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A Comparative Analysis on Various Noise Reduction Techniques Tested for Medical Images

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Abstract: Noise removing in the medical image is still a challenging task in the research field especially for the imaging devices like mammogram and ultra-sound. Even though advance scanning technology has been invented, these conventional devices play a vital role in scanning the mammogram breast cancer and fetus images. During the image acquisition itself, these images will get corrupted by the physical interference which appears as a noise in an image and affects its visual quality. In this paper we have applied the various traditional and conventional mean based noise removal techniques for the impulse noise corrupted mammogram breast image and standard benchmark. From this comparative analysis we have found that alpha-trimmed mean filters gives the better result than the other filters in terms of PSNR, SSIM and visual quality.

Keywords: Impulse noise, Wiener filter, Noise Reduction, Arithmetic mean filter, Medical image.

I. Introduction

Digital images played the vital role in the day to day life of the human. It provides useful information like weather forecasting through satellite cameras, traffic monitoring, medical imaging like X-rays, Medical Resonance Imaging (MRI), Computed Tomography (CT), ultrasound imaging etc., [1]. A traditional crisis in image processing is noise reduction [2]. The noise is characterized by its pattern and by its probabilistic characteristics. There is a wide variety of noise types while we focus on the most important types; they are Poisson noise and salt & pepper noise. A large number of linear and non linear filtering algorithms have been developed to reduce noise from corrupted images to enhance image quality [3]. Noise is present as a result of the electronic circuitry of cameras or in the image transmission period. Salt and Pepper noise is impulse type of noise also called as intensity spikes noise It is generated in the transmission channel. [5]. Due to physical interference also the signal forms the noises such as impulse, Poisson, Gaussian noises (Ramya et. al. 2017) [16].

The main function of filters is to suppress either the high frequencies in the image, that is smoothing the image, or the low frequencies, that is enhancing or detecting edges in the image. A digital filter is a system that performs mathematical operations on a sampled, discrete-time signal to reduce or enhance certain aspects of that signal [4].

Lim et. al. had proposed the super-resolution algorithm that combines Spatially Variant Apodization (SVA) with a modified geometric mean filter to improve the resolution of Synthetic Aperture Radar (SAR) images and reduce side-lobes simultaneously. This method does not required iterative calculation. This method expands the effective bandwidth and improves the resolution while maintaining the side-lobe performance of SVA. The various parameters are flexibly determined based on SNRs [6]. Ibrahim et. al. had described the impulse filter to detect the noise pixel. The detection stage is done with the intensity values, the pixels are roughly divided into two classes, which are "noise-free pixel" and "noise pixel". Then, the second stage is to eliminate the impulse noise from the image. In this stage, only the "noise-pixels" are processed. The "noise-free pixels" are copied directly to the output image. The method adaptively changes the size of the median filter based on the number of the "noise-free pixels" in the neighbourhood. For the filtering, only "noise-free pixels" are considered for the finding of the median value [7].

Nardernejad et. al. had presented the method consists of two stages to filter to de-noise the image, the first stage consists of a second order nonlinear anisotropic diffusion equation with new neighbouring structure and the second is a relaxed geometric mean filter, which processes the output of nonlinear anisotropic diffusion equation. The proposed algorithm enjoys the benefit of both nonlinear PDE and relaxed geometric mean filter. In addition, this algorithm will not introduce any artefacts, and preserves image details, sharp corners, curved structures and thin lines [8]. Yuan et.al proposed the noise detection-based median filters have been widely applied to impulse noise reduction. However, the number of pixels misclassified is obviously increased in high noise density. To overcome such drawback, a difference-type noise detector is proposed. In image filtering, a noise detection-based adaptive median algorithm is presented [9]. Wang Lei et.al proposed the wavelet multi-scale analysis is used to decompose the image signal to different direction sub-image. Through the estimation of the model parameter, combining wavelet's auto-adapted Wiener filter to de-noise its corresponding coefficient of scale and its coefficient of wavelet, the enhanced image is obtained by wavelet reconstructing [10].

Liu et.al had proposed the new nonlocal Polarimetric Synthetic Aperture Radar (PolSAR) filter based on Discriminative Similarity Measure (DSM). The DSM, which is implemented in the form of Maximum a Posteriori (MAP), deals with the speckle and the underlying speckle-free signal of PolSAR data individually. Due to its MAP form, the DSM achieves good balance between the similarity of the speckle and the similarity of the underlying speckle-free signal [11].

Afsham et.al (2015) proposed the new filter-based speckle tracking framework to increase the accuracy of out-of-plane displacement estimation. In this framework, they used the displacement estimation not only for the specific speckle pattern, but for the entire image. They developed a nonlocal means (NLM) filter based on a probabilistic normal variance mixture model of ultrasound, known as Rician-inverse Gaussian (RiIG). To aggregate the local displacement estimations, Stein's Unbiased Risk Estimate (SURE) was used as a quality measure of the estimations. They derived an explicit analytical form of SURE for the RiIG model and use it as a weight factor [12]. Ramya et al. (2017) proposed the modified histogram equalization technique for enhancing the medical images, which works effectively for improving the low contrast [14].

The work presented in this paper is the brief comparative analysis of the traditional de-noising filters such as median, wiener, arithmetic mean, harmonic mean, contra-harmonic mean and alpha-trimmed mean filter. These filters are applied for the medical image such as mammogram image and it is also tested with the standard image for various impulse noise densities from 10 % to 70% to analysis competence of the filters. The performance factors such as PSNR and SSIM is evaluated for each filters.

The paper is organized in the following order: section 2 explains the impulse noise model. In section 3, various filters used for the comparative analysis s briefly explained. Section 4 shows the experimental result and discussion of the results. The conclusion is drawn in section 5.

II. Impulse Noise Model

The noise is characterized by its pattern and probabilistic characteristics. There is a wide variety of noise types. It is the combination of small black (minimum intensity pixel value) and white (maximum intensity pixel value) dots hence it is called as salt and pepper noise. The salt-and-pepper type noise is typically caused by errors in the data transmission malfunctioning pixel elements from camera sensors, faulty memory locations, or timing errors in the digitization process salt & pepper distribution noise can be expressed by.

$$p(z) = \begin{cases} p_a & for\ z = a \\ p_b & for\ z = b \\ 0 & otherwise \end{cases} \tag{1}$$

Where *p1*, *p2* are the Probabilities Density Function (PDF), *p(z)* is distribution salt and pepper noise in image and *A*, *B* are the arrays size image. Gaussian and Salt & Pepper are called impulsive noise [13].

III. Review on Direct Noise Removal Filter

Noise removal in the medical images is an important process in the pre-processing stage of digital image processing. Before processing the medical image to the high level processing such as segmentation, registration, classification and recognization, there should not be any noise in an image. Their exist many different filters for de-noising the medical images each has different processing with the pixels. Here we have studied and analysed few direct noise removal filters, which directly process with an image and correct the corrupted pixels.

A. Median Filter

The median filter is normally used to reduce noise in an image, somewhat like the mean filter. However, it often does a better job than the mean filter of preserving useful detail in the image. Median filter considers each pixel in the image in turn and looks at its nearby neighbours to decide whether or not it is representative of its surroundings. Instead of simply replacing the pixel value with the mean of neighbouring pixel values [18].

$$g(x,y) = \underset{(s,t)\in S_{xy}}{median} \{f(s,t)\} \tag{2}$$

The value of the pixel at *(x,y)* is included in the computation of the median. Median filter are quite popular because, for certain types of random noise, they provide excellent noise-reduction capabilities, with considerably less blurring than linear smoothing filters of similar size.

B. Wiener Filter

Weiner filtering method requires the information about the spectra of noise and original signal and it works well only if the underlying signal is smooth. Weiner method implements the spatial smoothing and its model complexity control corresponds to the choosing the window size. *H(u, v)* is the degradation function and $H(u, v)^*$ is its conjugate complex. $G(u, v)$ is the degraded image. Functions $Sf(u, v)$ and $Sn(u, v)$ are power spectra of original image and the noise. Wiener Filter assumes noise and power spectra of object a priori [15].

$$f(u,v) = \left[\frac{H(u,v)^*}{H(u,v)^2 + \left[\frac{Sn(u,v)}{Sf(u,v)} \right]} \right] G(u,v) \tag{3}$$

C. Arithmetic Mean Filter

An arithmetic mean filter operation on an image removes short tailed noise such as uniform and Gaussian type noise from the image at the cost of blurring the image. The arithmetic mean filter is defined as the average of all pixels within a local region of an image.

It is an averaging filter that has used neighbourhood pixel values around pixel to be de-noised. The arithmetic mean computes the average value of a neighbourhood and places the average value at the centre. The following mathematical equation can be used to represent arithmetic mean filter [17]:

$$\hat{f}(x, y) = \frac{1}{mn} \Sigma_{(s,t) \in S_{xy}} g(s,t) \tag{4}$$

Where (s, t) be a pixel in the moving kernel window. The arithmetic filter smoothes the image but blurring is increased. Pixels that are included in the averaging operation are specified by a mask. The larger the filtering mask becomes the more predominant the blurring becomes and less high spatial frequency detail that remains in the image.

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D. Alpha-Trimmed Mean Filter

Alpha-trimmed mean filters are widely used for the restoration of signals and images corrupted by additive non-Gaussian noise. They are especially preferred if the underlying noise deviates from Gaussian with the impulsive noise components [19].

Alpha-trimmed mean filter is windowed filter of nonlinear class; by its nature is hybrid of the mean and median filters. The basic idea behind filter is for any element of the signal (image) look at its neighbourhood, discard the most atypical elements and calculate mean value using the rest of them.

This function will filter the image by the nonlinear alpha-trimmed mean method. This function works for only monochrome, 8 bit per pixel and 24 bit per pixel images. The alpha-trimmed mean filter is based on order statistics and varies between a median and a mean filter. It is used when an image contains both short and long tailed types of noise (e.g. both Gaussian and salt and pepper noise). The alpha-trimmed mean filter is given by.

$$AT = \frac{1}{N * N - 2P} \sum_{i=P}^{N*N-P} A_i \tag{5}$$

To define the alpha-trimmed mean filter, all pixels surrounding the pixel at the coordinate (x,y) in the image A which are specified by an input $N \times N$ size square mask $A_{(i)}$ are ordered from minimum to maximum value.

E. Harmonic Mean Filter

This function will filter the image by the nonlinear harmonic mean method. This function works for only monochrome, 8 bit per pixel and 24 bit per pixel images. The harmonic mean filter is member of a set of nonlinear mean filters which are better at removing Gaussian type noise and preserving edge features than the arithmetic mean filter. The harmonic mean filter is very good at removing positive outliers. The harmonic filter is formulated by.

$$HM = \frac{N}{\Sigma_{(i,j)eM} \frac{1}{A(x+i, y+j)}} \tag{6}$$

Where the coordinate $(x+i, y+j)$ is defined over the image A and the coordinate $(i\ j)$ is defined over the $N \times N$ size square mask.

The harmonic mean filter is better at removing Gaussian type noise and preserving edge features than the arithmetic mean filter. The harmonic mean filter is very good at removing positive outliers

F. Contra-Harmonic Mean Filter

This function will filter the image by the nonlinear contra-harmonic mean method. This function works for only monochrome, 8 bit per pixel and 24 bit per pixel images. The contra-harmonic mean filter is member of a set of nonlinear mean filters which are better at removing Gaussian type noise and preserving edge features than the arithmetic mean filter. The contra-harmonic filter is very good at removing positive outliers for negative values of P and negative outliers for positive values of P. The contra-harmonic filter is formulated by.

$$CHM = \frac{\Sigma_{(i,j)eM} A(x+i, y+j)^{P+1}}{\Sigma_{(i,j)eM} A(x+i, y+j)^{P}} \tag{7}$$

Where the coordinate $(x+i, y+j)$ is defined over the image A and the coordinate $(i\ j)$ is defined over the $N \times N$ size square mask.

IV. Experimental Result and Discussion

The performance of the noise removal techniques are performed based on Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) and it is tabulated in table 1 and table II. The table represent the PSNR and SSIM evaluation of different traditional filters such as median, wiener, harmonic mean, contra-harmonic mean, arithmetic mean and alpha-trimmed mean filters for mammogram breast image. The table II represent the performance evaluation of above mentioned filters for standard image (pears). This paper focuses mainly to de-noise the mammogram image from impulse noise. The mammogram images taken from the MIAS dataset and tested with the six different filters. Totally 50 images is tested and the mdb025 is shown how the existing the filters work with it. . The visual stimulation result were also presented in figure 1 which represent the mammogram image and fig. 2 represent the standard test image.

Table: I Performance Evaluation of Direct De-noising Filter for Mammogram Image Corrupted with Various Impulse noise Density from 10 % to 70%.

Filters	Evaluation Metrics							
	PSNR				SSIM			
	10%	30%	50%	70%	10%	30%	50%	70%
Median	30.242	27.157	24.854	21.470	0.692	0.578	0.4105	0.358
Weiner	31.563	28.617	25.220	22.254	0.7231	0.685	0.4100	0.315
Harmonic Mean	32.299	29.727	27.244	24.372	0.814	0.654	0.517	0.354
Contra-harmonic Mean	31.257	28.947	25.243	22.478	0.732	0.524	0.524	0.4987
Arithmetic Mean	34.956	30.254	27.758	23.752	0.861	0.787	0.557	0.445
Alpha-Trimmed Mean	35.453	33.367	29.467	26.246	0.914	0.895	0.747	0.698

Table: 2 Performance Evaluation of Direct De-noising Filter for Standard Image (Pears) Corrupted with Various Impulse noise Density from 10 % to 70%.

Filters	Evaluation Metrics							
	PSNR				SSIM			
	10%	30%	50%	70%	10%	30%	50%	70%
Median	31.322	26.842	23.180	22.127	0.615	0.457	0.4014	0.395
Weiner	32.580	28.289	26.245	23.247	0.727	0.614	0.528	0.424
Harmonic Mean	32.749	30.877	27.249	25.257	0.801	0.725	0.629	0.445
Contra-harmonic Mean	31.397	29.750	26.148	23.735	0.846	0.661	0.547	0.434
Arithmetic Mean	35.795	31.421	29.652	25.981	0.914	0.858	0.757	0.562
Alpha-Trimmed Mean	37.418	35.541	30.247	28.359	0.964	0.815	0.7853	0.690

In this section, an attempt made to estimate the performance of the six different traditional noise removal filtering techniques to increase the efficiency of pre-processing stage for medical image diagnosis. Each six techniques have been compared and evaluated their performance using PSNR which measured the differences between original images and the filtered ones and SSIM which shows the structural similarities between the source and enhanced image. Table I show the PSNR and SSIM results of different de-noising techniques for mammogram image (mdb025). The average results were categorized and depicted for performance evaluation and graphically represented in Fig. 3. The best filtering technique must report the highest PSNR value and the alpha-trimmed mean filter obtained best PSNR value compared to other five techniques. Based on the experiment conducted, result shows that arithmetic mean and harmonic mean filters nearly same PSNR result which has average value of 33 db. The median and wiener filters yield a very low PSNR value when the noise density goes maximum. The contra-harmonic mean filter present the moderate PSNR value and serves as intermediate of other mentioned techniques.

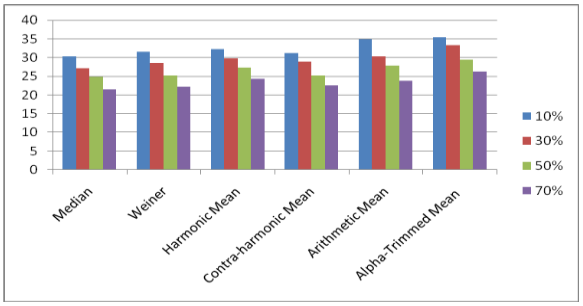


Fig. 1: Performance Analysis of PSNR for De-Noising Filters for Mammogram Image

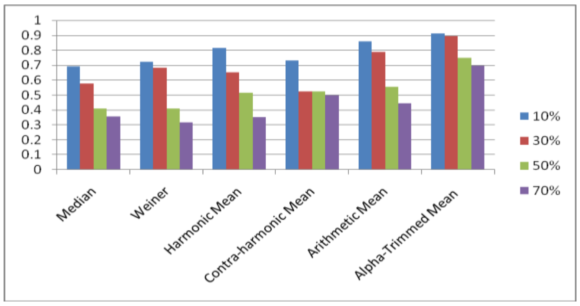


Fig. 2: Performance Analysis of PSNR for De-Noising Filters for Pear Image

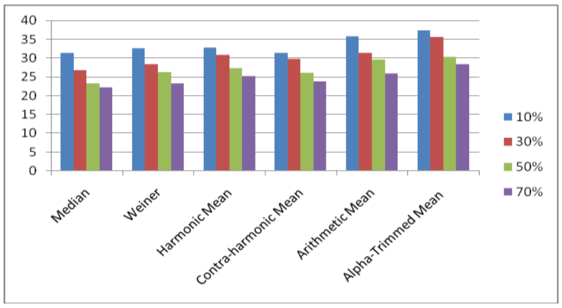


Fig 3: Performance Analysis of SSIM for De-Noising Filters for Mammogram Image

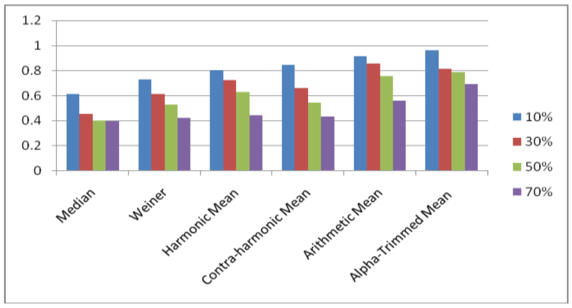
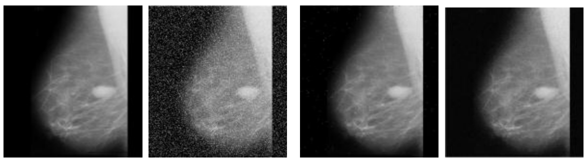
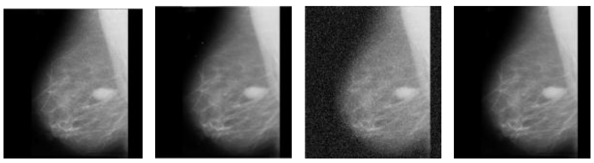


Fig 4: Performance Analysis of SSIM for De-Noising Filters for Pear Image

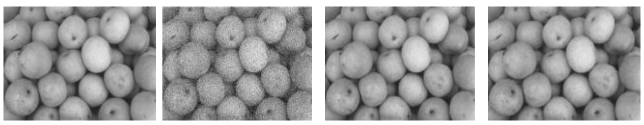


(a) (b) (c) (d)

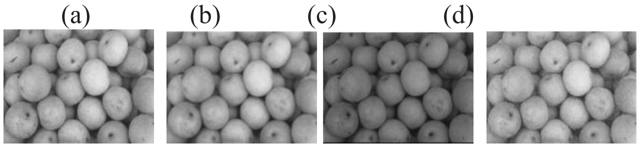


(e) (f) (g) (h)

Fig. 5: Direct De-Noising Filter Applied to the Mammogram Breast Image Corrupted with an Impulse Noise of 60%. (a) Show the Original Image, (b) Show the Noisy Image, (c) Median Filter, (d) Weiner Filter, (e) Harmonic Filter, (f) Contra-Harmonic Filter, (g) Arithmetic Mean Filter, (h) Alpha-Trimmed Mean Filter.



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



(e) (f) (g) (h)

Fig. 6: Direct De-Noising Filter Applied to the Standard Image (Pears) Corrupted with an Impulse Noise of 60%. (a) Show the Original Image, (b) Show the Noisy Image, (c) Median Filter, (d) Weiner Filter, (e) Harmonic Filter, (f) Contra-Harmonic Filter, (g) Arithmetic Mean Filter, (h) Alpha-Trimmed Mean Filter.

From the visual result it is shown the median and wiener filter fails to preserve the edges when the noise probability function goes maximum. The arithmetic mean, harmonic and contra-harmonic filters yields more or less same result but contra-harmonic filter suffers with the blurring effect. The arithmetic mean filters has the low intensity issue and harmonic filter fails to preserves the edges region in the interior portion. The alpha-trimmed median filter has distributed the intensity value evenly over the image and at the maximum noise density it preserves the edge component well. It also yields a good visual result in mammogram images which will be useful for the further processing like detection of cancer and classification accurately.

V. Conclusion

In this paper, we explored some of the traditional de-noising techniques for medical image. Here we analyzed and present a comparative study with the experimental result of various mean based noise removal filters for de-noising the medical image. These noise removal fitters are tested with the medical image and benchmark images and we have found that among six different filters alpha-trimmed mean filters yields a good result in terms of PSNR and SSIM. The alpha-trimmed filters are also gives a promising result in its qualitative visual perception.

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