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Performance Measurement of Filters on MRI Brain Images

Syed Zenith Rhyhan[1] , Pronab Kumar Mondal[2], Kazi Mahmudul Hasan[3]
[1](*Dept. of Computer Science and Engineering/ Jatiya Kabi Kazi Nazrul Islam University, Bangladessh)*
[2](*Dept. of Computer Science and Engineering/ Jatiya Kabi Kazi Nazrul Islam University, Bangladessh)*
[3](*Dept. of Computer Science and Engineering/ Jatiya Kabi Kazi Nazrul Islam University, Bangladessh)*
Corresponding Author: Syed Zenith Rhyhan

Abstract: *Noise reduction is the process of removing noise from an image. Removal of noise is the most important task for preprocessing on biomedical MRI brain images. Filtering is a tool for noise removing. In this paper we compare the performance of four filters- Median Filter, Averaging/Mean Filter, Gaussian Filter, Wiener filter. This paper presents which filter is best for removing noise like Gaussian, Salt & Pepper, Poisson, and Speckle noise from stoned kidney image. Which filter is best, is measured by calculating the MSE and PSNR of filtered image.*

Keywords: *MRI (Magnetic Resonance Imaging), Brain Tumor, Filters (Mean, Median, Wiener, Gaussian), Preprocessing, MSE, PSNR.*

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I. Introduction

Digital image processing is one of the most emerging and challenging subject of research now a days. In biomedical image processing, de-noising of images is the most important task for preprocessing operations.[1]Digital image processing is useful for CT scan, MRI, and Ultrasound type of biomedical images.[2]Magnetic resonance imaging (MRI) is an imaging technique based on the physical phenomenon of Nuclear Magnetic Resonance (NMR).[3] It is used in medical science to produce images of the inside of the human body. The Information conveyed by digital images sometimes get corrupted by impulse noise during image acquisition.**Error! Reference source not found.** So, at first the input image should be de-noised by using several filters for removing the unwanted noise from the corrupted image. However, in this paper first image is taken and some noise is added to image to make it as noisy image and then noisy image is decomposed by filters. The principle approach of image de-noising is filtering. Filters used to remove noise are averaging/mean filters, median filters, wiener filter, Gaussian Filter and Adaptive Wiener filter.

The algorithm of the proposed work is given below:

i. Acquisition of MRI brain tumor image.
ii. Adding different type of noises to the input brain image.
iii. Applying different type of filters to noised brain image.
iv. Calculate MSE (Mean Squared Error) PSNR (peak signal-to-noise ratio) for each type of filtering image.
v. Decide which filter is gives the best performance for removing noise from brain image according to lowest MSE and highest PSNR.

II. Mathematical Representations of Various Filtering Techniques

Median Filter:

In image processing statistics, filter is also known as median filter [4] and it is the simplest technique which is used to remove speckle noise, pulse noise or spike noise from the image. Median filter is specially used to smoothing filter which gives better result by noise removal. In this process pixel value of image is replaced by the median of the gray levels of the neighborhood of that pixel [5]:

$$\hat{f}(x,y) = \underset{(s,t)\in Sxy}{\text{median}}\{g(s,t)\} \qquad (1)$$

Mean Filter:

Mean filter is usually used to suppressing the small details in an image and also bridge the small gaps exist in the lines or curves [7].The arithmetic mean filtering process computes the average value of the corrupted image g (x, y) in the area defined by S_{xy}. The value of the restored image $\hat{f}$(x,y) at any point (x, y) is simply the

Arithmetic mean which is computed using the pixels in the region defined by S_{xy}. The mean filter is defined as the following [5].

$$\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t) \in Sxy} \{g(s,t)\} \qquad (2)$$

This operation can be implemented using a spatial filter of size mxn in which all coefficients have value 1/mn. A mean filter smooth local variations in an image, and image is reduced as a result of blurring **Error! Reference source not found.**.

C. **Wiener Filter:**

Wiener filter is a linear filter. The mathematical function for wiener filter is defined by:

$$f(u,v)=\left[\frac{H(u,v)*}{H(u+v)^2+\left[\frac{sn(u,v)}{sf(u,v)}\right]}\right]G(u,v) \qquad (3)$$

where H(u,v)is the degradation function & H(u,v)* is its conjugate complex and G(u,v) is the degraded image. Functions Sf (u, v) and Sn (u, v) are power spectra of the original image and the noise [7].

Gaussian Filter:

Gaussian filter is a well-known filter for blurring and suppressing the noise.[8]Gaussian filtering g is used to blur images and remove noise and detail. In one dimension, the Gaussian function is: s

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-:} \qquad (4)$$

Where σ is the standard deviation of the distribution. The distribution is assumed to have a mean of 0.

III. Types of Noise

Image noise is random variation of brightness or color information in images, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera. Image noise is an undesirable by-product of image capture that obscures the desired information. Here, we discuss about the common types noise of an image:

Gaussian Noise:

Gaussian noise is statistical noise having 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 [9]:

$$P_G(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}} \qquad (5)$$

Where z represents the gray level, μ the mean value and σ the standard deviation.

Salt and Pepper Noise*:*

Salt and pepper noise is a form of noise sometimes seen as images. It is also known as impulse noise. This noise can be caused by sharp and sudden distribution in the image signal.

The probability density function (PDF) P of a bipolar impulse noise (salt and pepper noise) is given by [6]:

$$_{P}I(g) = \begin{cases} P_a g = a \\ P_b g = b \\ 0, otherwise \end{cases} \qquad (6)$$

Poisson Noise:

Poisson noise is a type of electronic noise which can be modeled by a Poisson process. In electronics, shot noise originates from the discrete nature of electronic change. It is a kind of electronic noise which arises along the paucity of Photons.

Speckle Noise:

Speckle noise is the noise that arises due to the effect of environmental conditions on the imaging sensor during image acquisition. Speckle noise is being mostly detected in case of medical images, active Radar images and Synthetic Aperture Radar (SAR) images. This noise can be modeled by random value multiplications with pixel values of the image and can be expressed as

J = I + n * I (2) (7)

Where, J refers to speckle noise distribution image, I is the input image and n is the uniform noise image having mean 0 and variance v [11].

IV. Performance measurement parameters

The performance measure is the most important task by evaluating the several filters operations for preprocessing. The most commonly used performance measurements of parameters such as Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) between the original image and de-noised image.

Mean Square Error (MSE):

MSE of an estimator (of a procedure for estimating an unobserved quantity) measures the average of the squares of the errors. It is the squared difference between the original and de-noised image defined by:

$$\text{MSE}=\frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2$$

Where, I(I,j) is the original image K(I,j) is the de-noised image. MSE should be as lowest as possible.

Peak Signal to Noise Ratio (PSNR):

PSNR is used to measure the quality of reconstruction of lossy and lossless compression (e.g., for image compression). Although a higher PSNR generally indicates that the reconstruction is of higher quality, in some cases it may not. It is defined most easily via the MSE [12]:

$$\text{PSNR}=10\log_{10}\left(\frac{MAXi^2}{MSE}\right)$$

Where MAX_i is the maximum pixel value of the image.

V. Simulation & Results Analysis

In this research work, the following figures represents how the brain tumor images after simulating the Salt & Pepper, Gaussian, Speckle and Poisson Noise and de-noising the results by using Median filter, Mean filter, Gaussian filter and Wiener filter. The simulation is done by MATLAB R2017a.

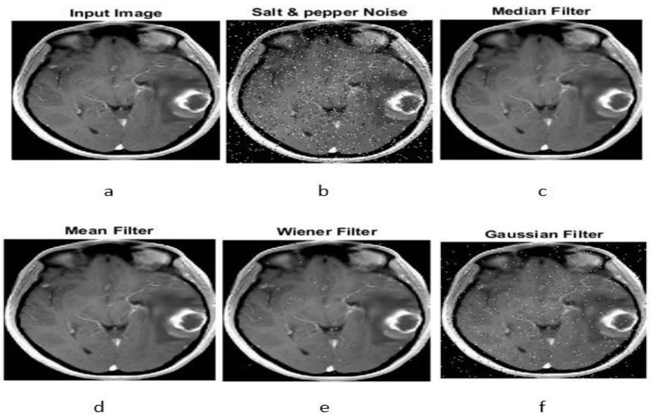

Fig.1. a) Input image b) Adding Salt and Pepper noise and de-noising by c) Median Filter d) Mean Filter e) Wiener Filter f) Gaussian Filter

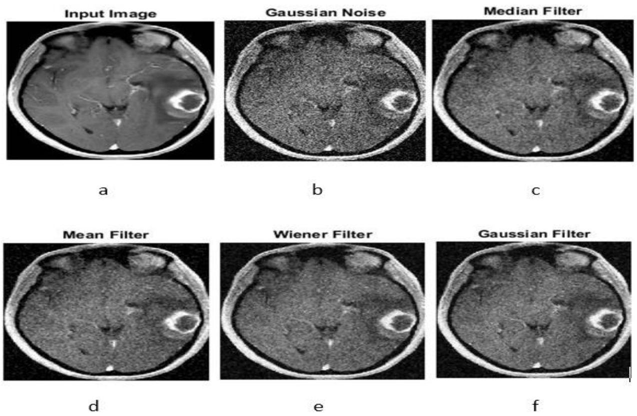

Fig.2. a) Input image b) Adding Gaussian noise and de-noising by c) Median Filter d) Mean Filter e) Wiener

Filter f) Gaussian Filter

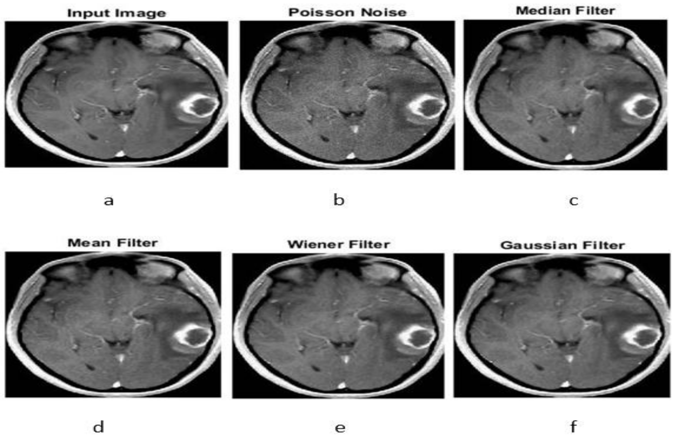

Fig.3. a) Input image b) Adding Poisson noise and de-noising by c) Median Filter d) Mean Filter e) Wiener Filter f) Gaussian Filter

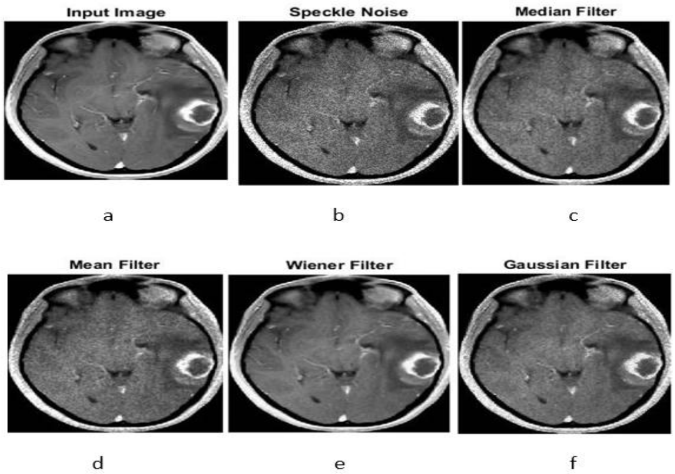

Fig.4. a) Input image b) Adding Speckle noise and de-noising by c) Median Filter d) Mean Filter e) Wiener Filter f) Gaussian Filter

By comparing the results of filtered images to identify the most effective filter for removing noises has been evaluated by calculating the peak signal-to-noise ratio (PSNR) and mean square error (MSE) which is the well-known process to compare with the original and de-noised image.[13] Most of the cases, the lowest MSE with the highest PSNR denotes a high quality enhanced image and less noisy image. The following table shows how the PSNR and MSE values vary for de-noised images by using several filters to compare their performance and to choose the best effective filter.

Table 1: Performance Measured by Filtering for Salt and Pepper Noise

Sl. No	Filtering Method	MSE	PSNR
1	Median filter	7.18	39.60
2	Mean filter	7.46	38.44
3	Wiener filter	7.44	39.45
4	Gaussian filter	8.76	38.26

After analyzing table 1, the most effective filter for removing Salt and Pepper noise is Median filter. Since, Median filter has lowest MSE and highest PSNR value which provides the best performance.

Table 2: Performance Measured by Filtering for Gaussian Noise

Sl. No	Filtering Method	MSE	PSNR
1	Median filter	57.95	28.69
2	Mean filter	55.87	30.26
3	Wiener filter	53.54	31.88
4	Gaussian filter	54.53	30.80

After analyzing table 2, the most effective filters for removing Gaussian noise is Wiener filter. Since, Wiener filter has lowest MSE and highest PSNR value which provides the best performance.

Table 3: Performance Measured by Filtering for Poisson Noise

Sl. No	Filtering Method	MSE	PSNR
1	Median filter	17.43	35.75
2	Mean filter	17.35	35.77
3	Wiener filter	14.44	39.57
4	Gaussian filter	14.47	36.56

After analyzing table 3, the most effective filters for removing Poisson noise is Wiener filter. Since, Wiener filter has lowest MSE and highest PSNR value which provides the best performance.

Table 4: Performance Measured by Filtering for Speckle Noise

Sl. No	Filtering Method	MSE	PSNR
1	Median filter	44	31.73
2	Mean filter	43.77	31.75
3	Wiener filter	32.16	33.09
4	Gaussian filter	33.06	33.06

After analyzing table 4, the most effective filter for removing Speckle noise is Wiener filter. Since, Wiener filter has lowest MSE and highest PSNR value providing the best performance.Finally comparing the four types of filtering techniques for de-noising we have summarized the best effective one for our research work.

Table 5: The best filter for removing noise for Preprocessing

Filtering Method / Noises	Median Filter	Mean Filter	Wiener Filter	Gaussian Filter
Salt & Pepper Noise	Works best			
Gaussian Noise			Works best	
Poisson Noise			Works best	
Speckle Noise			Works best	

So, from the above table we can decide that in most of the cases for de-noising MRI images wiener filter is the best effective one.

VI. Conclusion and future work

In this paper, we have discussed four types of filtering method for de-noising four types of noises (Salt & Pepper, Gaussian, Poisson and Speckle) which are being added to the brain MRI image. The main purpose of this task is performing the comparison by calculating the MSE and PSNR value to choose the best effective filters for noise removal. The table-5 shows that in most of the cases wiener filter provide the best results for de-noising of brain image.

Since the purpose of this paper is to give idea to the researchers for selecting the best effective filtering techniques in the preprocessing of their brain MRI images to provide a desired result. In future work we would like to perform further operations of tumor detection and classification and evaluate the efficiency and accuracy of our proposed method with other existing methods.

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