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De-Noising Techniques for Bio-Medical Images

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Abstract: Now a day's, theImage Processing used for diagnosing various diseasesin medical field. A biomedical image is used to capture the image both for diagnostic and sanative purpose. Different techniques are introduced for capturing biomedical images like Computed Tomography (CT) scans, ultrasound, Magnetic Resonance Imaging (MRI), endoscopy etc., the introduction of noise in medical images which are produced by different parts like the sensors, cameras or the scanners. Due to the presence of noise image is visualized as blotchy, grainy, textured or snowy appearance, which leads to deviations in procedure of treatment and hence it should be removed or minimized. Different noises obtained in biomedical images are Gaussian noise, salt and pepper noise, poison noise and speckle noise. De-noisinghelp the physicians to diagnose various diseases. Mainly two approaches are required for de-noising of biomedical images: one is Filter based and secondly Wavelet based. Filter based techniques are conventional like averaging filter, a median filter, wiener filter, adaptive filter, etc., which are used to reduce the noises for biomedical images. Wavelet-based technique is one of the advanced techniques used in de-noising of biomedical images. This paper deals with reducing various noises for biomedical images using various filters, its performance and concludes which filter give better performances for these respective noises.
Keywords: Computed Tomography, filtering, Magnetic Resonance Imaging, noise, PSNR.

I. INTRODUCTION

Medical Imaging became an integral part of diagnosing various diseases in the present medical field. Since the last few decades, many technologies have been implemented to capture the images of anatomical Structure within the body. X-rays, CT, Endoscope, MRI and Ultrasound are popular medical imaging techniques to diagnose various diseases. These image modalities are suffering from a problem called noise. Noise is the undesirable effect produced in medical images where pixel values change from their true values. During Image Acquisition or transmission several factors are responsible forintroduction of noise in medical images such as, Gaussian noise, speckle noise, salt and pepper noise, Poison noise and Rican noise. The noise present in images will degrade the contrast of an image, which creates a problem in diagnoses. So de-noising is very useful to remove noise in medical images. Image de-noising plays a vital role in an Image processing which is used for removal of noise completely as far as possible and also to preserve the edges in an image. Magnetic Resonance Imaging (MRI) is one of the image techniques which provides a high detailed image of tissues and organs in the human body. The MRI has limited acquisition time, due to this the MR images have a low signal to a noise ratio (SNR). The quality of MR images is degraded by noise interference, which in further modelled as the Rican noise. MR de-noising is used to provide images with good spatial resolution and high SNR. CT scan basically uses X-ray to know the anatomical structure within the body. The technical parameter in a CT scan is considered as radiation dose. The quality of an image depends on this radiation dose, but more usage of this leads to destroy of cells in the body.

Many researchers have attempted to work on de-noising in different technologies. The attempt on comparative analyses of various methods to de-noise CT scan images such as Poisson noise has been made by Tripti Malhotra et al., [1] in their work, comparative analyses on different de-noising technologies are being considered, which helps in assessment of image quality and fidelity. Switched based clustering algorithm has also been used by IzaSazanita Isa et al., [2] in their work, the images which are corrupted by Salt and pepper noise are minimized by using this algorithm. This algorithm, has the ability to minimize the effect of noise without affecting the original image when compared with conventional clustering algorithm. Various approaches and related de-noising are being proposed by Vanitha et al., [3] in this spectral subtraction takes place which doesn't change the statistical characteristics of the signal and with their correlated noises. In this de-noising techniques does not alter the statistics of an image and also its resolutions. Wavelet domain de-noising has been used by Parul Arora et al., [4] where Rican noise is minimized from MR images. This method chooses the threshold parameter which turns the efficiency of de-noising. WB-Filter is used for de-noising which is explained by M. Suganthi et al., [5] it focuses mainly on removal of speckle noise and Gaussian noise in CT scan. In this, the quality of the image is measured by PSNR, RMSE and MSE. Different MRI techniques for de-noising has been explained by V. V. Hanchate et al., [6] in this de-noising is performed where we get accurate diagnosis of diseases. The techniques used in this are compared based on metric performance, such as PSNR, SNR and MSE in order to find a better technique for de-noising in order to get better performance of an image. Different MRI imaging techniques are explained by Pallavi et al., [7] and then comparison of various filters for noise removal in MRI images are explained by J. Venugopala Krishnan et al., [8]. De-noisy techniques for medical images are explained by Rajini and KanikaGupata at et al., [9] and [10].

II. BACKGROUND

In the medical imaging, noise is introduced due to random variations in image intensity, such as brightness or color intensity of an image. Due to the presence of, an image is visualized as blotchy, grainy, textured or snowy appearance, which leads to deviation in the process of treatment and hence it should be removed or minimized. The different noises that can be present in biomedical images are Gaussian noise, Salt and pepper noise, Poison noise and Speckle noise.

2.1 Gaussian noise

The principal source of Gaussian noise in digital images arises due to accession. It may be due to changes in temperature or transmission. Due to this noise, even after smoothening of an image undesirable output takes place with blurring of fine scaled image edges and also blocking of high frequencies. A Gaussian noise is also a statistical noise where it's probability density function equal to its normal distribution. This type of distribution is also known as a Gaussiandistribution. It is independent both at signal intensity and each pixel. Gaussian random variable represented by 'Z'. It is given by:

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

Where 'z' and 'μ' are represents gray level and mean value respectively.

$\sigma$is the standard deviation.

2.2 Salt and pepper noise

The salt and pepper noise is also known as spike noise. This noise presents itself as exiguous occurring of white and black pixels. In this noise the frequency is high, so for salt noise, the value is high and for pepper noise, the value is low. This noise is generated during the errors in data transmission or during Analog-to-Digital conversion. Each of pixel values are replaced by corrupted pixels either with minimum and maximum pixel values of an image. This minimum and maximum pixel depends on the bits we use in an image.

2.3 Speckle noise

This speckle or granular noise occurs while interference of the returning wave at the transducer aperture. The quality of active radar and synthetic aperture radar (SAR) images is reduced because of granular noise. The origin of this can be seen by modelling the reflective function as an array of scatters due to the finite resolution of the cell. Scattered signals can be added constructively and destructively, which depends on the related phase for each scattered waveform. Constructive interference and destructive interference can be represented as dark and bright dots in an image.

2.4 Shot noise (Poisson noise)

Poisson noise is called as photon shot noise. It originates from the discrete nature of electronic noise. It is a typical electronic noise occurs during a finite numberof bits which conveyelectrons in the electronic circuit and convey photons in anoptical device which is small enoughfor the move up of fluctuations in a measurement. Shot noise has a root mean square value to the square root of the image intensity and the noise present in different pixels are independent of one another. Shot noise follows a Poisson distribution, except at very low intensity levels, which approximates a Gaussian distribution. This noise is dominant when a finite number of particles that carry energy which has uncertainties due to Poisson distribution, which describes the occurrence of independent random events.

2.5 Filter

It is a technique used for modifying an image, where we can emphasize certain features of an image, or we can remove the other features in an image. The techniques used in filtering an image can be noted as linear and nonlinear. Linear filtering is a process of varying the time of input signals in order to produce output signals. In nonlinear filtering the output signal is not linear to the input signal.

2.6 Mean filter

This comes under linear filtering which removes certain types of noise. In this, each pixel of the imageuses a mask. The mask is used for averaged the pixels to form a single pixel. This filter is also called as averaging filter and it has poor edge preserving. The purpose of mean filtering in an image, the every pixel value is improvedby the mean value of its adjacent, as well as itself. It has the effect of reducing the pixel values which are unrepresentative of their surroundings. This filter either uses convolution or correlation to smooth an edge and also to interpolate the result. Both the operations are similar in linear filtering, but the approach is slightly differed. Convolution is establishednearby a Kernel, which denotes the size and shape of the neighborhood to be tested when the mean is calculated. If suppose 3 x 3 square kernel matrix is used, the region is selected according to the matrix function array and then convolution or the correlation is performed.

The output from this process will be placed at the center of the window region of the input matrix, and then the window will slide to the next corresponding pixel. By using this process, there occurs a problem where, the center of the window cannot be placed on the corner regions of the input array matrix. It has some points between functions which cannot be overlapped. Before the selection of the Kernel, the above problem can be resolved by padding an image matrix with zeros. The output obtained from this process depends on neighboring pixels. If input pixels are unrepresentative of those surroundings will be eliminated and standard deviation of the output matrix will also be reduced.

2.7 Gaussian filter

This technique is carried out in the frequency domain via Fourier transform. This filter design can be controlled by manipulating a single variable and also the variance. The Gaussian filter function is defined as:

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{\frac{x^2+y^2}{2\sigma^2}} \quad (2) \qquad \text{Where } \sigma \text{ is variance}$$

G (x, y) is anoutput pixel at position (x, y)

The sigma value and the variance correspond inversely to the amount of filtering. The smaller frequency values of are suppressed, i.e. it performs low pass filtering action when the variance of Gaussian function is high and then high pass filtering action is performed when variance is very low. Here Fourier transforms offers flexibility in design and implementation of filtering solution in areas of image restoration.

2.8 Wiener filter

The goal of Wiener filter is to filter out corrupted noise in the signal. This filter is also called as adaptive filter. The blur in an image due to linear motion results of poor sampling. By using linear random process spectral characteristics of the signal and the noise should be stationary. The filter must be physically realizable and the performance criteria of MSE maintained a minimum. It employs a pixel by pixel adaptive Wiener method depends on statistics estimated from a neighborhood which deals with every pixel presents in it. In these, the two dimensional analogy can be defined as:

$$G(u,v)=F(u,v).H(u, v) \quad (3)$$

Where, F is the Fourier transform

In this H is the blurring function and also the sine function of the pixels in a line which contain information from the same point of an image. Wiener filter is the best known approach of linear image restoration. The Wiener filter search for an approximation$f^{|}$ that degradesthe statistical error function as:

$$e^2 = E((f - f^{|})^2) \quad (4)$$

Where E is the estimated value operator and f is the undegraded image. The result of this in frequency domain can be given as:

$$F(u, v) = \frac{|H(u,v)|^2}{H(u,v)|H(u,v)|^2 + \left(\frac{S_n(u,v)}{S_f(u,v)}\right)} G(u, v) \quad (5)$$

Where

H (u, v) is the degraded function

$|H(u,v)|^2$is H* (u,v)H(u,v)

H* (u, v) is complex conjugate

$S_n(u,v) = |N(u,v)|^2$is the power spectrum of the noise

$S_f(u,v) = |F(u,v)|^2$is the power spectrum of undegraded image

2.9 Median filter

It is one of the nonlinear digital filter techniques often used to remove the noise in images. It is a robust filter which is widely used as smoothers for image processing, signal processing and time series processing. The Median filter eliminates the effect of input noise values with extreme large magnitudes while preserving edges. Theobject of the Median filter in an image, all pixels are scanned, and change each value with the median value of adjacent pixels. The median is calculated by sliding window in numerical order on each pixel of an image. If a window has an odd number of entries, then the median is simply defined as just its middle value. For an even number of entries, there is more than one possible median. At moment 't',the median filter output 'y' is calculated for different input moments 't'.

y(t) = median((x(t - T/2),x(t - T1+1), ... , x (t), ... , x (t + T/2))(6)

Where 't' is the size of the window in Median filter.

III. PROPOSED METHOD

Digital images are prone to various noises. The result of noise shows the error in the process of image acquisition. Different filter techniques are considered for removal of the noise in an image. For Gaussian noise and Shot noise if we apply the above filters, then Wiener filter shows better performance compared to mean filter and Median filter. In this Wiener filter, if the variance is large then Wiener performs little smoothening and if the variance is small, then the Wiener performs more smoothening. It preserves edges and high frequency parts of an image.

For salt and pepper noise the Median filter shows better performance when compared to above filters. Noise can be removed significantly by reducing the sharpness of an image. For removal of Speckle noise we perform adaptive and non-adaptive filtering on the pixels. This filtering also eliminates actual information of an image such as high frequency information, tradeoff. Adaptive speckle filtering is better at preserving edges and detail in high texture areas. Non-adaptive filtering is simpler to implement and requires less computing power.

We also perform PSNR for these filters after removal of noises in an image. PSNR describes the ratio between maximum possible signal power andcorrupting noise power that affects the quality and reliability of its representation. The PSNR can be can be calculated as:

$$\text{PSNR} = 10\, log_{10} \left(\frac{max_i^2}{MSE}\right) \quad (7)$$

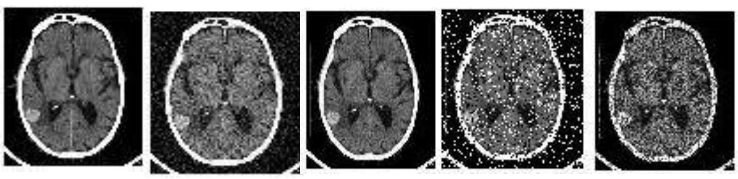
$$= 20\, log_{10} \left(\frac{max_i}{\sqrt{MSE}}\right)$$

$$= 20\, log_{10} (max_i) - 10\, log_{10} (\sqrt{MSE})$$

Here max is the maximum possible pixel value of an image. For RGB images, the image is dividedintoaltered color spaces and calculated the PSNR against to respective channel of the color space.

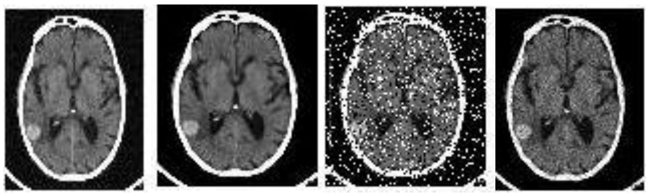
IV. RESULTS

Different techniques such as X-Ray, MRI and CT scans are used in de-noising of images. Each noise is assigned with different filters such as Mean, Median, Gaussian and Wiener. Then we calculate PSNR for each of the noise using the above technologies.

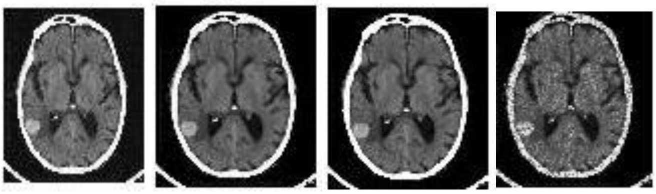


CT scan image Gaussian noise Poisson noise Salt and pepper noise Speckle noise

Median filter



Wiener filter



IM- filter

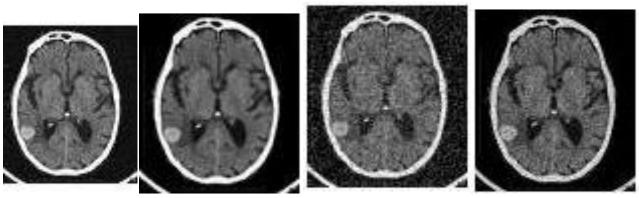
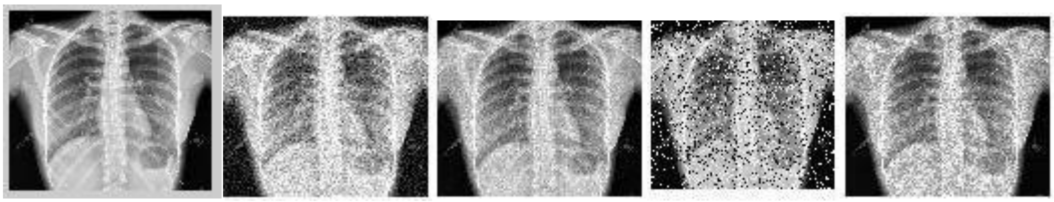


Fig.1 Different noises present in CT scans and usage of different filters to reduce the noise

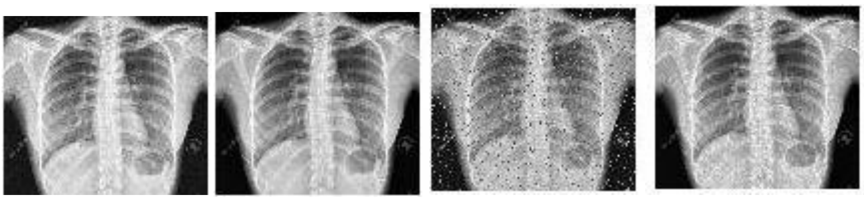


MRI image

Gaussian noise Poisson noise Salt and pepper noise Speckle noise

Median filter

Gaussian filter



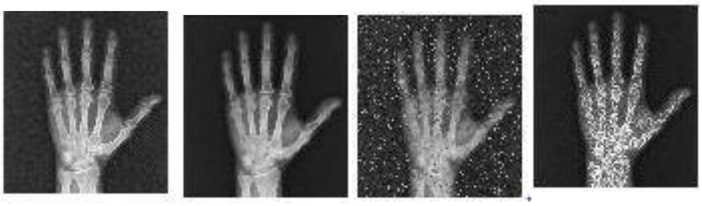
Multidimensional Image filtering

Fig.2 Different noises present in the MRI image and the usage of different filters to reduce the noise

X-Ray scan Gaussian noise Poisson noise Salt and pepper noise Speckle noise

Median filter

Gaussian filter



Multidimensional Image filtering

Fig.3 Different noises present in the X-ray scan and usage of different filters to reduce the noise

Table 4.1. Usage of different filters for Salt and pepper noise

Noise 10%	Mean	Median	Wiener	Gaussian
X-ray	32.6698	34.9759	31.0101	30.5498
MRI	32.4747	34.8929	32.7029	31.6452
CT scans	32.7825	34.1409	33.7171	32.3694

Table 4.2. Usage of different filters for Speckle noise

Noise 10%	Mean	Median	Wiener	Gaussian
X-ray	35.4785	34.8872	34.0607	34.1112
MRI	32.4672	30.2066	30.7209	30.5752
CT scans	31.1041	30.1309	30.6477	29.5714

Table 4.3. Usage of different filters for Gaussian noise

$\mu = 0.01; \sigma = 0.01$	Mean	Median	Wiener	Gaussian
X-ray	32.8887	33.0254	33.2337	32.3413
MRI	33.3379	32.4884	34.8165	32.6412
CT scans	30.9104	31.0052	31.5913	30.0344

Table 4.4. Usage of different filters for Poisson noise

Poisson	Mean	Median	Wiener	Gaussian
X-ray	34.0781	35.0300	35.8501	34.8311
MRI	35.5482	33.3421	35.9031	33.6659
CT scans	32.6653	32.0177	32.8551	31.3217

V. CONCLUSION

Image processing plays an important role in the medical field. At present,different technologies were introduced for diagnosing abnormalities in the field of medical images. By using these technologies, the noise, which degrades the quality of an image. So in order to avoid noises we go for the de-noising process which removes noise in medical images. Here we consider some biomedical images in 'JPG' format and we add some peculiar noises such as Gaussian, Speckle, Salt and pepper and Poisson to these images with a standard deviation of 0.001. MR de-noising is used to provide images with good spatial resolution and high SNR. CT scans basically use X-rays to know the anatomical structure within the body. The technical parameter in CT scans is the radiation dose. The quality of an image depends on this radiation dose, but more usage of this leads to destroy the cells in the body. The performance of Wiener filter is better in the preservation of edges both for Poisson and Gaussian noises when compared with Mean filter and the Median filter. After de-noising Salt and pepper noise the Median filter gives better performance when compared withthe Mean filter, Wiener filter, and Gaussian filter. For Gaussian noise, the Wiener filter gives better performance compared with the Mean filter and the Median filter.

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