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De-noising of MRI Images in Wavelet Domain

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***Abstract**: Magnetic resonance imaging (MRI) is a diagnostic medical procedure that utilizes solid attractive fields and radio waves to deliver definite pictures of within the body. Extensive research has been completed into whether the attractive fields and radio waves utilized during MRI sweeps could represent a hazard to the human body. No proof has been found to propose there's a hazard, which means MRI outputs are one of the most secure restorative methodology accessible. MRI has several advantages which make it ideal in numerous situations, in particular, it can identify small changes of structures inside the body. The disadvantage is the noise that degrades the quality of the image.*

A threestep processing algorithm is proposed to reduce this noise. Here, first it includes soft thresholding in wavelet domain where the original image is divided into blocks that do not overlap. Then it includes restoration of the object boundaries and texture which are lost as a result of the first step and finally enhancing the image using CLAHE (Contrast Limiting Adaptive Histogram Equalization). It is then analyzed using the error parameters like peak signal to noise ratio and mean square error.

***Keywords**: MRI, Medical image denoising, Rician noise, Soft thresholding, CLAHE.*

I. INTRODUCTION

Restorative analysis by Magnetic Resonance (MR) have become vital [5]. Anyway the utilization of good pictures is a critical aspect in such application of picture handling. Regardless of huge enhancements as of late, magnetic resonance images (MRI) got straightforwardly by the instruments are often times deficient by therapeutic examination, particularly in heart and cerebrum images since they present large amounts of Rician noise. Albeit, numerous image handling methods could improvement the picture quality by separating or honing it, the affirmation of the amount of noise present in these is basic for sufficient de-noising plan[2][4][6][7]. Typically, the real and imaginary portions of the MR complex crude information are viewed as altered by white added substance Gaussian noise, in which the difference in noise is thought to be the equivalent in the two sections. According to the limit of the complex information, the noise is changed into Rician noise. Noise in magnitude MRIs can be well modeled by Rician distribution when computed from a single complex raw data as well. MRI scans are influenced by noise which will lessen the precision of perception and conclusion. An essential issue in image rebuilding is the issue of expelling noise while keeping the subtleties of the picture [15]. One of the main problems in MRI images is Rician noise. It reduces the spatial and contrast resolution and conceals the anatomy underneath. This artifact presents fine-false structures, lines diminishing picture difference, and veiling the genuine limits of the tissue prompting the lessening in the effectiveness of further picture processing. A decent de-noising calculation will constrict noise while in the meantime protecting motor improvement data and fine basic subtleties, and limiting the presentation of new artifacts. Here it is done in the wavelet domain [12]. Here, first it includes soft thresholding on pixels in wavelet domain in which the original picture is segregated into non overlapping blocks. Then it incorporates reclamation of the object limits and surface which disappear as a result of the first step and then enhancing the image using CLAHE (Contrast Limiting Adaptive Histogram Equalization).

II. PROPOSED TECHNIQUE

The proposed technique involves a threestep process in the wavelet domain. First, is the block thresholding of the medical image then fusion of thresholded image with the original image followed by image enhancement using CLAHE. The thresholding used is soft thresholding which removes the noise but also blurs the edges. The next step is to restore the edges lost while CLAHE improves the contrast of the denoised image. Global thresholding results in edge blurring and decrease in the contrast of the whole image. This can be avoided somewhat by using block thresholding instead. Block thresholding makes it local to that particular block and preserves the contrast in the medical images. Here, we have used soft thresholding which is discussed as follows:

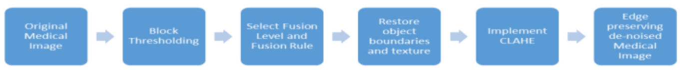

Fig.1 Proposed system design

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A. Soft thresholding

Block based soft thresholding according to the soft threshold value T in each block is computed as

$$T = \xi\,(2\log m)^{1/2} \qquad (1)$$

where m is the count of pixels of the image and ξ is

$$\xi = \frac{|\mathrm{median}(U(x,y))|}{0.6745} \qquad (2)$$

Where U(x,y) is the medical image

Though thresholding in wavelet domain removes Rician well, the blurring around the edges remains. The solution for this is the fusion of the original and denoised image which improves the quality of the image by combining the wavelet coefficients of the denoised image along with those of the original image. [1]

B. Fusion of images

Soft thresholding of original image results in the denoised image but with blurred edges. There are various techniques to fuse the images [9]-[11].To obtain images that are free of noise but also retaining the edges, the solution is to fuse the original image with the denoised image.

After performing the threshold, the edge magnitude and direction in the block is calculated of the pixels. The next step is to compare the histogram of adjacent blocks and magnitude. This will disclose the presence of object. For this comparison, normalized differential mean is calculated of adjacent blocks which is given by [1]

$$N^{b(K,K+n)}{}_{\epsilon} = \Sigma \frac{|h^{i(k)}\epsilon\,(x,y) - h^{i(k+n)}\epsilon(x,y)|}{||h^{i(k)}\epsilon\,(x,y) + h^{i(k+n)}\epsilon(x,y)||} \qquad (3)$$

$$N^{b(K,K+n)}{}_{\theta} = \Sigma \frac{|h^{i(k)}\theta\,(x,y) - h^{i(k+n)}\theta(x,y)|}{||h^{i(k)}\theta\,(x,y) + h^{i(k+n)}\theta(x,y)||} \qquad (4)$$

Where $N^{b(K,K+n)}{}_{\epsilon}$ and $N^{b(K,K+n)}{}_{\theta}$ represent the histogram of gradient magnitude $h^{i(k)}\epsilon$ and the histogram of gradient direction $h^{i(k)}\theta$ between K^{th} and $K+n^{th}$ blocks for every pixel of the block

$[F^{(A_{img1}, D_{max})}, L1] <= 1 < (N^b\varepsilon, N^b\theta) < 0.955$
$[F^{(A_{img1}, D_{min})}, L1] <= 0.954 < (N^b\varepsilon, N^b\theta) < 0.855$
$[F^{(A_{img2}, D_{max})}, L2] <= 0.854 < (N^b\varepsilon, N^b\theta) < 0.755$
$[F^{(A_{img2}, D_{min})}, L2] <= 0.754 < (N^b\varepsilon, N^b\theta) < 0.655$
$[F^{(A_{min}, D_{min})}, L3] <= 0.654 < (N^b\varepsilon, N^b\theta) < 0.555$
$[F^{(A_{min}, D_{min})}, L4] <= 0.554 < (N^b\varepsilon, N^b\theta) < 0.455$
$[F^{(A_{min}, D_{min})}, L5] <= 0.454 < (N^b\varepsilon, N^b\theta) < 0.001$

L1 to L5 are fusion levels. Eight fusion rules are represented as $F^{(A_{max}, D_{max})}$, $F^{(A_{min}, D_{max})}$, $F^{(A_{max}, D_{min})}$, $F^{(A_{min}, D_{min})}$, $F^{(A_{img1}, D_{max})}$, $F^{(A_{img1}, D_{min})}$, $F^{(A_{img2}, D_{max})}$, $F^{(A_{img2}, D_{min})}$, $F^{(A_{max}, D_{max})}$. [1]

C. CLAHE(Contrast Limiting Adaptive Histogram Equalization):

It is a popular method of contrast enhancement [8]. It produces the optimal equalization in terms of maximum entropy and also constrains the image contrast [14]. The basic algorithm is described below [3]:

1: Segregate the input image into blocks of equal size which do not overlap.
2: Calculate the intensity histogram of each contextual regions.
3: Set the clip limits for clipping the histograms.
4: Modify each histogram by selecting a transformation function.
5: The transformation is done for each histogram in a way that the height did not go over the clip limit that is selected.

The mathematical expression for transformed gray levels for standard CLAHE method with Uniform Distribution can be given as

$$g = [g_{max} - g_{min}] * P(f) + g_{min} \qquad (5)$$

where g_{max} = Maximum pixel value
g_{min} = Minimum pixel value
g = Computed pixel value
P(f) = CPD (Cumulative Probability Distribution)

For exponential distribution gray level can be adapted as

$$g = g_{min} - (1/\alpha) * \ln[1 - P(f)] \quad (6)$$

where α is the parameter that measures the clip.

CLAHE functions on tiles i.e smaller regions, instead of the whole image. To make sure the output region histogram matches that which is given by distribution type, the contrast of each tile is enhanced. The cumulative distribution function of Rayleigh distribution is given as;

$$y = P\left(f\left(\frac{x}{b}\right)\right) = \int_0^x \frac{x}{b^2} e^{-\frac{x^2}{2b^2}} \qquad (7)$$

6: The adjacent tiles were fused by bilinear interpolation and in accordance to the modified histograms the grayscale values of the image were altered.[3]

III. RESULTS

The parameters applied to test the proposed method are PSNR i.e peak signal to noise ratio MSE i.e mean squared error.

MSE: It is the mean squared error. It is the total error that's squared between the filtered image and the reference image.

$$MSE = \Sigma \frac{[I_1(i,j) - I_2(i,j)]^2}{M * N}$$

Where M is the number of rows and N is the number of columns in input images, I_1 and I_2.

PSNR: It is the peak signal to noise ratio. It is the peak error measurement parameter.

$$PSNR = \frac{10\log_{10} R^2}{MSE}$$

Where R is maximum pixel value in the input image data type.

Table- I: Values of error metrics of denoised images

Error Metrics		
Sigma Level	***MSE***	***PSNR***
0.01	0.566	24.2019

0.05	0.5661	24.6494
0.08	0.5661	24.9641
0.09	0.5660	25.0674
0.1	0.5659	25.1743

Acquisition time is constrained in MRIs, hence the SNR is low. As seen in the table above, images were tested and the values for PSNR and for MSE show that the proposed method works well in denoising the MRI images.

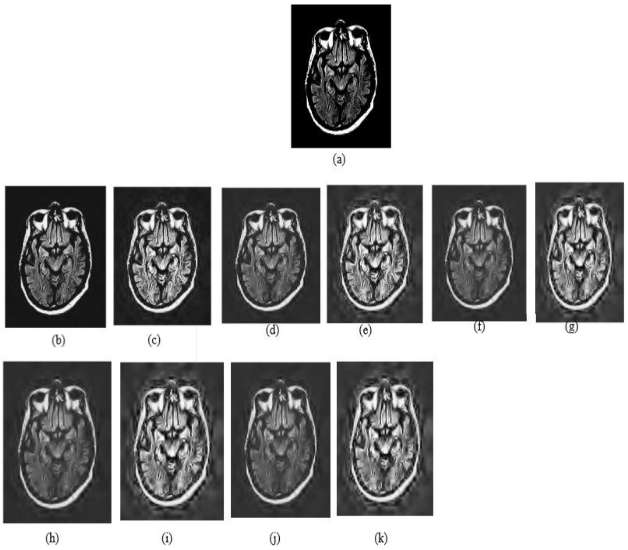

Fig.2 (a) Original image. (b)Denoised and fused image at sigma level 0.01 (c) Enhanced image at sigma level 0.01 (d) Denoised and fused image at sigma level 0.05 (e) Enhanced image at sigma level 0.05 (f) Denoised and fused image at sigma level 0.08 (g) Enhanced image at sigma level 0.08 (h) Denoised and fused image at sigma level 0.09 (i) Enhanced image at sigma level 0.09 (j) Denoised and fused image at sigma level 0.1 (k) Enhanced image at sigma level 0.1

IV. CONCLUSION

The metrics used to compare the quality of the images are PSNR and MSE majorly. With increased value of PSNR, quality of the image improves whereas lower value of MSE is preferred for a better image. As already seen, the proposed method satisfies the criteria and denoises the MRI images.

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