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Performance Analysis of Intensity Averaging by Anisotropic diffusion Method for MRI Denoising Corrupted by Random Noise

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Abstract - The two parameters which plays important role in MRI (magnetic resonance imaging), acquired by various imaging modalities are Feature extraction and object recognition. These operations will become difficult if the images are corrupted with noise. Noise in MR image is always random type of noise. This noise will change the value of amplitude and phase of each pixel in MR image. Due to this, MR image gets corrupted and we cannot make perfect diagnostic for a body. So noise removal is essential task for perfect diagnostic. There are different approaches for noise reduction, each of which has its own advantages and limitation. MRI denoising is a difficult task as fine details in medical image containing diagnostic information should not be removed during noise removal process. In this paper, we are representing an algorithm for MRI denoising in which we are using iterations and Gaussian blurring for amplitude reconstruction and image fusion, anisotropic diffusion and FFT for phase reconstruction. We are using the PSNR(Peak signal to noise ration), MSE(Mean square error) and RMSE(Root mean square error) as performance matrices to measure the quality of denoised MRI .The final result shows that this method is effectively removing the noise while preserving the edge and fine information in the images.

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Strictly as per the compliance and regulations of:

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Abstract - The two parameters which plays important role in MRI (magnetic resonance imaging), acquired by various imaging modalities are Feature extraction and object recognition. These operations will become difficult if the images are corrupted with noise. Noise in MR image is always random type of noise. This noise will change the value of amplitude and phase of each pixel in MR image. Due to this, MR image gets corrupted and we cannot make perfect diagnostic for a body. So noise removal is essential task for perfect diagnostic. There are different approaches for noise reduction, each of which has its own advantages and limitation. MRI denoising is a difficult task as fine details in medical image containing diagnostic information should not be removed during noise removal process. In this paper, we are representing an algorithm for MRI denoising in which we are using iterations and Gaussian blurring for amplitude reconstruction and image fusion, anisotropic diffusion and FFT for phase reconstruction. We are using the PSNR(Peak signal to noise ration), MSE(Mean square error) and RMSE(Root mean square error) as performance matrices to measure the quality of denoised MRI .The final result shows that this method is effectively removing the noise while preserving the edge and fine information in the images.

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I. Introduction

MRI Stands for Magnetic Resonance Imaging; once called Nuclear Magnetic Resonance Imaging. The "Nuclear" was dropped off about 15 years ago because of fears that people would think there was something radioactive involved, which there is not. MRI is a way of getting pictures of various parts of your body without the use of x-rays, unlike regular x-rays pictures and CAT scans. A MRI scanner consists of a large and very strong magnet in which the patient lies. A radio wave antenna is used to send signals to the body and then receive signals back. These returning signals are converted into pictures by a computer attached to the scanner. Pictures of almost any part of your body can be obtained at almost any particular angle.

Medical information, acquired from MRI and composed of clinical data, images and other physiological signals, has become an essential part of a patient's care for diagnosis in medical field. Over the past three decades, there is a vast development in information technology (IT) & Medical Instrumentation, which has improved the level of medical imaging. This development are Computed Tomography (CT), Magnetic Resonance Imaging(MRI), the different digital radiological processes for vascular, cardiovascular and contrast imaging, mammography, diagnostic ultrasound imaging, nuclear medical imaging with Single Photon.

Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET). All these methods generate good quality of medical image [1] and each has its own specific features corresponding to the physical and physiological phenomena studied, as shown in "Fig.1

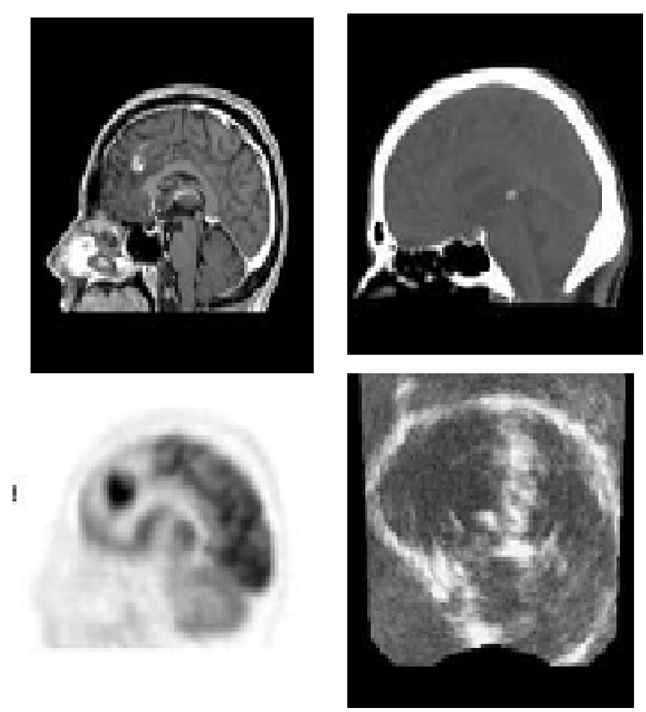

Figure 1 : Sagittal slices of the brain by different imaging modalities: a) magnetic resonance imaging (MRI), b) computed tomography (CT), c) positron emission tomography (PET), d) ultrasound (US)

All medical images contain Random noise. The presence of noise gives an image a mottled, grainy,

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textured, or snowy appearance. Image noise comes from a variety of sources. No imaging method is free of noise, but noise is much more prevalent in certain types of imaging procedures than in others. Noise is also significant in MRI (Medical Resonance Imaging), CT, and ultrasound imaging. In comparison to these, radiography produces images with the least noise. Fluoroscopic images are slightly noisier than radiographic images. The presence of noise degrades the image quality and decreases visibility of lower contrast image. So there is a need for noise removal technique to improve the image quality and to recover the fine details of image which is required for perfect diagnostic. This paper is divided into seven sections. Section one gives idea about MRI and denoising. Section two shows a literature survey .Section three defines implementation of algorithm .Section four and five gives idea about Gaussian blur and anisotropic diffusion. Section six defines pproposed algorithm for denoising while section seven is conclusion

II. Related Work

Various algorithms for image denoising are discussed in [2]. The de-noising of Magnetic Resonance Images using wave atom shrinkage is proposed in [3] and also proved that this approach achieves a better SNR compared to wavelet and curvelet shrinkages. A NL-Denoising method for Rician noise reduction is proposed in [4 & 5].In [6], Total Variation Wavelet-Based technique is used to remove a noise from MR image. The method to improve image quality using adaptive threshold based on contourlet transform is given in [7]. A new filter to reduce random noise in multicomponent MR images by spatially averaging similar pixels and a local principal component analysis decomposition using information from all available image components to perform the denoising process is proposed in [8]. An estimator using a priori information for devising a single dimensional noise cancellation for the variance of the thermal noise in magnetic resonance imaging (MRI) systems called ML estimator has been proposed in [9]. A noise removal technique using 4th order PDE is introduced in [10] to reduce noise in MRI images.. A phase error estimation scheme based on iteratively applying a series of non-linear filters each used to modify the estimate into greater agreement with one piece of knowledge, until the output converges to a stable estimate is introduced in [11].

III. Implementation

Fig. 3 shows the block diagram, gives general idea for MRI denoising using intensity averaging method.

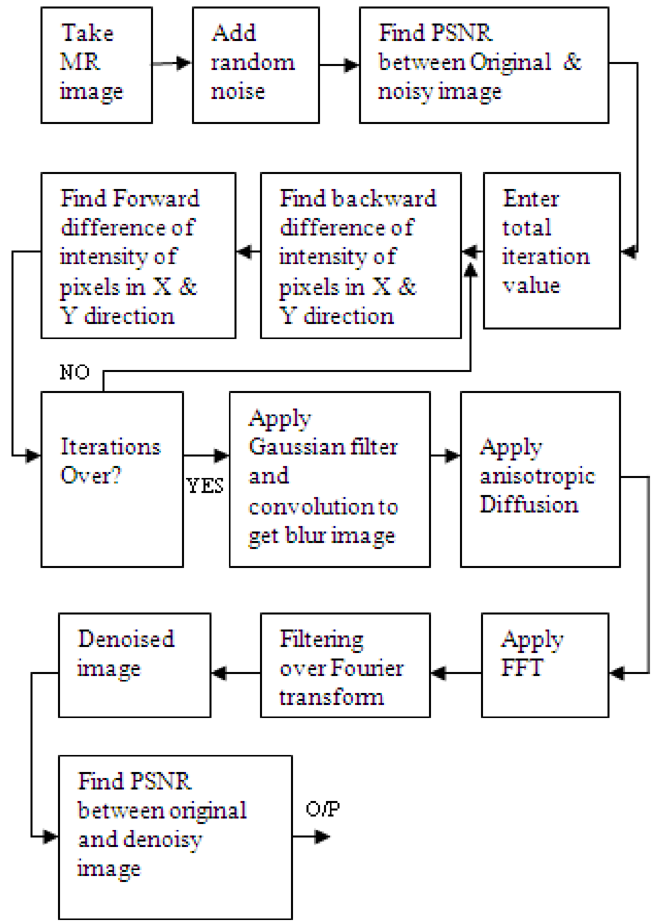


Fig. 3 : Block diagram of intensity averaging algorithm

In proposed algorithm we have taken the image of [fig.2] for evaluating our method. First we will apply amplitude correction on noisy MR image by finding forward and backward difference of intensity of pixels in X and Y direction. This gives average type of value to each pixel and then image is blurred by Gaussian filter and convolution. After completion of this amplitude correction, we apply a phase correction algorithm. Here, we are splitting amplitude corrected image into its red, green and blue band and then we are rotating each band by appropriate amount to correct the phase of MR image. After this, we are applying anisotropic diffusion and FFT to remove the noise from image.

Fig. 2 : MRI of knee

IV. Gaussian Blur

Gaussian blur is also known as Gaussian smoothing used to blur (smooth) the image. Typically it is used to reduce a random noise from the image. Mathemetically, Gaussian blur is equivalent to applying a convolution between image and Gaussian function [12, 13]. Gaussian distribution in 1-D is given as,

$$G(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}$$

Where σ is the standard deviation of distribution. In 2-D, an isotropic Gaussian has the form,

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

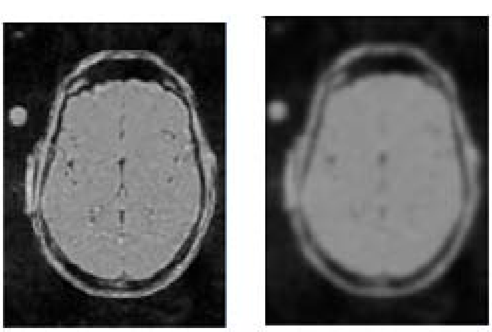
Here, we are producing a discrete approximation of the Gaussian function before we perform the convolution as image is considered as a collection of pixels. Ideally we require an infinitely large convolution kernel because the Gaussian distribution is non-zero everywhere, but in practice we can truncate the kernel as Gaussian distribution in it is effectively zero, more than about three standard deviations from the mean. The degree of smoothing depends on the value of standard deviation. The Gaussian outputs a `weighted average' of each pixel's neighborhood, with the average weighted towards the value of the central pixels. So,

$$I(x,y) = I0(x,y) * G(x,y) \quad (1)$$

I(X,Y) = Gaussian blurred image
I0 (x,y) = Noisy image
G(x,y,t) = Gaussian filter function

This is in contrast to the mean filter's uniformly weighted average.[14] Because of this, a Gaussian provides gentler smoothing and preserves edges better than a similarly sized mean filter. The main problem with Gaussian filter is,

- Loss of fine detail
- Smoothing across boundaries as shown in fig.3.



(a) (b)

Fig. 3 : (a) Before Gaussian blur (b) After Gaussian blur

This problem can be solved by anisotropic diffusion as discussed below.

V. Image Fusion and Anisotropic Diffusion

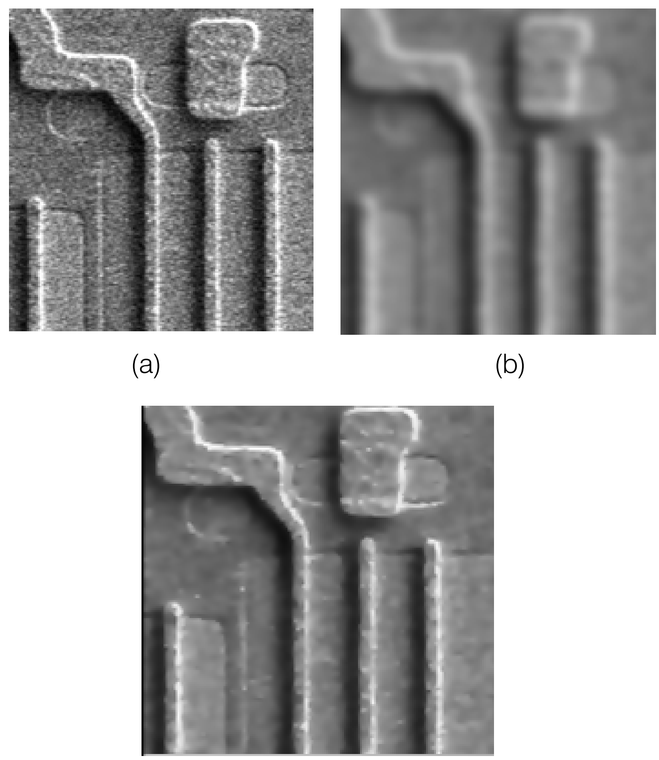
Image fusion describes the concept of combining multiple images into one image which gives more information compared to individual one [15]. Linear diffusion provides over smoothing of image as shown in fig. 3, we will use non-linear smoothing in which each pixel is treated with varying intensity depending on its neighboring value. In general,

if (x,y) is a part of an edge ➔ apply little smoothing
if not a part of an edge ➔ apply full smoothing

This idea can be implemented by using a gradient function as given below.

$$Grad(I) = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}\right)$$

So non linear smoothing gives good intraregion smoothing as well as doesn't do much with interregion smoothing (edges and lines) as shown in fig.4 [16]



(a) (b)

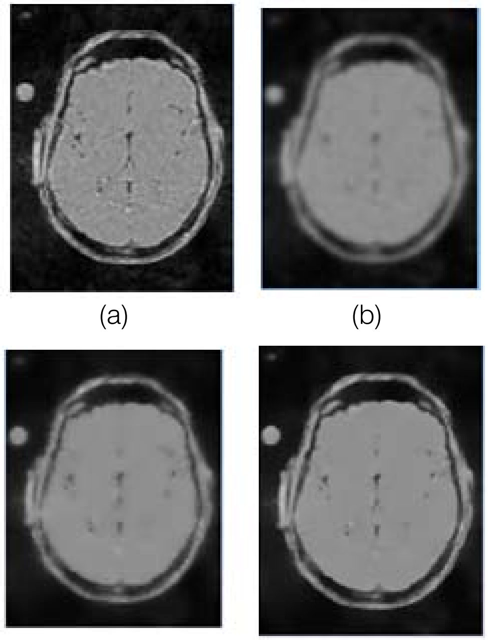
(c)

Fig. 4 : (a) Original image (b) image after linear smoothing (c) image after Non-linear smoothing

This problem can be solved with anisotropic diffusion [17] when equation no.1 can be viewed as heat equation as shown below,

$$It = \Delta I = (Ixx, Iyy)$$

The matter in an image is not heat, but brightness level. So, an image could be generalized to be a surface, where bright spots are "hot" and dark spots are "cold". So the idea is to use a varying size of kernel. Comparison of linear, non-linear and anisotropic diffusion is shown in fig.5



(a) (b) (c) (d)

Fig. 5 : (a) original image (b) image after linear fusion (c) image after non-linear fusion (d) image after anisotropic fusion

VI. Proposed Algorithm

1. I/P Image.
2. Add Random noise
3. Find PSNR between Original and Noisy Image.
4. Steps for applying Magnitude Reconstruction using iteration method on MR image:
   a. Enter iteration value.
   b. Find the backward difference of intensity of pixels in X and Y direction till the iteration ends.
   c. Find the forward difference of intensity of pixels in X and Y direction till the iteration ends.
   d. Find PSNR between Original and Denoisy Image after iteration process [psnr2].
   e. Apply Gaussian filters to blur the image.
   f. Perform convolution.
   g. Find PSNR between Original and Denoisy image after Gaussian blurring. [psnr3].
5. Steps for applying Phase Reconstruction on Noisy MR image.
   a. Apply anisotropic diffusion.
   b. Find PSNR between Original and Denoisy image after iteration Process for Smoothing [psnr4]
   c. Apply FFT on Diffused Image.
   d. Perform the Filtering over Fourier transform.
   e. Find PSNR between Original and Denoisy image after FFT on filtering [psnr5].
   f. Apply Image Sharpening Using Filtering.
6. Denoised Image

Now, we will evaluate the algorithm by taking different values of iterations (A).

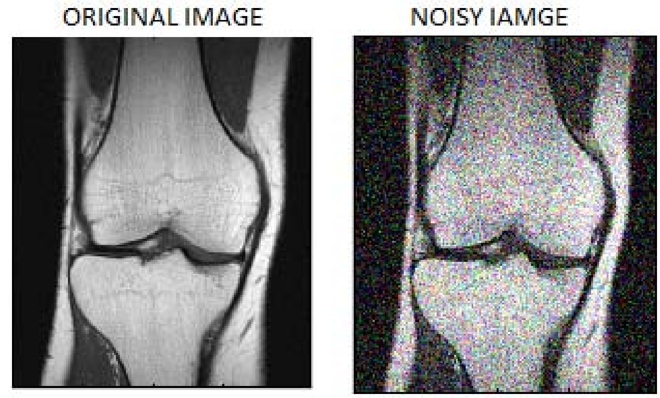
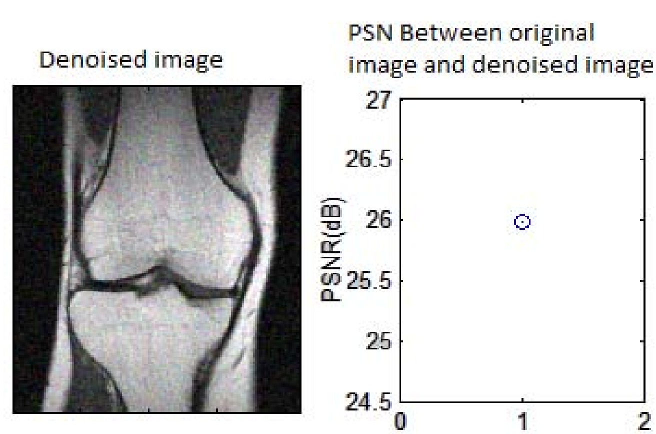


Fig. 6 : (a) Input image (b) Noisy input image

Now apply different values of “A” (no. of iterations) on noisy MR image as shown in fig.6 (b). As the value of “A” increases, we are getting more and more noise removal from noisy image as shown in fig. (7), (8) and (9). We are taking following parameters to evaluate the algorithm.

- Psnr2:- PSNR between Original and Denoisy image after iteration process
- psnr3:- PSNR between Original and Denoisy image after Gaussian blurring Image.
- Psnr4:- PSNR between Original and Denoisy image after iteration process for Smoothing using anisotropic diffusion.
- Psnr5:- PSNR between Original and Denoisy image After FFT on filtering
- Mse2:-Difference between Original and Denoisy image after iteration process
- Mse3:-Difference between Original and Denoisy image after Gaussian blurring Image.
- Mse4:- Difference between Original and Denoisy image after iteration process for Smoothing using anisotropic diffusion.
- Mse5:-Difference between Original and Denoisy image After FFT on filtering.

FOR A=10:-

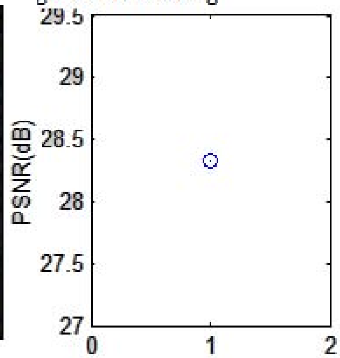


(a) (b)

Denoised image after gaussian Blur

(c)

PSNR Between original image and denoised image after gaussian blurring

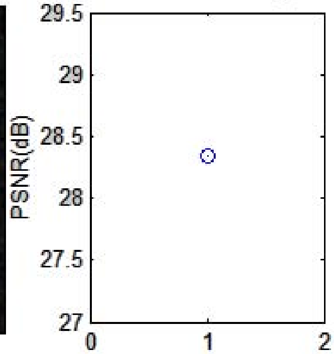


(d)

Denoised omage after iteration process for smoothing

(e)

PSNR between original and denoised image after iteration process for smoothing

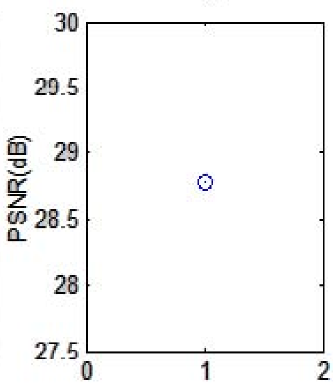


(f)

Denoised image after FFT on filtering

(g)

PSNR between original and denoised image after FFT on filtering



(h)

Fig. 7 : Denoised image after (a) iterations (c) Gaussian blur (e)iteration process for smoothing using anisotropic diffusion (g) FFT on filtering

Table 1 : Obtained Result for A=10

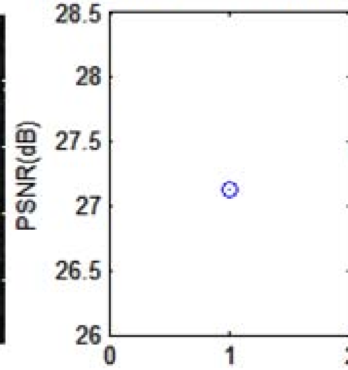
Psnr2=25.98	Mse2=15.51
Psnr3=28.35	Mse3=17.86
Psnr4=24.37	Mse4=17.95
Psnr5=28.81	Mse5=18.2

FOR A=15:-

Denoised image

(a)

PSNR between original image and denoised image

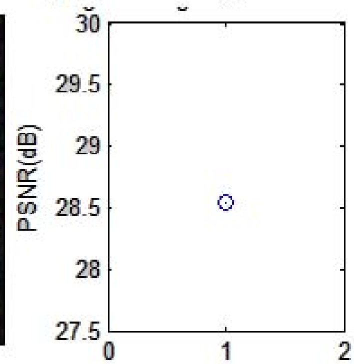


(b)

Denoised image after gaussian Blur

(c)

PSNR Between original image and denoised image after gaussian blurring

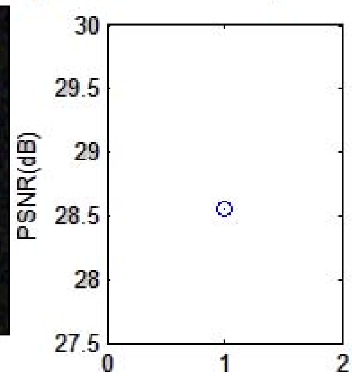


(d)

Denoised omage after iteration process for smoothing

(e)

PSNR between original and denoised image after iteration process for smoothing



(f)

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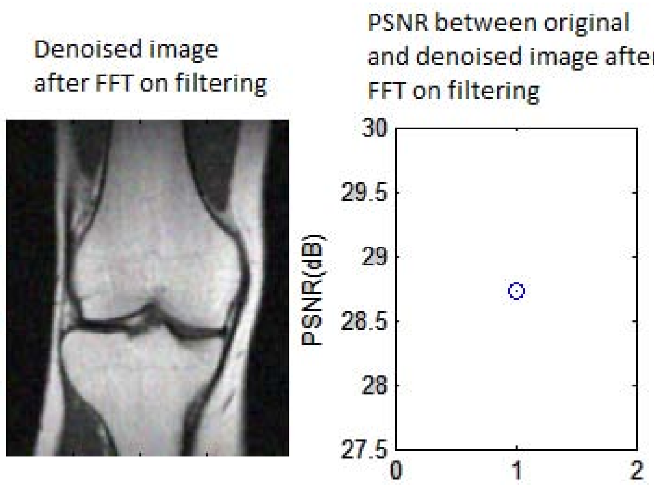


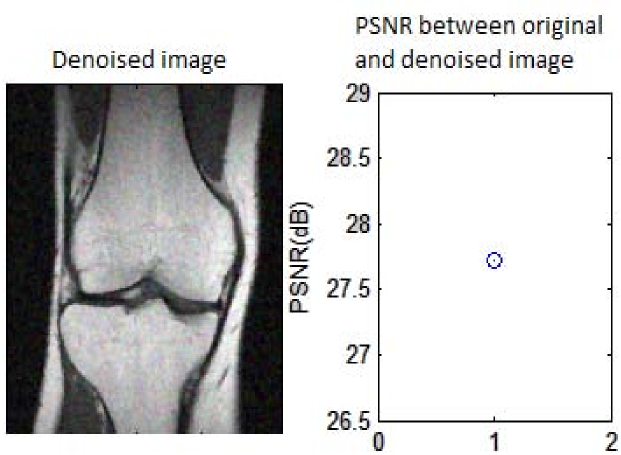
(g) (h)

Fig. 8 : Denoised image after (a) iterations (c) Gaussian blur (e)iteration process for smoothing using anisotropic diffusion (g) FFT on filtering

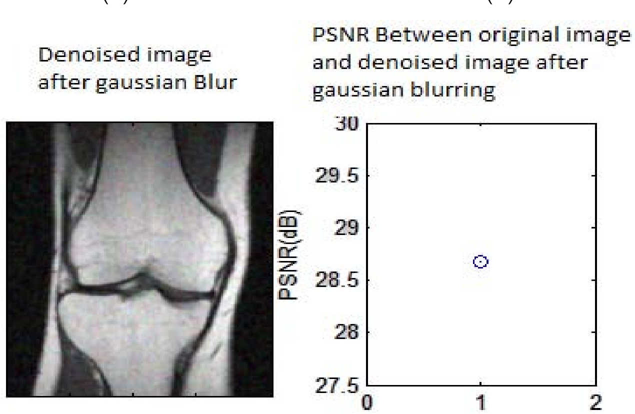
Table 2 : Obtained Result for A=15

Psnr2=27.10	Mse2=16.63
Psnr3=28.53	Mse3=18.06
Psnr4=27.60	Mse4=18.07
Psnr5=28.73	Mse5=18.25

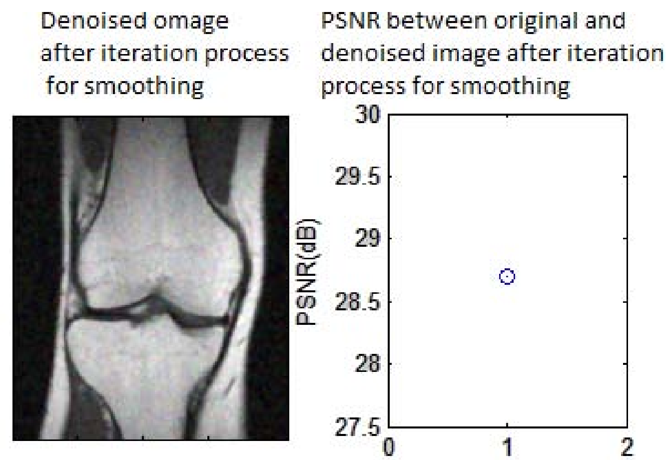
FOR A=20:-



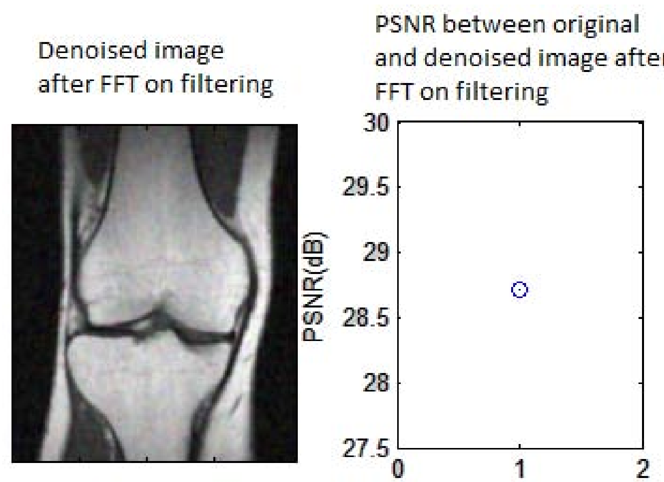
(a) (b)



(c) (d)



(e) (f)



(g) (h)

Fig. 9 : Denoised image after (a) iterations (c) Gaussian blur (e)iteration process for smoothing using anisotropic diffusion (g) FFT on filtering

Table 3 : Obtained Result for A=20

Psnr2=27.75	Mse2=17.28
Psnr3=28.69	Mse3=18.22
Psnr4=28.70	Mse4=18.23
Psnr5=28.75	Mse5=18.29

VII. Conclusion

From the above result we conclude that, our algorithm is efficiently removing the noise from MR image. As number of iterations increases ("A"), we are getting more and more improved image. Experimental results show that, we are getting good Result in terms of PSNR and image quality. This algorithm is capable of removing noise from images and at the same time it is preserving fine details of images too. We also conclude that, for large value of iteration (A>25), increment in PSNR is less compared to small values of iterations (A<25).

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