JSR Publications

Available Online

J. Sci. Res. **3** (1), 81-89 (2011)

JOURNAL OF SCIENTIFIC RESEARCH

www.banglajol.info/index.php/JSR

Short Communication

A New Method to Remove Noise in Magnetic Resonance and Ultrasound Images

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Received 19 July 2010, accepted in revised form 3 October 2010

Abstract

In medical image processing, medical images are corrupted by different type of noises. It is very important to obtain precise images to facilitate accurate observations for the given application. Removing of noise from medical images is now a very challenging issue in the field of medical image processing. Most well known noise reduction methods, which are usually based on the local statistics of a medical image, are not efficient for medical image noise reduction. This paper presents an efficient and simple method for noise reduction from medical images. In the proposed method median filter is modified by adding more features. Experimental results are also compared with the other three image filtering algorithms. The quality of the output images is measured by the statistical quantity measures: peak signal-to-noise ratio (PSNR), signal-to-noise ratio (SNR) and root mean square error (RMSE). Experimental results of magnetic resonance (MR) image and ultrasound image demonstrate that the proposed algorithm is comparable to popular image smoothing algorithms.

Key words: Magnetic resonance image; Ultrasound image; PSNR; SNR; RMSE.

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doi:10.3329/jsr.v3i1.5544 J. Sci. Res. **3** (1), 81-89 (2011)

1. Introduction

In medical image processing, it is very important to obtain precise images to facilitate accurate observations for the given application. . Low image quality is an obstacle for effective feature extraction, analysis, recognition and quantitative measurements. Therefore, there is a fundamental need of noise reduction from medical images. There are currently a number of imaging modalities that are used for study of medical image processing. Among the newly developed medical imaging modalities, Magnetic Resonance Imaging (MRI) and Ultrasound imaging are believed to be very potential for accurate measurement of organ anatomy in a minimally invasive way. In this paper, MR

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image and Ultrasound image are experimented to remove noise. MRI is a powerful diagnostic technique. However, the incorporated noise during image acquisition degrades the human interpretation, or computer-aided analysis of the images. Noise in MR images obeys a Rician distribution [1]. Unlike additive Gaussian noise, Rician noise is signal-dependent and consequently separating signal from noise is a difficult task [2].

Ultrasound imaging is widely used in the field of medicine. It is used for imaging soft tissues in organs like liver, kidney, spleen, uterus, heart, brain etc. The common problem in ultrasound image is speckle noise which is caused by the imaging technique used that may be based on coherent waves such as acoustic to laser imaging [3, 4].

For these kinds of noises, de-noising should be performed to improve the image quality for more accurate diagnosis. The main objective of image-de-noising techniques is to remove such noises while retaining as much as possible the important signal features.

There are many works on the restoration of images corrupted by noise. Several filters are used to remove noise from an image by making a determination of a more accurate version of pixels. By taking neighboring pixels into consideration, extreme “noisy” pixels can be filtered out. Unfortunately, extreme pixels can also represent original fine details, which can also be lost due to the smoothing process. There is no unique technique for noise removing from affected image. Different algorithms are used depending on the noise model. The averaging filtering technique can successfully remove noise from the distorted image but in this case the filtered image suffers the blurring effect. For the mean filtering techniques each pixel is considered to calculate the mean and also every pixel is replaced by that calculated mean. So affected pixels are considered to calculate the mean and unaffected pixels are also replaced by this calculated mean.

The median filter was once the most popular nonlinear filter for removing noise, because of its good de-noising power [5] and computational efficiency [6]. Their main drawback is that the noisy pixels are replaced by some median value in their vicinity without taking into account local features such as the possible presence of edges [7]. Hence details and edges are not recovered satisfactorily, especially when the noise level is high.

This paper examines three common noise removing algorithms and introduces a new algorithm for noise reduction from medical images that combine both median filtering and mean filtering to determine of a more accurate value of pixels of noisy image. The experimental result shows the efficacy of the proposed method.

2. Different Noise Models

Noise modeling in images is affected by capturing instrument, data transmission media, image quantization and discrete source of radiation. Gaussian noise (random additive) is observed in natural images [8], speckle noise is observed in ultrasound images [9-11] where as rician noise [2] affects magnetic resonance image (MRI). The characteristics of noise depend on its source, as does the operator which reduces its effects.

2.1. *Rician noise*

MR images are corrupted by Rician noise, which arises from complex Gaussian noise in the original frequency domain measurements. The Rician probability density function for the corrupted image intensity *x* is given by

$$\mathrm{p}(x) = \frac{x}{\sigma^2}\exp\left(-\frac{x^2+A^2}{2\sigma^2}\right) I_0\left(\frac{xA}{\sigma^2}\right) \tag{1}$$

where *A* is the underlying true intensity, σ is the standard deviation of the noise, and I_0 is the modified zeroth order Bessel function of the first kind.

2.2. *Speckle noise*

A different type of noise in the coherent imaging of objects is called speckle noise. This noise is, in fact, caused by errors in data transmission [12, 13]. This kind of noise affects the ultrasound images [13]. Speckle noise follows a gamma distribution and is given as

$$F(\mathrm{g}) = \left[\frac{g^{\propto-1}}{(\propto-1)!a^{\propto}}\ \mathrm{e}^{-\frac{g}{a}}\right] \tag{2}$$

where, a^2 is the variance, $\propto$ is the shape parameter of gamma distribution and *g* is the gray level.

3. Review of Noise Removal Methods

Noise reduction is the process of removing noise from a signal. Medical images are corrupted with different kinds of noise while image acquisition. Some noise removal techniques are described below:

3.1. *Linear smoothing filter*

The Mean filter is a linear filter which uses a mask over each pixel in the signal. Each of the components of the pixels which fall under the mask are averaged together to form a single pixel [14].

$$f(\mathrm{x,y}) = \frac{1}{mn}\sum_{(s,t)\in \mathrm{Sxy}} g(\mathrm{s,t}) \tag{3}$$

where *f* is the restored image and *g* is the corrupted image.

3.2. *Median filter*

The median filter is also the simpler technique and it removes the speckle noise from an image and also removes pulse or spike noise [14-16]. The Median Filter is performed by taking the magnitude of all of the vectors within a mask and sorting the magnitudes. The pixel with the median magnitude is then used to replace the pixel studied. The Operation of median filter can be expressed as:

$$f(x,y) = \text{median}_{(s,t)\in \mathbf{Sxy}}\{g(s,t)\} \quad (4)$$

where S_{xy} represents the set of coordinates in a rectangular sub image window, centered at point (x,y), and median represents the median value of the window.

3.3. *Midpoint filter*

In the midpoint filter, value of each pixel is replaced with the average of highest pixel and the lowest pixel (with respect to intensity) values in a surrounding region. The operation of this filter can be expressed as:

$$f(x,y) = \frac{1}{2}[\, \max_{(s,t)\in \mathbf{Sxy}}\{g(s,t)\} + \min_{(s,t)\in \mathbf{Sxy}}\{g(s,t)\}\,] \quad (5)$$

where S_{xy} represents the set of coordinates in a rectangular sub image window, centered at point (x,y), also max and min represents the maximum and minimum value of the window respectively.

4. Proposed Method

We propose a procedure that combines both median filtering and mean filtering to determine more accurate value of each pixels of noisy image. Our proposed method is one of the order statistics filters that give more accurate output than other existing order statistics filter. We observed that the median value finding from existing median filtering not always fit with the actual value of original image. This value always middle value of ranking result of all the pixel of each odd sized rectangular sub image window of the noisy image. But except pure impulse noise, median filter cannot always determine the required value because median filter always considers the median value of the window. For various random noises, that are not so lighted or so dark, the existing median filter cannot successfully provide accurate output. So we propose such a way that makes scope to determine the required value by applying the median value to each pixel of the window, than calculate the required output. Our proposed method is described in the next sections.

4.1. *Calculation of the median value*

At first, we consider any odd sized rectangular sub image window or mask (for example 3x3) to easily determine the median value of the window; therefore, it is convenient to use odd list sizes when looking for a median. The Median Filter is performed by taking the magnitude of all of the vectors within a mask and sorting the magnitudes. The pixel with the median magnitude is then used to replace the pixel studied. This median value will be found like as existing median filtering.

$$\text{Median} = \text{median}_{(s,t)\in \mathbf{Sxy}}\{g(s,t)\}$$

where S_{xy} represents the set of coordinates in a rectangular sub image window, centered at point (x,y), and median represents the median value of the window.

4.2. *Calculation of the average value*

Now, the average value between each pixel of the sub image window Sxy and the median value is calculated as in section 4.1**.** It should be done to determine more accurate values of pixels. It also gives the most utilization of neighborhood pixels. Then we get a window in which each pixels value contains more accurate information. This is performed by following way.

$$\text{Average value}_i = \text{average}_{(s,t)\in \mathbf{Sxy}}\ \{g_{\mathrm{i}}(s,t)\ ,\ \text{Median}\}$$

where, S_{xy} is the sub image window and $g(s,t)$ is the each pixel of the sub image window. For example, if we consider the size of sub window is 3x3, we get total 9 average value.

4.3. *Calculationof the center pixel's value*

Now we simply apply arithmetic mean filtering on all ***Average Value*** of the sub image window to calculate more accurate value to replace each pixel of noisy image.

$$\text{Center pixel value} = \frac{\sum_{i=1}^{N} \text{Average value}_i}{N}$$

Here N is multiplication result of number ROW and COLOUMN of sub image window (N = ROW x COLUMN).

5. Statistical Parameters used for Analyzing the De-noised Image

Different kinds of statistical measurement can be used to analysis the performance of the output image. The root mean square error (RMSE), signal-to-noise ratio (SNR), and peak signal-to-noise ratio (PSNR) are used to evaluate the enhancement performance.

Signal-to-noise ratio (SNR) is a measure to quantify how much a signal has been corrupted by noise. The root mean square error (RMSE) is used to find the total amount of difference between two images. It indicates the root of average difference of the pixels throughout the image. The peak signal to noise ratio (PSNR) is the ratio between the maximum possible power of a signal and the power of corrupted noise that affects the fidelity of its representation. A higher PSNR would normally indicate that the reconstruction is of higher quality.

6. Experimental Results and Performance Analysis

The proposed method is very promising algorithm for removing noise from MR image and ultrasound image. To test our proposed method we took a magnetic resonance imaging (MRI) image of human brain. The human brain MRI image suffers from rician noise. The size of image is 256×256 and 16-bit signed integer. Fig. 1 shows the noisy MRI image. Result from the experiment using the proposed noise removal method is presented in Fig. 2. Background part is excluded when our proposed noise removal method is applied in MRI image. Fig. 2 shows that the rician noise is removed significantly.

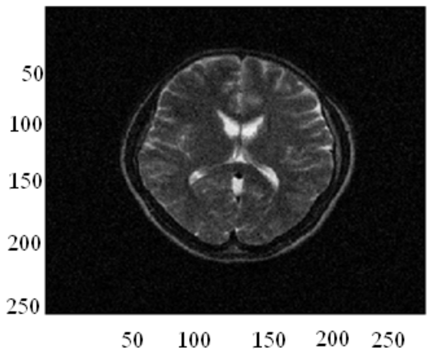

Fig. 1. Original noisy MRI image of human brain.

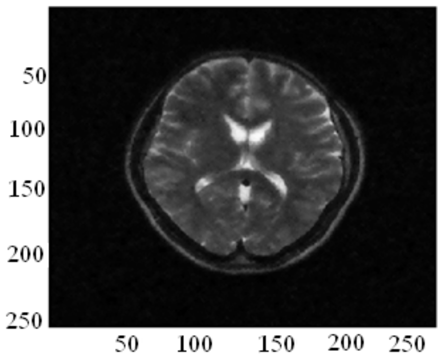

Fig. 2. MRI image after removing noise using proposed method.

We also compare our experimental result with the result using normal smoothing or mean filter, midpoint filter and median filter. Fig. 3 demonstrates the comparison of proposed method with the normal mean filter. From Fig. 3, we can observe that when we use normal averaging the output image looks blurring. The output image after using the proposed method looks sharper.

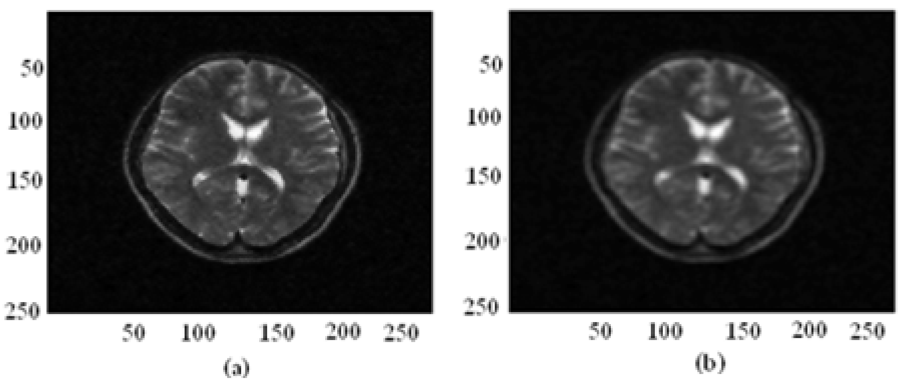

Fig. 3. (a) MRI image after removing noise using proposed method. (b) MRI image after removing noise using normal mean filter.

To test our proposed method we also used ultrasound image of human kidney. The size of the ultrasound kidney image is 246x216 an 8-bit signed integer. The ultrasound image shown in Fig. 4(a) suffers from speckle noise. Fig. 4(b) is the output image after removing noise using proposed method.

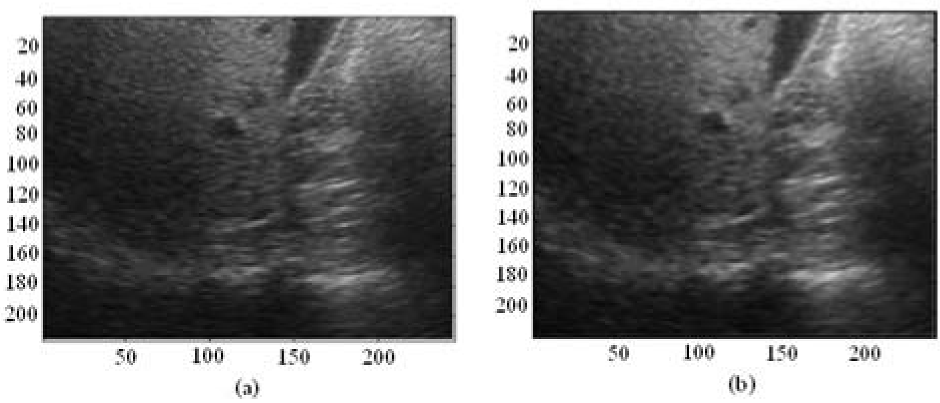

Fig 4. (a) Noisy ultrasound image of human kidney. (b) Ultrasound kidney image after removing noise using proposed method.

To determine the accuracy of an image after applying noise removal algorithm, there are two way exist. First, we can observe the image for out looking. This is subjective. But this process not always provides good result because it may vary from one user to another. Second process tends to be based on mathematical or probabilistic model. To determine the performance of the output image RMSE, SNR, and PSNR are used. If the value of RMSE is low and the values of SNR and PSNR are large the enhancement approach is better. The comparison results of mean, median and midpoint filters with our proposed method are summarized in Table 1.

Table 1. Comparison results of different filtering method with the proposed filtering method.

Image name	Filtering method	SNR (dB)	PSNR (dB)	RMSE
MR brain image	Smoothing filter	3.81	43.43	441.58
	Median filter	3.71	43.64	431.33
	Midpoint filter	3.60	42.08	515.75
	Proposed filtering method	3.80	43.68	429.00
Human kidney image	Smoothing filter	5.58	19.67	26.48
	Median filter	5.26	19.79	26.12
	Midpoint filter	4.06	19.26	27.78
	Proposed filtering method	5.53	19.94	25.66

From Table 1 it is clear that our proposed method shows the better result than median filter and midpoint filter. Here smoothing or mean filter provides best result in terms of SNR. But the main drawback of smoothing filter is that it tends to blur the image. In Fig. 3, we can see that the output image looks blurring when we use smoothing filter. The output image after using the proposed method looks sharper.

7. Discussions and Conclusion

In this paper, we present a simple and efficient technique to remove noise from the medical images which combines both median filtering and mean filtering to determine the pixel value in the noise less image. Experimental results show that our proposed method performs much better than the other filtering methods. The proposed method has been compared with smoothing, median, and midpoint filter using quantitative parameters like PSNR, SNR and RMSE. It has been found that the proposed method performs better than all other methods while still retaining the structural details. Although smoothing filter shows better result, it suffers from blurring effect. Because in the mean filtering techniques each pixel is considered for calculating the mean and also every pixel is replaced by that calculated mean. So affected pixels are considered for calculating the mean and unaffected pixels are also replaced by this calculated mean.

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