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Edge Enhanced Anisodiffusion Filter for Denoising Gaussian Noise in Medical Images

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ABSTRACT

Recently the need for medical images has enormously increased for accurate diagnosis of various diseases. However, the images obtained from medical imaging techniques (MRI, Ultrasound, CT etc.,) often include imaging noises. Therefore denoising is an essential and used as a preprocessing process to remove their noises before extracting some meaningful information from these images. Gaussian noise is found to be the most common imaging noise especially for medical images. Therefore, in this paper, a denoising technique based on Anisodiffusion filter is developed. This proposed method enhances the edges in the denoised image. The proposed method is tested with MRI, Ultrasound, and CT scan medical images. The performance of this method is compared with the existing standard filters and it has produced good result in terms of MSE and PSNR measures.

Keywords: Noise removal, denoising method, anisotropic diffusion method, Gaussian noise, edge enhancement.

1. INTRODUCTION

Medical imaging is one of the technique and process of creating visual representations of the interior of a body for clinical analysis and visual representation of internal structures of human organs [1].There are many imaging techniques available today, among them Magnetic Resonance Imaging (MRI), Ultrasound, Elastography and Computer Tomography (CT) are most widely used imaging techniques. Magnetic Resonance Imaging (MRI) uses most powerful magnets to polarize and excite hydrogen nuclei of water molecules in human tissue, producing a detectable signal which is spatially encoded, resulting in images of the body. Medical ultrasonography is useful for high frequency broadband sound waves in the megahertz range that are reflected by tissue to varying degrees to produce 2D and 3D images. Ultrasound is used for imaging the abdominal organs, heart, breast, muscles, tendons, arteries and veins.

Elastography is one of the relatively new imaging modality that maps the elastic properties of soft tissue. Elastography is useful in medical diagnoses, as elasticity can discern healthy from unhealthy tissue for specific organs and growth. Computed Tomography (CT) scan, produces 2D image of the structures in a thin section of the body. In CT, a beam of X-rays spins around an object being examined and is picked up by sensitive radiation detectors after having penetrated the object from multiple angles. A computer then analyses the information received from the scanner's detectors and constructs a detailed image of the object. However the images produced by these image sources are sensitiveto image noise and thus degrade the quality of the image.

Noise is any degradation of the image signal caused by external disturbance [2]. Usually the medical images, are affected by noises due to the disturbance in the imaging process and inclusion of imaging artifacts. These image noises are classified as Amplifier noise (Gaussian noise), Salt-and-pepper noise (Impulse noise), Shot noise, Quantization noise (uniform noise), Film grain noise, Speckle noise (Multiplicative noise) and Periodic noise. Gaussian is an idealized form of white noise, which is caused by random fluctuations in the signal [3]. In Gaussian

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noise, each pixel of the image will be changed from its original value by a small amount. There are many standard filters are available in the literature to remove the noises form the medical images. The standard Median Filter (MF) is effective filter but works better only at low noise densities [4], that is, if the noise level is above 50%, edge details of original image cannot be preserved by the standard median filter. Similarly, Adaptive Median Filter (AMF) works well at low noise densities [5], but in high level noise the window size has to be increased which leads to produce blurring effect in the image. Also these filters will not take into account the local features, as an outcome of which the edges may not recovered satisfactorily.

Anisotropic diffusion is a noise removal method employed for both image enhancement and denoising proposed by Perona-Malik (PM) in 1990 [6]. This model makes use of anisotropic diffusion to filter out the noise. In this model, the rate of diffusion is managed by edge stopping function. Catt et al., [7] suggested modified versions of PM models named as anisotropic diffusion model with Gaussian filter in 1992. In this model, an image must be smoothened by convolving with Gaussian filter and then the gradient is computed. The edge detection functions are very efficient in preserving sharp edges and adequate fine details to restore optical objects [8]. Bilateral filtering is a technique to smooth images while preserving edges. Mahesh et al., [9] proposed a new fuzzy filter for the noise reduction of images corrupted with additive noise. This filter consists of two stages; the first stage computes a fuzzy derivative for eight different directions. The second stage uses these fuzzy derivatives to perform fuzzy smoothing by weighting the contributions of neighboring pixel values. Both stages are based on fuzzy rules and make a use of membership functions. This filter can be applied iteratively to reduce the heavy noise. Schulte et al., [10] developed a method based on the concept of fuzzy gradient values. This fuzzy set is represented by a membership function that will be used for the filtering and provides a significant improvement over the other existing filters [11].

In the field of image noise reduction, several linear and non linear filtering methods are proposed [12]. Linear filters are not able to effectively eliminate impulse noise as they have a tendency to blur the edges of an image. Sanches et al., [13] presents a Bayesian denoising algorithm which copes with additive white Gaussian noise and multiplicative noise described by Poisson and Rayleigh distributions. This algorithm is based on the maximum of the posteriori (MAP) criterion, and edge preserving and avoids the distortion of relevant anatomical details. The main contribution of this work is unification of a set of Bayesian denoising algorithms for additive and multiplicative noise using a well-known mathematical framework, and the Sylvester–Lyapunov equation.

Shinde et al., [14] experimented the denoising process using median filter techniques with different medical images like MRI, CT, X-ray, and ultrasound and calculated standard derivations and mean of all these medical images.

Flores and Leon [15] presented a new approach for noise reduction and contrast enhancement for different types of medical images. Then an anisotropic scheme is used to iteratively reduce noise as well as enhances image regions.

Mixed noise removal based on Hybrid fourth order nonlocal filtering for brain MRI is developed in [16]. Similarly the adaptive nonlocal filtering for brain image restoration is proposed in [17].

In this paper, we analyzed the performance of standard filters such as mean filter, median filter, linear filter, adaptive filter, Gaussian filter, bilateral filter, Unsharp filter, and Sobel filter to remove Gaussian noise in the medical images and also we have modified the Anisodiffusion filter to enhance edge details in the noise removal process.

2. METHODOLOGY

The overall flowchart of the proposed method is given in Figure 1 and the denoising process by the proposed method is illustrated in Figure 2. In the following section, we described about Gaussian noise, formulation of existing standard method and the proposed denoising process.

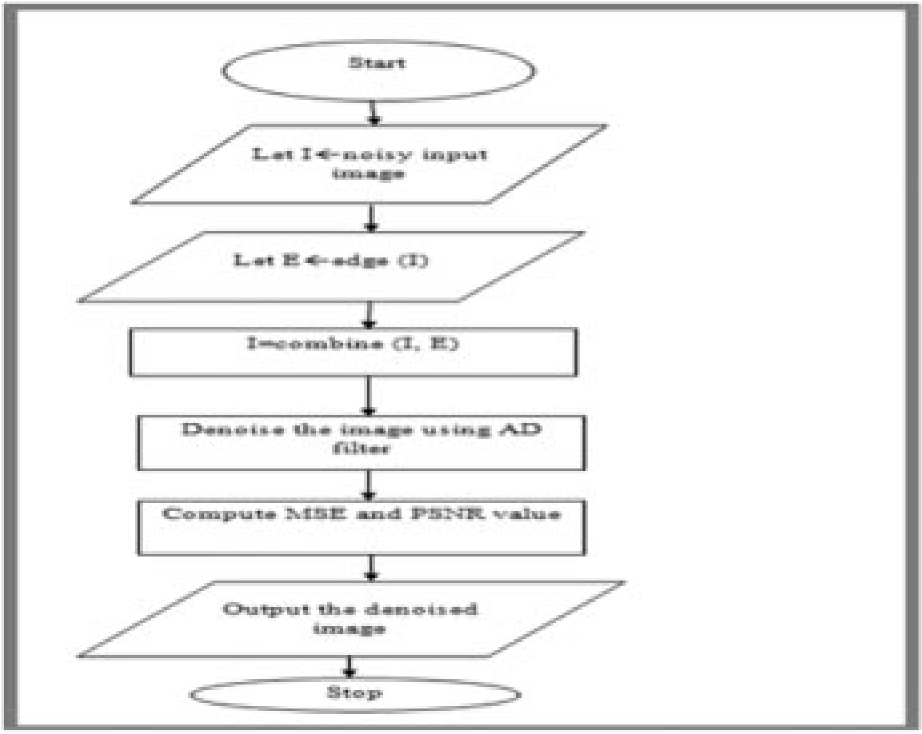

Figure 1: Flowchart of the proposed method

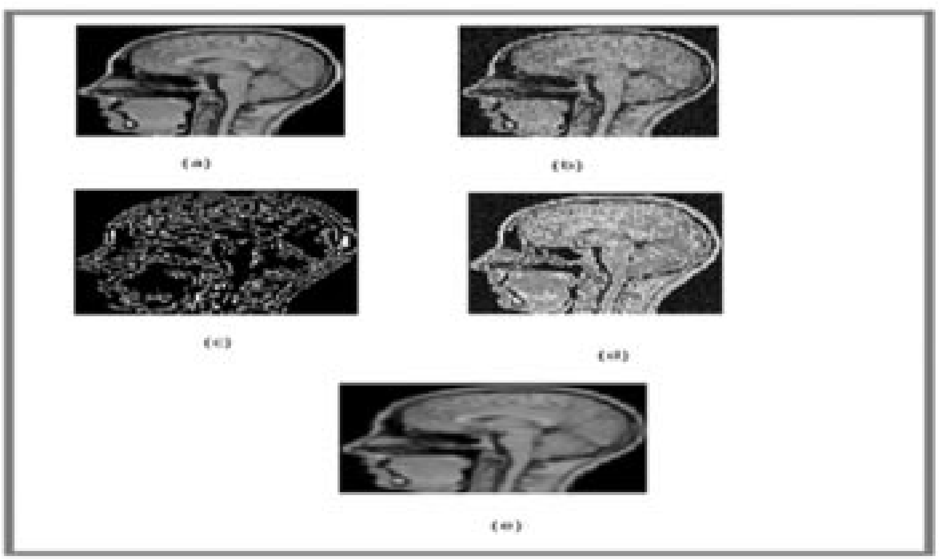

Figure 2: Denoising process by our proposed method; (a) Original image (b) Noisy image (c) Edge image (d) Edge added noisy image (e) Denoised image

2.1. Gaussian noise

Gaussian noise is one of the statistical noise having a probability density function (PDF) equal to that of the normal distribution, which is also known as the Gaussian distribution.

The probability density function *p* of a Gaussian random variable *z* is given by:

$$pG^{(z)} = \frac{1}{\partial\sqrt{2\pi}} e^{-\frac{(z-\mu^{2}}{2\partial^{2}}} \quad (1)$$

where, *z* represents the grey level, μ the mean value and σ the standard deviation. Figure 3, shows an example image with 25% of Gaussian noise.

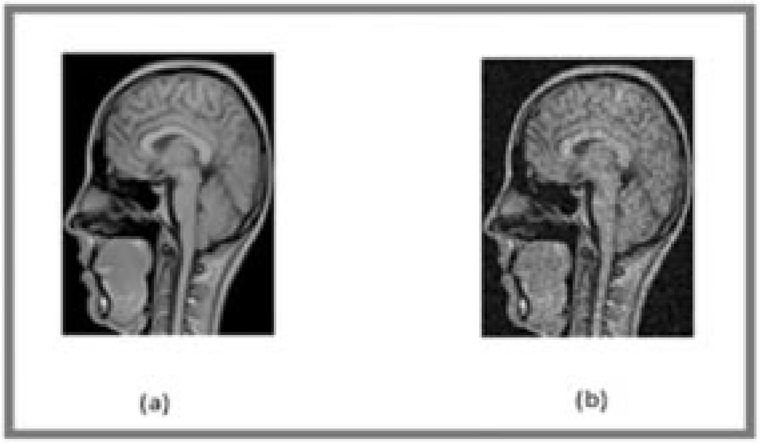

Figure 3: Gaussian noise; (a) Original image (b) Gaussian noise image

2.2. Existing standard filters

2.2.1. Mean filter

The idea of mean filtering is simply to find and replace the each pixel value in an image with the mean value of its neighbors, including itself. The mean filter is defined as follows:

(2)

where, f is the denoised image, g represents the corrupted image, m, n is the size of the sliding window and S_{xy} represents the set of coordinates in a sliding window of size m*n centered at point of (x, y).

2.2.2. Median filter

In median filter, the values of output pixels are determined by the median of the neighborhood pixels, rather than the mean filter. The median is much less sensitive than the mean to extreme values. Median filtering is therefore better to remove the noise without reducing the sharpness of the image.

$$y(m,n = median\ x[i,j],(i,j \in w \qquad (3)$$

where, w represents neighborhood defined by the user centered around location [m, n] in the image.

2.2.3. Linear filter

Linear filter is used to remove certain types of noises. Averaging or Gaussian filters are appropriate for this purpose. Linear filters are also end to blur sharp edges, destroy lines and other fine image details, and perform poorly in the presence of the signal-dependent noise [18]. The linear filter is defined as:

$$Y(t = \int_0^T x(t - T(h \quad dt$$

$$y_k = \sum_{i=0}^{N} xk - ihi \qquad (4)$$

2.2.4. Adaptive filter

The adaptive filter is most selective than a comparable linear filter, preserving edges and other high frequency parts of an image. In addition, there are no design tasks the wiener 2 function handles all preliminary computations, and implements the filter for an input image. Wiener 2, however, requires more computation time than linear filtering and it is given by:

$$y_{k=\sum_{L=0}^{L}\frac{w}{k}x_k=}W_{kx_k}^{T} \tag{5}$$

2.2.5. Gaussian filter

Gaussian filters have the properties of having no overshoot to a step function while minimizing the rise and fall time. This behavior is closely connected to the fact that the Gaussian filter has the minimum possible group delay. It is considered the ideal time domain filter. The Gaussian filter is formulated as:

$$G(x,y = \frac{1}{2\pi\sigma^2}\varepsilon\frac{x^2+y^2}{2\sigma^2} \tag{6}$$

where, x and y represents the grey levels, μ the mean value and σ the standard deviation.

2.2.6. Bilateral filter

A bilateral filter is a one of the non-linear, edge-preserving and noise-reducing smoothing filter for images. The intensity value at each pixel in an image is replaced by a weighted and average of intensity values from nearby pixels. These weights are based on a Gaussian distribution. Crucially, the weights depend not only on Euclidean distance of pixels, but also on the radiometric differences. This preserves sharp edges by systematically looping through each pixel and adjusting weights to the adjacent pixels accordingly.

The bilateral filter is defined as:

$$I^{filtered}(x = \frac{1}{w_p}\sum_{x_i\in\Omega}(x_i \; f_r \; \|(I \; x_i \; -(I \; x \| \; g_s \; \|x_i - x\| \, , \tag{7}$$

$$g(x,y = f(x,y - f_{smooth}(x,y$$

where, the normalization term is given by:

$$w_p = \sum_{x_i\in\Omega} f_r \; \|I(x_i \; -(\; x \| \; g_s \; \|x_i - x\| \tag{8}$$

2.2.7. Unsharp filter

Unsharp masking (USM) is technique, often available in digital image processing software. The “Unsharp” of the name derives from the fact that the technique uses a blurred, or “Unsharp”, negative images to create a mask of the original image. The unsharped mask is then combined with the image, creating an image that is less blurry than the original. In the context of signal processing, an unsharp mask is generally a linear or non-linear filters that are amplifies the high-frequency components of a signal. Unsharp masking produces an edge image g(x,y) from an input image $f(x,y)$ via

(9)

2.2.8. Sobel filters

The Sobel operator, also called the Sobel–Feldman operator or Sobel filter, is used in image processing and computer vision, particularly within edge detection algorithms to create an image emphasizing edges. The Sobel–Feldman operator is used on convolving the image with a small, separable, and integer-valued filter in the horizontal and vertical directions and it’s therefore relatively inexpensive in terms of computations. On the other hand, the gradient approximation that it produces is relatively crude, in particular for high-frequency variations in the image.

2.3. Proposed edge enhanced Anisotropic Diffusion Filter

Anisotropic diffusion, also called Perona-Malik diffusion is a technique to reduce image noise without removing significant parts of the image content, such as edges, lines or other details, which are important to the interpretation of the image. Anisotropic diffusion resembles the process that creates a scale space, where an image generates a parameterized family of successively more and more blurred images based on a diffusion process. Each of the images resulting in this family is given as a convolution between the image and a 2D isotropic Gaussian filter, where the width of the filter increases with the parameter. This diffusion process is a linear and space-invariant transformation of the original image. Anisotropic diffusion is normally implemented, by means of an approximation of the generalized diffusion equation.

Formally, let $\Omega \subset R^2$ denote a subset of the plane and $I(. , t): \Omega \rightarrow R$ be a family of gray scale images, then anisotropic diffusion is given by:

$$\frac{\partial I}{\partial t} = div\ c(x, y, t\ \nabla I\ = \nabla c . \nabla I + c(x, y, t,\ \Delta I \qquad (10)$$

where, Δ denotes the Laplacian, ∇ denotes the gradient, *div*-(...) is the divergence operator and $c(x, y, t)$ is the diffusion coefficient and it controls the rate of diffusion, usually chosen as a function of the image gradient so as to preserve edges in the image. The functions for the diffusion coefficients are defined as:

(11)

and

$$c\ \|\nabla I\|\ = \frac{1}{1+\left(\frac{\|\nabla I\|}{K}\right)^{2}} \qquad (12)$$

In above equation, constant K controls sensitivity of edges and is usually chosen experimentally or as a function of the noise in the image. Though the Anisodiffusion filter is an edge preserving filter when it is used as a preprocessing procedure for image segmentation and analysis, the preserved edge details are not enough for accurate segmentation of individual objects present in the images, especially for medical images. Therefore, in this proposed method the edge details are added to the noisy image before applying the denoising procedure based on the Anisodiffusion filter. There are many edge detection operators are available in literature. Image edge detection using bit-plane-slicing is reported in [19]. The performance of the spatial mean filters to detect image edges are compared in [20] and [21]. The canny is one of the well-known and produce continues edges in the images. Hence, in this method we use canny edge detector to detect the edges and these edges are added to the noisy image before denoising using Anisodiffusion filter.

3. RESULTS AND DISCUSSION

In this paper, we have evaluated the standard filters such as mean filter, median filter, linear filter, adaptive filter, Gaussian filter, Unsharp filter, Sobel filter for denoising Gaussian noise from the medical images, we have also tested our proposed edge enhanced anisotropic diffusion filter for denoising Gaussian noise from MRI, Ultrasound and CT scan medical images. The denoising performance of this modified filter is compared with the standard filter by calculating MSE and PSNR values. The performance of the standard filters on some of the selected medical images are shown Figure 4, and the computed MSE and PSNR value are given Table1. In Figure 4, image 1 and 2 are a MRI image, 3 and 4 are ultrasound image, 5 and 6 are CT scan image. From Figure 4 and Table 1, it can be identified that our proposed edge enhanced Anisodiffusion filter produce higher PSNR value for all the images and this may be applied as a preprocessing process for any medical image segmentation method.

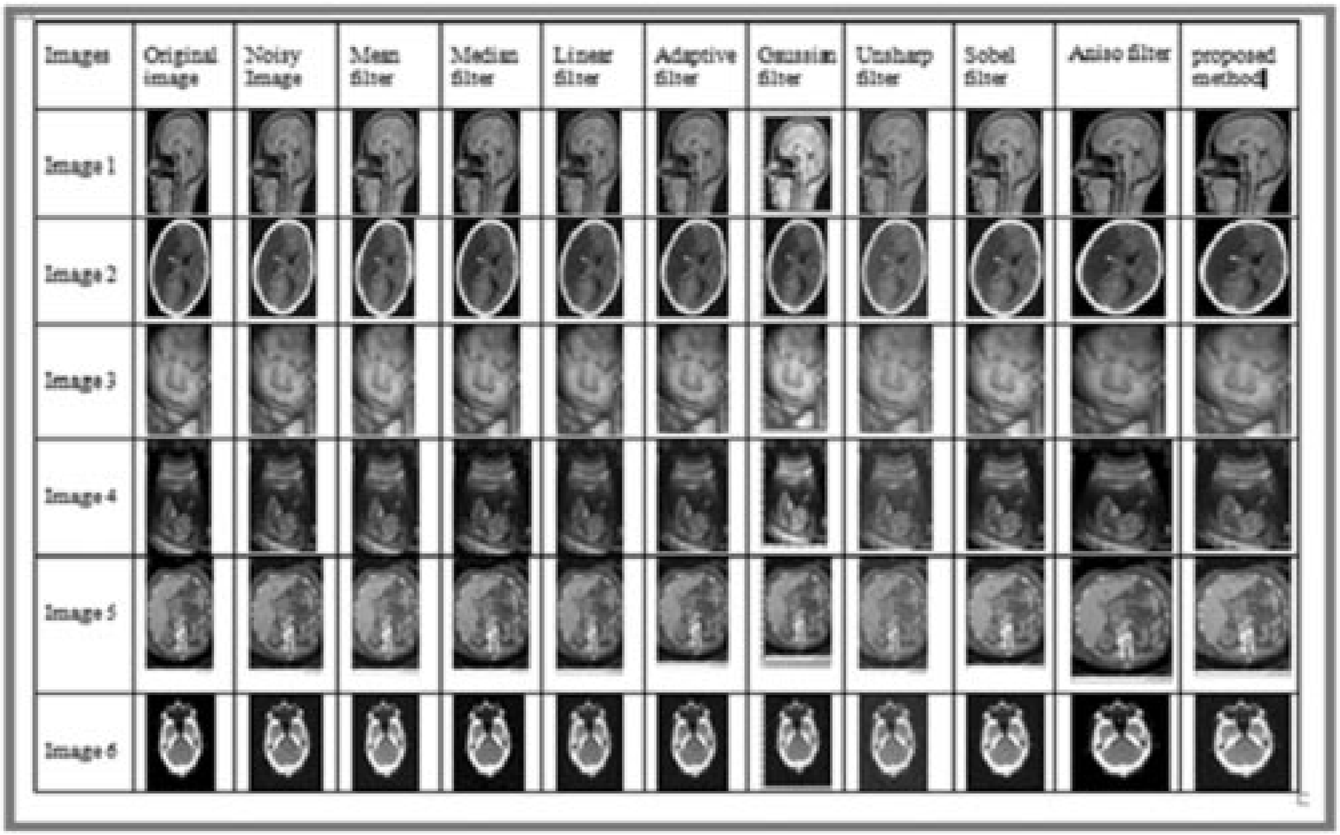

Figure 4:Output of the noise removal using standard filters and proposed method

Table 1
Computed MSE and PSNR value for the denoised image given in Figure 4.

List of filters	Image 1		Image 2		Image 3		Image 4		Image 5		Image 6	
	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR
Mean filter	12.34	37.25	16.53	35.98	4.16	41.97	15.96	36.13	18.05	35.60	17.91	35.63
Median filter	53.08	30.91	57.71	30.55	66.46	29.93	67.56	29.58	61.72	30.26	32.19	33.08
Linear filter	48.55	31.30	56.15	30.67	34.86	32.74	33.69	32.89	58.99	30.46	39.89	32.16
Adaptive filter	42.77	31.85	54.31	30.81	39.79	32.16	39.14	32.23	58.35	30.50	37.46	32.42
Gaussian filter	8.39	38.92	8.55	38.84	15.59	36.23	15.63	36.22	10.96	37.76	7.74	39.27
Unsharp filter	69.40	29.75	72.05	29.58	101.17	28.07	72.17	29.58	80.98	29.08	31.71	33.15
Sobel filter	25.85	34.04	29.82	33.41	4.84	41.31	5.06	41.12	24.21	34.32	26.23	33.97
Aniso filter	0.01	63.36	0.01	63.35	0.01	62.60	0.01	62.89	0.01	63.89	0.01	64.02
Proposed method	0.01	68.24	0.01	68.42	0.01	68.60	0.01	68.62	0.01	67.86	0.01	67.03

4. CONCLUSIONS

In this paper, we have developed a method to remove the Gaussian noise present in medical images by preserving the edges. This proposed method is tested with MRI, CT scan and Ultrasound medical images. The performance of this method is also compared with the standard filters, Mean filter, Median filter, Linear filter, Adaptive filter, Gaussian filter, Unsharp filter, Sobel filter by calculating MSE and PSNR values. Presently, we have denoised only the Gaussian noise in the medical images, in future it may be modified to eliminate all types of noises in medical images.

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