A Novel Approach for MRI Image De-noising and Resolution Enhancement

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***Abstract*— Image pre-processing and enhancement techniques are important part of the medical image processing. These techniques are used for reducing image noise, highlighting edges, or improving the image resolution. Resolution of image is one of the principle characteristics, and it is required to enhance the resolution of the image without degrading the quality of image. In this paper, we propose a new technique to enhance the quality of MRI image by de-noising and resolution enhancement. The proposed algorithm requires average, median and wiener filtering for image de-noising And Discrete Wavelet Transform (DWT) with Daubechies 9/7 wavelet for resolution enhancement. The performance evaluation is done by using Peak Signal to Noise Ratio (PSNR).**

Index Terms*— Gaussian noise, Mean Filter, Median Filter, Wiener Filter, Resolution enhancement, interpolation, Discrete Wavelet Transform (DWT), Sub-bands, Inverse DWT.

I. INTRODUCTION

Magnetic resonance imaging is a medical imaging technique used in the diagnosis, characterization, and planning of treatment for brain tumors. There is no accurate measure for detection of tumor region due to the presence of noise in MRI image. Even small amount of noise can change the classification. So the noise is preprocessed using de-noising techniques. Most of the imaging techniques are degraded by noise so that the image is preprocessed using de-noising technique to extract the useful information. To analyze the medical image i.e. segmenting the brain tissues, initially the noise must be removed from the MRI image for retaining the original information. Noise in medical imaging is mainly caused by variation in the detector sensitivity, reduced object visibility (low contrast), chemical or photographic limitations and random fluctuations in radiation signal.

In order to significantly compare the performance of de-noising techniques, the Mean, Median and Wiener filters are used to eliminate the noise present in the MRI image. High resolution images have better appearance and quality as they have the capability to show even the finer details present in the scene. Interpolation of an image results in increase in number of pixels in the image. The resolution of de-noised image is enhanced using Discrete Wavelet Transform with Daubechies 9/7 wavelet. The performance of these enhancement techniques is measured using Peak Signal to Noise Ratio. Fig. 1 shows the overview of the proposed work.

II. DE-NOISING

De-noising of magnetic resonance images (MRI) is of importance for clinical diagnosis and computerized analysis, such as tissue classification, segmentation, and registration. Image filtering algorithms are applied on images to remove the different types of noise that are either present in the image during capturing or injected into the image during transmission. At first the MRI image is taken as input image and then it is added with Gaussian noise. Then de-noising is performed using Mean, Median and Wiener filters.

A. Gaussian Noise

Gaussian noise is statistical noise that has its probability density function equal to that of normal distribution, also called Gaussian distribution. The mean (average) and variance (standard deviation) are the defining factors. Gaussian noise whose frequency spectrum after a Fourier transform has a bell shaped curve and is symmetric around mean. In order to test the resistance of an image and also to evaluate the performance of the MRI brain image Gaussian noise is added and filtered using some noise filters.

B. Mean Filter

Mean filter or averaging filter is a simple linear filter and easy to implement method for smoothing images. Average filter is often used to reduce the noise in an image and also reduce the amount of intensity variation from one pixel to another. Here, first step is to take an average that is sum of the pixel values and divide the sum by the number of pixels. Next step is to replace each pixel in an image by the average of pixels in a square window surrounding this pixel.

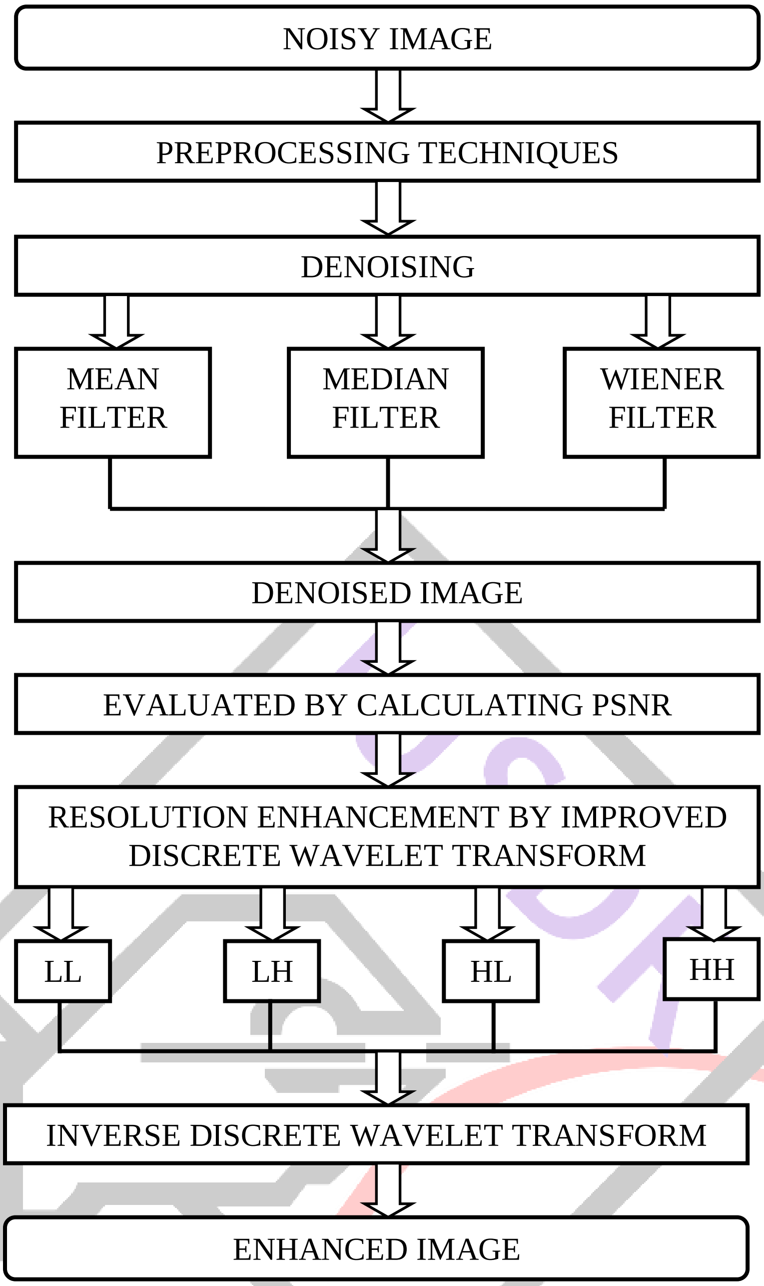

Fig. 1 Overview of the proposed work

C. *Median Filter*

The Median Filtering is performed by taking the magnitude of all of the vectors within a mask and sorted according to the magnitudes. The pixel with the median magnitude is then replaced with the pixel studied. The Median Filter has an advantage over the Mean filter because median of the data is taken instead of the mean of an image. The pixel with the median magnitude is then replaced with the original pixel. The median of a set of pixel values is more robust with respect to the presence of noise. The median filter is given by,

$$Median\, filter(x1 \ldots x_N) = Median(\left\|X_1\right\|^2 \ldots \ldots \left\|X_N\right\|^2)$$

D. *Wiener Filter*

The goal of the Wiener filter is to filter out noise which is present in the signal and that has corrupted a signal. It is based on the statistical approach. Typically filters are designed for a desired frequency response. The Wiener filter approach is filtering from a different angle. It is assumed to have knowledge of the spectral properties of the original signal and the noise, and it seeks the LTI filter whose output would come as close to the original signal as possible. Wiener filters are characterized by the following:

a. Assumption: signal and (additive) noise are stationary linear random processes with known spectral characteristics.
b. Requirement: the filter must be physically realizable, i.e. causal (this requirement can be dropped, resulting in a non-causal solution).
c. Performance criteria: minimum mean-square error.

The Wiener filter is:

$$G(u,v) = \frac{H^*(u,v)P_s(u,v)}{|H(u,v)|^2 P_s(u,v) + P_n(u,v)}$$

Dividing through by **Ps** makes its behavior easier to explain:

$$G(u,v) = \frac{H^*(u,v)}{|H(u,v)|^2 + P_n(u,v)/P_s(u,v)}$$

Where,
H(u, v) = Degradation function
H*(u, v) = Complex conjugate of degradation function
Pn (u, v) = Power Spectral Density of Noise
Ps (u, v) = Power Spectral Density of un-degraded image
The term **Pn /Ps** can be interpreted as the reciprocal of the signal-to-noise ratio.

III. Resolution Enhancement

Resolution of an image is always an issue in medical image processing. Resolution is a measure of the amount of detail information in the image. High resolution gives more image details. In order to segment an image accurately preserving the edges and contour information is important. Resolution is the measurement of quality of a de-noised image. In order to enhance the resolution of an image an improved discrete wavelet transform is proposed. The improved DWT preserves the edges and the contour information. The performance of resolution enhancement technique is measured using Peak Signal to Noise Ratio.

IV. Discrete Wavelet Transform (DWT)

Wavelets are playing a significant role in many image processing applications. A wavelet transform (WT) is based on wavelets. It is used to analyze a signal (image) into different frequency components at different resolution scales (i.e. multi-resolution). This allows revealing image’s spatial and frequency attributes simultaneously. Any wavelet-based image processing approach has the following steps. Compute the 2D-DWT of an image, alter the transform coefficients (i.e. sub-bands), and compute the inverse transform. Wavelet transforms are used in a wide range of image processing applications such as image and video compression, feature detection and recognition, and image de-noising. The 2-D wavelet decomposition of an image is performed by applying the 1-D discrete wavelet transform (DWT) along the rows of the image first, and then the results are decomposed along the columns. One level DWT (with Daubechies 9/7 as wavelet function) is used to decompose an input image into different sub-band images. Three high frequency sub-bands (LH, HL, and HH) contain the high frequency components of the input image. The sub-band images are referred to low-low (LL), low-high (LH), high-low (HL) and high-high (HH). The frequency components of those four sub-bands are interpolated to cover the full frequency spectrum of the original image. The interpolation technique is used to increase the number of pixels in an image. The high frequency sub-band of the image is interpolated to low frequency sub-bands of the image to give high resolution enhanced image. Fig 2 and Fig 3 shows the one level decomposition of DWT and block diagram of DWT. The low resolution image (LL sub-band), without quantization (i.e., with double-precision pixel values) is used as the input for the proposed resolution enhancement process. In other words, low frequency sub-band images are the low resolution of the original image. Therefore, instead of using low-frequency sub-band images, which contains less information than the original input image, the input image is used through the decimation process

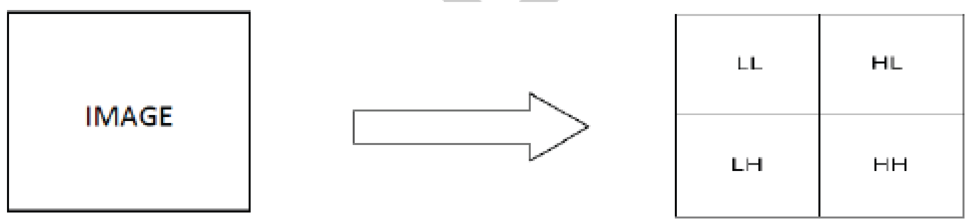

Fig. 2 One Level Decomposition

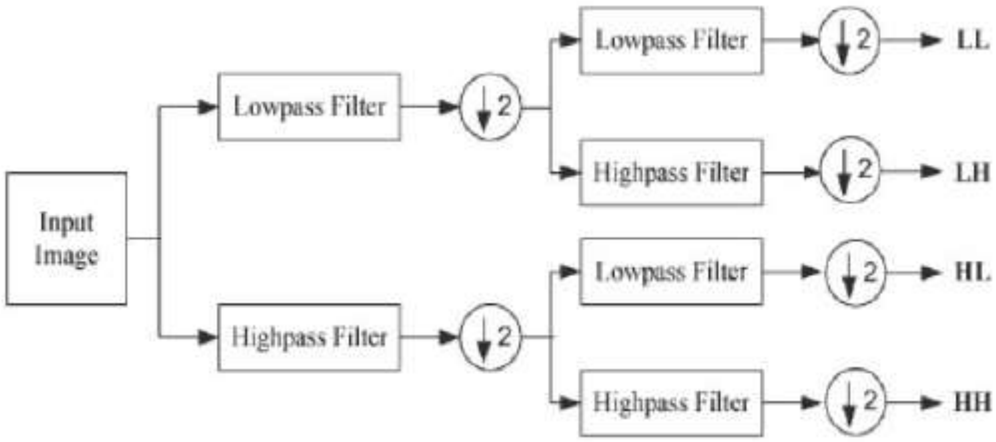

Fig. 3 Block diagram of Discrete Wavelet Transform

V. *INVERSE DISCRETE WAVELET TRANSFORM (IDWT)*

A process by which components can be assembled back into the original image without loss of information is called reconstruction. Inverse Discrete Wavelet Transform (IDWT) reconstructs an image from the approximation and detail coefficients derived from decomposition. The performance of de-noised and enhanced image is evaluated by calculating PSNR value.

VI. SIMULATION RESULTS

The MRI image is taken as the input image and added with Gaussian noise. The de-noising is performed by using Average filter, Median filter and Wiener filter. Fig. 3 and Fig. 4 show the original input image and de-noised image by different filters. Fig. 6 shows the performance comparison of de-noised image using different filters. The performance of Wiener filter for de-noisng is better than average and median filters. The de-noised image is decomposed into four sub-bands namely LL, LH, HL, and HH using Discrete Wavelet Transform (DWT). Fig. 5 shows the decomposition levels of the image. Fig.7 and Fig. 8 show de-noised image and resolution enhanced image along with PSNR comparison. Results clearly indicates that visually and analytically resolution enhanced image has better quality to be used for different applications. When compared performance of de-noised and enhanced images, the PSNR value of enhanced image is improved from 33db to 40db with reduced error.

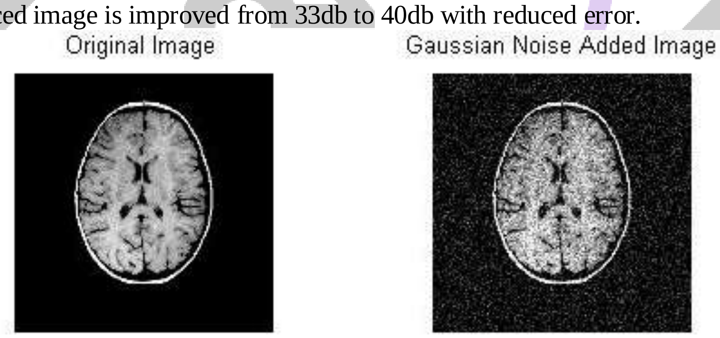

Fig. 3 Original image and noisy image

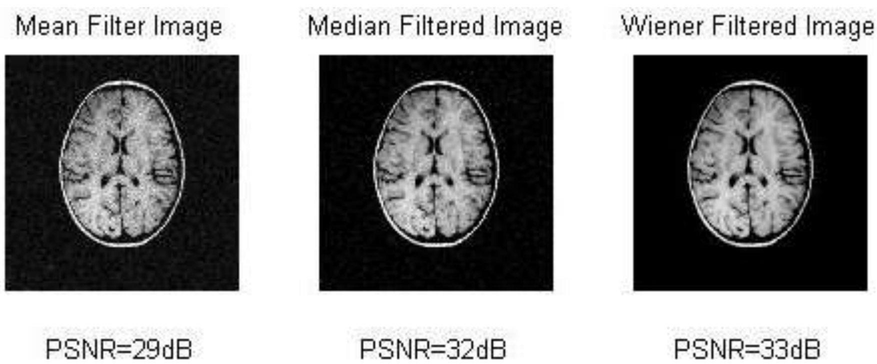

Fig. 4 De-noised images

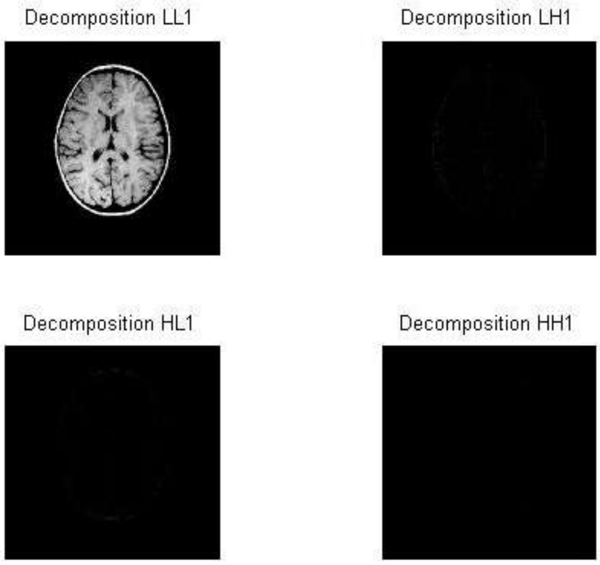

Fig. 5 Decomposition Levels

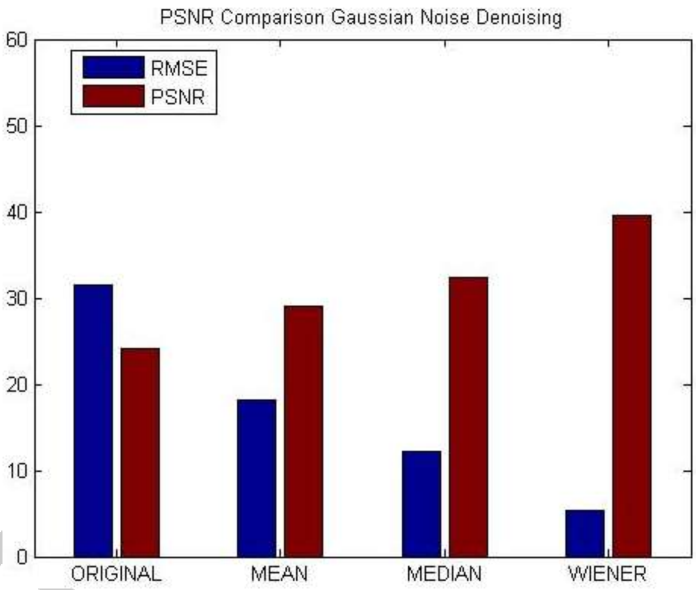

Fig. 6 PSNR values of De-noised Image

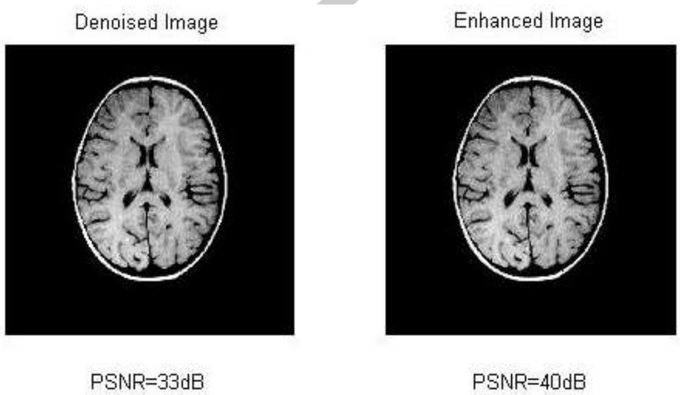

Fig. 7 De-noised and Enhanced Image

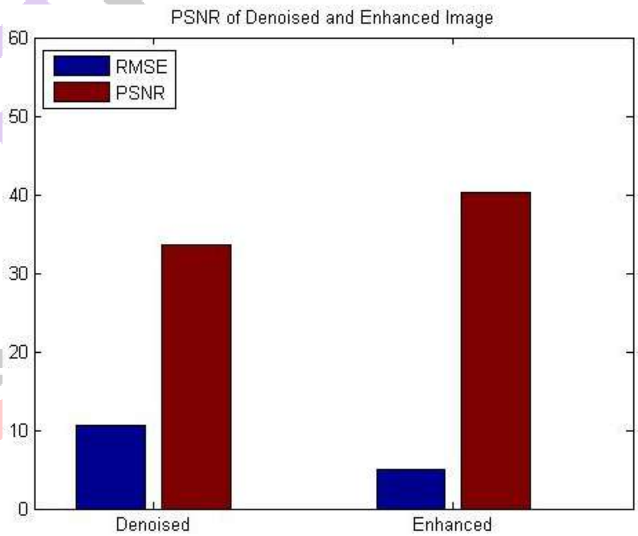

Fig. 8 PSNR of De-noised and Enhanced Image

VII. Conclusion

This paper has proposed a new resolution enhancement technique based on the interpolation of the high-frequency sub-band images obtained by DWT of the input MRI image. The proposed technique has been tested on MRI images, where their PSNR, RMSE and visual results show the superiority of the proposed technique over the conventional and state-of-art image resolution enhancement techniques.

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