construct the pyramid transform of the source images. Pyramid transforms of the source images are combined and on applying inverse pyramid transform fused image is obtained. The basic idea used is to form multi scale transforms on the input images, and to form a multi scale composite representation from these and form the required image by applying inverse transforms. In case of Wavelet based image fusion, Wavelet decomposition is applied to the original images by passing the input images through a wavelet filter which gives the Approximation coefficients and Detail coefficients of the images. The Approximation and Detail coefficients of the two images are combined using average of the coefficients or the maximum or minimum of the coefficients. The resultant image is formed by passing the coefficients thus obtained through a reconstruction filter. Fig. 2 shows image fusion of multimodality images. Images of different modalities such as MR image and CT scan image are used for fusion as the images have complementary and redundant images. Thus on applying proper fusion techniques resultant image containing both the redundant and complementary images is formed.

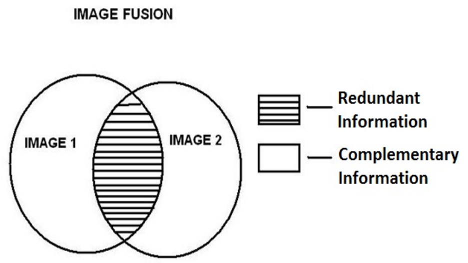

Fig. 2. Block Diagram depicting basic image fusion

D. The image fusion algorithm

The MR image fusion approach first proposed by Burt and Adelson [15] was implemented using pyramid structures called the Laplacian pyramid. The basic idea was to use multi scale transform (MST) on the source images followed by inverse multi scale transform (IMST) resulting into composite of images. In the first step multi scale transforms or multi resolution analysis involves decomposition of the original image into different levels. The image signal consists of various bands like low-low, low-high, high-low and high-high on decomposition by wavelet transform. Higher number of decomposition levels [16] does not necessarily produce better result because by increasing the analysis depth the neighboring features of lower band may overlap. This leads to discontinuities in the composite representation and thus introduces distortions, such as blocking effect or ringing artifacts into the fused image. Thus in the next step, selection of the appropriate decomposition level allows the combination of salient features of each image. The block diagram of the basic image fusion is shown in the Fig. 3.

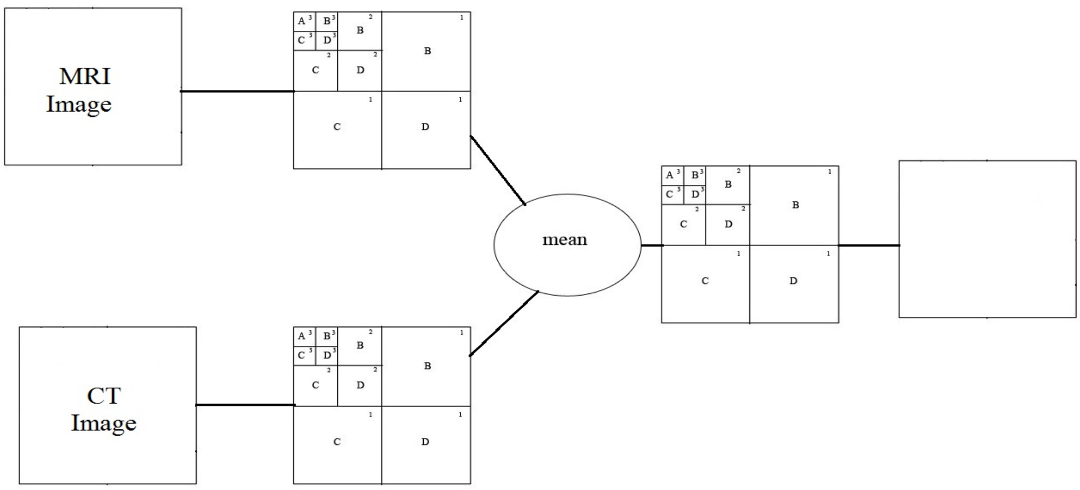

Fig. 3. Block diagram depicting basic image fusion using multi resolution analysis.

We may lose parts of the images composed of small objects as the depth of the pyramid increases, which is the main drawback of the above specified MST. Hence in this paper absolute transform coefficients were to overcome this problem. The absolute transform coefficients obtained by wavelet transforms correspond to sharp changes in intensity of the input image. Selection of the highest absolute coefficient during the integration is a best suited method for optimization of relative resolutions of each image. This will result fusion to takes place in all the resolution levels in the new multi resolution representation further preserving the most dominant features at each scale. Subsequently a new and better image is formed by applying an inverse wavelet transform.

III. PROPOSED ALGORITHM

In the first step, Image processing techniques are applied on the source images i.e. MR image and CT scan image to increase the contrast, brightness. In the next step, wavelet transform is further applied on these images by passing the processed images through the respective wavelet filters. The wavelet transform is applied on the source images with different wavelets such as Daubechies, Symlets, and Coiflets in order to try and obtain optimum results. Fusion can be performed either by taking the average of the coefficients either the minimum of the coefficients or maximum of the coefficients. In this paper, fusion is performed by taking the absolute maximum of the coefficients as the larger coefficients correspond to sharper brightness changes thus making the salient features visible. Thus fusion takes place in all resolution levels (as shown in Fig. 3) and the prominent features at each scale are preserved. The resultant image is formed by performing inverse wavelet transform. The wavelet transform technique of image fusion allows us to effectively extract the salient features of the input images due to the availability of directional information. Thus the wavelet techniques produce better results than Laplacian pyramid based methods. The reconstruction of the final image is also better in wavelet transform technique than in Laplacian Pyramid based methods as errors such as blocking effects are effectively removed.

In this wavelet based image fusion algorithm, we propose a feature selection method for better efficiency of tumor detection. The fused image is converted in to binary form for computational ease and better efficiency of detection by applying appropriate threshold values. The optimum value of the threshold is determined experimentally, to have best result. The image can be seen as a 2D matrix consisting of 1s and 0s. The pixels having 1s are white and 0s are black. In the proposed feature selection algorithm, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the binary image with its neighbors. This method may add or remove pixels from the boundaries of the objects in the image depending on the size and structuring element [17] used to process the image. This facilitates better detection of the tumor with minimum error. The output of the proposed image fusion algorithm is dependent on three maisan parameters: (a) the wavelet used for the image decomposition i.e. Haar(haar), Daubechies(db), Coiflets(coif) or symlets(sym) (b) the approximation or detail coefficients obtained can be fused with different approaches, which involve taking the maximum, the minimum or the mean of the coefficients from the two input images (c) the total number of decompositions of the image using the wavelets analysis. As number of decompositions increase we may lose some minute details of image in the image as these small regions can be of significant importance in the medical analysis. Hence, the first level decomposition is used in the proposed algorithm. The results are analyzed by varying the other two parameters in order to obtain optimum results.

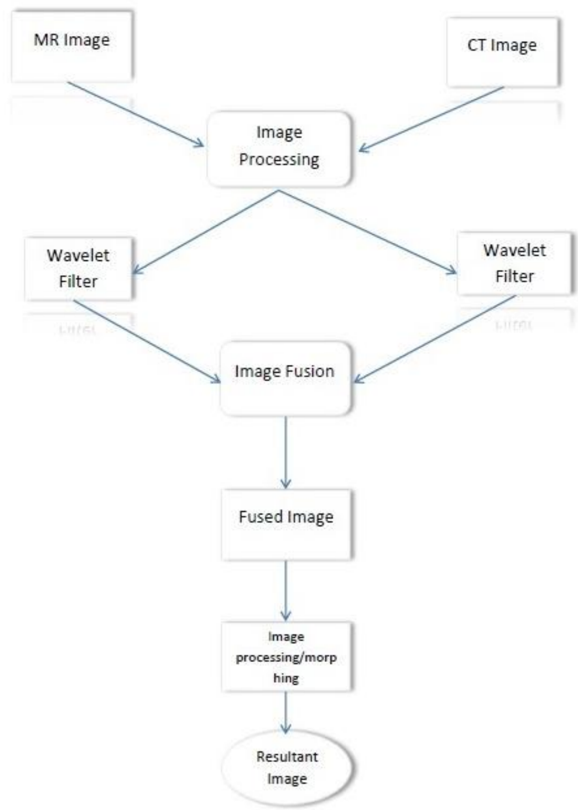

Fig. 4 Flow Chart of the Proposed Algorithm

IV. EXPERIMENT SIMULATION AND RESULT ANALYSIS

This section elaborates and compares the results obtained for brain tumor detection using wavelet based image fusion. The results obtained enable us to investigate the capabilities of the image fusion algorithm applied to MR image and CT scan image (Fig. 5(a) and 5(b) respectively). This section further analyses the results upon the variation of different wavelet parameters. The performance of the algorithm is evaluated on MATLAB (Version 7.10.0.499).

$$PSNR = 20\log_{10}\left(\frac{256}{E}\right) \quad (3)$$

$$E = \sqrt{\frac{\sum_i (r_i - d_i)^2}{mn}} \quad (4)$$

The efficiency of the proposed algorithm is compared with the Gradual Vector Flow (GVF) and Segmentation with Bing-Bang optimization, which are validated through the individual simulation results. The comparisons are made on the basis of accuracy of detection and computational efficiency. The GVF algorithm is applied on MRI images for tumor detection which involves manually setting the parameters for the snake to be released for segmentation. As, the parameters have to be adjusted manually, the accuracy of the results mainly depends on the parameters selected by the user. Once the parameters are adjusted, the snake elongates and compresses finally acquiring the shape of the tumor. The maximum PSNR obtained is 8.1 for maximum distance of 1.75 between the initial points. GVF is a time consuming process and it is prone to errors as the parameters do not depend on the image used. Segmentation is done using the spatial or geometrical features i.e. Spatial index and density index of the algorithm. Spatial and density index are used to differentiate between the non-tumor region and the tumor region. Segmentation is done on the MR image. The thresholds are set using hit and trial method, thereby selecting the threshold which gives the least error. In this paper a spatial index of 1.4 and density index of 2.5 is used in this paper for segmentation. Thus, regions are classified as tumor if the value of shape index is less than 1.4 and if density index is greater than 2.5. Thus, segmentation extracts the tumor features from the MR image. The PSNR obtained using the segmentation approach is 10.4. In case of the wavelet based image fusion, wavelet transform divides the input images into respective decomposed sub-images. The fusion is performed on the low frequency sub-images of various decomposition levels. The proposed algorithm uses spatial low-frequency operation, which improve the efficiency of the image fusion algorithm through elimination of ambient elements from the source images. Low-pass filter operations emphasize on large homogenous areas of similar tones, and eliminate the smaller details i.e. noise, resulting in a better efficiency of tumor detection. Fig.7 shows the PSNR values of the results obtained by different wavelets in the wavelet family at the fourth decomposition level. It is clearly observed that the wavelets coif2 and sym4 produce a better efficiency i.e. a better PSNR of 10.655 at the fourth decomposition level as compared to other wavelets as seen from Fig.7. The high accuracy is attained as the method effectively extracts the complementary and redundant information from the MR image and CT scan image thereby producing a highly reliable fused output image for detection of tumor. The method takes 0.774 seconds for the whole process when a 4th level decomposition is used. The evaluation based on PSNR show that best results attained for the detection of tumor have a PSNR of 10.655 and run time of 0.774 seconds, which is achieved when the algorithm is used with coif2 wavelet with fourth level decomposition. The efficiency of the proposed algorithm as compared with GVF and segmentation algorithm can be seen in table 1.

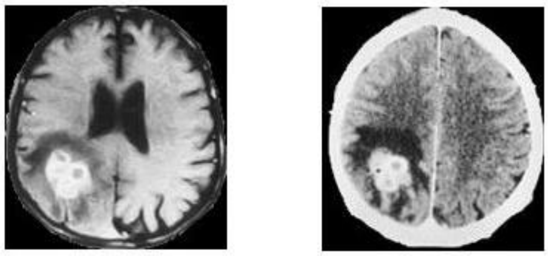

Fig. 5. Input MR Image and CT scan Image.

TABLE I. COMPARSION OF PSNR RESULT OF WIF, SEGMENTATION, GVF.

Method Used	Wavelet Based Image Fusion	Segmentation	Gradual Vector Flow
PSNR Values	10.67	10.4	9.3

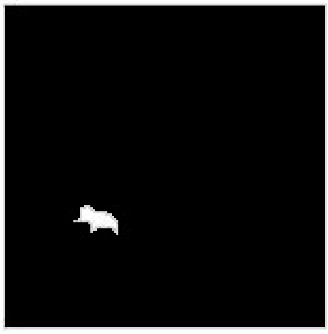

Fig. 6. The Segmentation results after the algorithm is applied on the input images using coif2 wavelet.

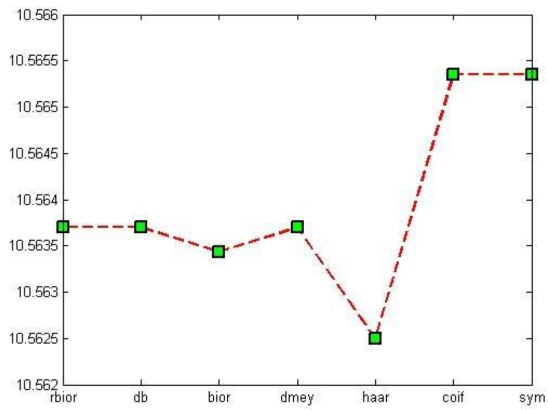

Fig. 7. Variation of PSNR when the algorithm is applied on different wavelets at 4th decomposition

The PSNR is the lowest for GVF algorithm as the parameters in it are manually set by the user and hence is erroneous. The PSNR value obtained using segmentation algorithm is less than the PSNR value obtained using the proposed algorithm.

The result obtained for image fusion using wavelet transform techniques are shown in Fig 6. A comparative study on the efficiency various wavelets on the performance efficiency of the algorithms are verified in terms of PSNR value and tabulated as shown Table 1.The algorithm performed effectively when sym and coif2 wavelets were used for the wavelet analysis giving a PSNR value of 10.5652 and 10.5654 respectively. The method effectively extracts the complementary and redundant information from the MR image and CT scan image thereby producing a highly reliable fused output image for brain tumor detection. The error of detection is found to be maximum when using the sym7 wavelet and minimum when using the db10 wavelet.

Another important factor which determines the performance of the algorithm is the decomposition level used for the wavelet transform. The method takes 1.08 seconds for the whole process when a 1st level decomposition is used. It takes 1.06 seconds, 0.88 seconds, 1.07 seconds for 2nd level, 3rd level and 4th level decomposition respectively. It is observed that the tumor detection efficiency is maximum i.e. the error is minimum when first level decomposition is used. Hence 1st level decomposition is considered as the optimum threshold to be set even if it takes more time to execute. The best result i.e. detection of the tumor with an accuracy of 96.964 percent is obtained when the algorithm is used with db10 wavelet with first level decomposition.

V. CONCLUSION

In this paper we studied the performance of wavelet based image fusion algorithm. The efficiency of the proposed algorithms compared with some standard algorithms like GVF and segmentation. Future a relative study is made on the performance of the algorithms based on PSNR for various wavelets used in the wavelet transform. From the above results, we see that sym and coif2 wavelet transform gives best results with a PSNR value of 10.565, when compared with GVF and segmentation algorithms, with a great improvement in the computational efficiency. Hence, we demonstrate an accurate and computationally efficient algorithms for detection of brain tumor through wavelet based image fusion.

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