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A Study on De-Noising Technique to Pre-Process Computed Tomography Image for Image Registration

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Abstract— Image registration is the process of over lapping two or more image of scene taken at different time or from different view point and/or obtained by different sensor. The effectiveness of registration algorithm depends upon the quality of image at the input. Noise can degrade the image at acquisition time or during transmission. So, getting effective noise reduction method is a key challenge before processing them for further analysis and type of noise needed to be removed depends on kind of noise present in the image. In this paper detailed study on de-noising method is used to preprocess the biomedical image. Computed tomography images acquired at different axis are considered. Statistical analysis is done using Peak Signal to Noise Ratio (PSNR), Root mean Square Error (RMSE), and visual interpretation is used to analyze the quality of image after de-noising.

Keywords— Image registration, Median filter, Wiener filter, wavelet filter, Gaussian filter

I. INTRODUCTION

Digital image plays a vital role in the research and technological field such as, geographical information system, astronomy and in the field of medical science [1]. Application of digital imaging based on requirement such as Ultra Sound, Magnetic Resonance Imaging, Computed Tomography and Position Emission Tomography imaging technique are used in medical analysis [2, 3]. Image registration is the process of over lapping two or more image of scene taken at different time or from different view point and/or obtained by different sensor. Image registration is used to monitor long term existing abnormalities and to plan treatment, surgery and extraction of specific body parts from the image acquired [2]. During acquisition process, transmission and compression of the image it gets degraded. Image degradation caused due to noise and blocking artefact which cause blurring and interference of noise in the image [4]. Noise is the interference of unwanted signal that cause corruption in the original image. To restore the degraded image, Image de-noising is a pre-processing step in restoring the image without losing the information. Noise often arises in medical images are like Gaussian noise, Poisson noise, and Salt and Pepper noise. In our discussion we propose a comparative study of efficient noise reduction technique for CT images using spatial and transformation domain.

The spatial and transformation domain de-noising technique is used to improve the quality of the image, but it is a challenging job to retain the required data in the image during De-noising.In this paper, section II gives detail about method and methodology used, section III explains experiment and result, section IV discussion on the conclusion.

II. MATERIAL AND METHODS

A. Computed Tomography

Computed Tomography (CT) is a most commonly used 3D imaging technique and this process used to create images of the human body for clinical diagnosis purpose. The X-rays and computer enhancements procedure is used to produce multiple cross-sectional images of the body in the CT scan Imaging. This technology creates an image many times detailed than a simple X-ray can produce. The images obtained from CT Scans are in the form of gray scale image and this imaging technique usually used to determine tumours and stones [11].

B. Noise model

In digital image processing, image acquisition, transmission, and storage are the common steps followed where noise is found likely to affect in this process. Whereas noise is an unwanted signal that interfere the image and it is tough to remove noise from the image. De- noising technique is usually found to degrade the existing information

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in the image. So understanding noise model of the biomedical images is required to design a De-noising filter. The commonly affected noise in biomedical image is Gaussian noise, Poisson noise, Rayleigh noise, Exponential noise and Impulse noise. In our study we consider Gaussian noise, Poisson noise and Salt & Pepper noise.

Gaussian noise: Gaussian noise is an additive noise which is independent of pixels and of the signal intensity. It is also called as amplifier noise is a result into bell shaped Probability Distribution Function (PDF) [6]. The PDF of Gaussian random noise is given as

$$p(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{(\sigma-\mu)^2}{2\sigma^2}} \quad \text{............ (1)}$$

where x is the intensity value, μ is the mean of intensity value, σ is standard deviation.

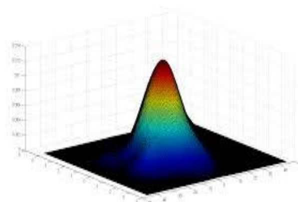


Fig. 1 Gaussian model

Poisson Noise: Poisson noise is also known as short noise that is caused when the number of photon sense by sensor is not sufficient to provide detectable statistical information. This noise has root mean square (RMS) value is directly proportional to square root of intensity of the image [4].

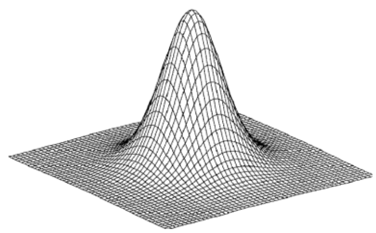


Fig. 2 Poisson noise model

Salt and Pepper noise: Salt and pepper noise is also referred as impulse noise, this noise generally caused due to transmission error or due to faulty memory location. Probability of corruption is less than 0.1. The corrupted pixels are set alternatively to the minimum or to the maximum value, resulting “salt and pepper” like appearance in the image. Unaffected image pixels remain unchanged [7, 8]. The PDF for salt and pepper noise is given by

$$P(Z) = \begin{cases} p_a & for\ Z = a \\ p_b & for\ Z = b \\ 0 & otherwise \end{cases} \quad \text{............... (2)}$$

where, a, b and Z are intensity values. If a < b, ‘a’ corresponds to pepper (dark) and ‘b’ corresponds to salt (bright).

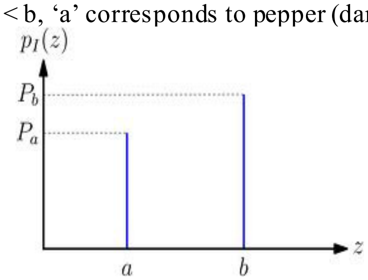


Fig. 3 Salt and Pepper Noise model

C. De-Noising technique

De-nosing is a restoration technique used to improve the quality of image that has been degraded by noise. De-nosing is performed based on prior knowledge of degradation and it has two approaches like, spatial and transformation domain. In Spatial domain method which suppress noise directly in the spatial domain. In Transformation domain, image is transformed from the spatial domain into a different transformation domain (e.g., frequency domain, wavelet domain) and before transforming to spatial domain, noise is suppressed in the transformed domain itself. Each technique has its own advantage and utilization, is based on its application. The challenge in de-noising biomedical image is that, the noise should be removed by preserving the edges and without blurring the image. Various filtering techniques are developed over the years, which can be used for removing noise. Depending on the type of noise model that exists in an image, the major types of noise that can be observed in biomedical images are Gaussian noise, Poisson noise and salt and pepper noise. We have chosen median filter and adaptive filter (wiener filter) of spatial domain and two transformation domain filter like frequency filter and wavelet filter are used.

Wiener filters: Wiener filter is a linear filter that belongs to adaptive filtering family. Its transfer function and mean error is used to adjust to the changing parameters in the transfer function. This filtering technique is often used in the situations where the local changes in an image are not known. This situation often arises with spectral noises and Gaussian noise [11]. The Wiener filter design is given as follows

$$F(u,v) = \left[\frac{1}{H(u,v)}\frac{|H(u,v)|^2}{|H(u,v)|^2 + \frac{S_n(u,v)}{S_f(u,v)}}\right]G(u,v) \quad \ldots\ldots (3)$$

where, H(u,v) is degradation function, Sn(u,v) is power spectrum of noise and Sf(u,v) is power spectrum of original image.

Median filter: Median filter is a spatial nonlinear filter used in noise filtering, which smooth's additive noise and effectively removes impulse noise [10]. In filtering the image, it utilizing the median value of the neighbourhood pixels of the image, Whereas Median filtering technique is less sensitive than linear techniques to extreme changes in pixel values, further performance can enhanced by using adaptive nature to the median filter [11].

Frequency filter: Image is a function of spatial coordinates, in practice it is found that spatial filter gives poorer result compared to filters designed in frequency domain. The frequency domain filters can be designed either directly in frequency domain or spatial filter functions can be Fourier transformed to frequency domain. Frequency domain low
pass filter, smooth's the image and high pass filter sharpen the image. The Gaussian response of low pass filter can be designed using the relation

$$H(u,v) = e^{\frac{-(d^2(u,v)}{2D_0^2}} \quad \ldots\ldots\ldots\ldots (4)$$

Where, D_0 stands for cut-off frequency.

Wavelet filter: Wavelet filter attempts to remove the noise present in the image while preserving signal characteristics, regardless of its frequency content. The concept depends upon thresholding the value of discrete wavelet coefficients which effected by noise, is performed using either hard or soft thresholding technique. The selection of threshold value is a challenging concept, whereas small thresholding yields result closer to input but result may contain noise. But higher thresholding values may result over smoothing therefore smoothing will suppress the edge details. The thresholding relation is given in the expression and λ is a threshold value [10].

The hard threshold operator is $T_h(Y,\lambda)$ given by

$$T_h(Y,\lambda) = \begin{cases} y & if\ |y| \geq \lambda \\ 0 & otherwise \end{cases} \quad \ldots\ldots\ldots\ldots (5)$$

The soft threshold operator is $T_s(Y,\lambda)$ given by

$$T_s(Y,\lambda) = \begin{cases} Y-\lambda \ if\ Y \geq \lambda \\ Y+\lambda \ if\ Y \leq -\lambda \\ 0 \quad otherwise \end{cases} \quad \text{................ (6)}$$

D. Statistical Parameters

Peak Signal to Noise Ratio (PSNR): PSNR is used to determine the quality of image during de-noising the image. The ratio of peak energy to maximum square error in the reconstructed image is expressed in terms of decibels. The value of PSNR is used to determine the quality of the reconstructed image. The PSNR of an image can be found using the expression.

$$PSNR = 10\ \log_{10}\left(\frac{R^2}{MES}\right) \quad \text{.................. (7)}$$

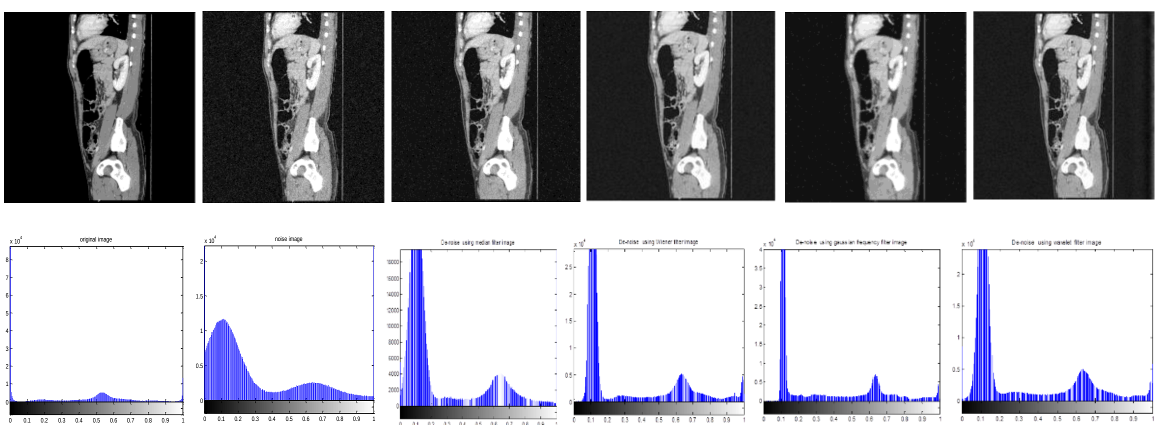
Where, R is the maximum intensity value.

Root Mean Square Error (RMSE): RMSE is an estimator used to difference between values predicted by a model and the values actually observed from the environment that is being modelled. The RMSE of a model prediction with respect to the estimated variable is defined as the square root of the mean squared error

$$RMSE = \frac{1}{n}\sqrt{(I_{original} - I_{noisy})^2} \quad \text{..................... (8)}$$

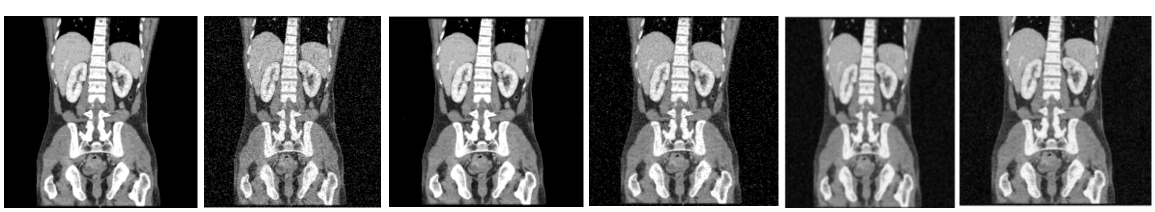
III. RESULT AND DISCUSSION

The proposed comparative study of CT image de-noising technique is implemented in the working platform of MATLAB. The performance has been evaluated by de-noising the CT images. For test purpose CT images are corrupted by salt & pepper noise, Gaussian Noise, and Poisson Noise. We have utilized the CT images of size 512 X 512 (M = 512 and N = 512). Over the study, it is found that spatial median filter performs better and best suited for impulse noise (salt and pepper noise). In order to remove noise like Gaussian and Poisson some other filters are required. An adaptive filter has ability to remove more Gaussian and random noise in spatial domain. The Frequency filter is good in its response, but it fails to preserve edges in the image. Wavelet filter performance is good in removal of additive Gaussian noise, as well as it preserves the edges, but they have some constraints regarding resolution degradation. Whereas for bio-medical image processing preserving the edge detail is important which should not happen that pre-processing removes the most of details.



Original image noisy image Median filter wiener filter frequency filter wavelet filter

Fig. 4 CT image corrupted with Gaussian noise and response of filters along with their histogram plot



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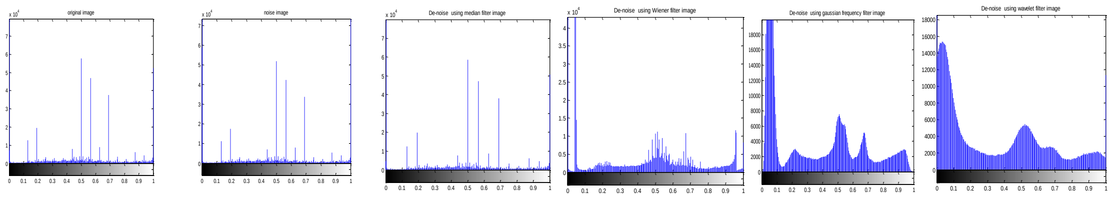
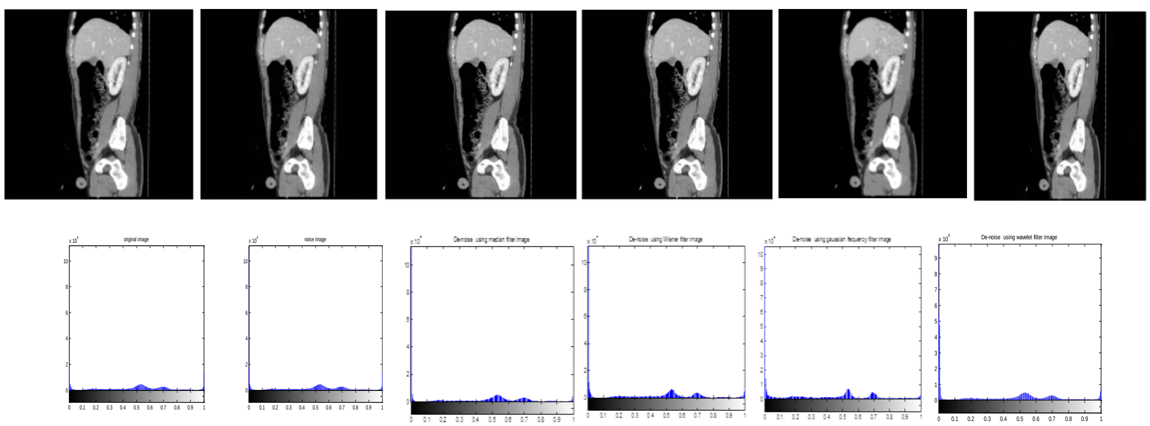


Original image noisy image Median filter wiener filter frequency filter wavelet filter

Fig. 5 CT image corrupted with salt and pepper noise and response of filters along with their histogram plot



Original image noisy image Median filter wiener filter frequency filter wavelet filter

Fig. 6 CT image corrupted with Poisson noise and response of filters along with their histogram plot

TABLE 1: FILTER RESPONSE FOR IMAGE CORRUPTED BY GAUSSIAN NOISE

	Wavelet Filter		Adaptive Filter		Median Filter		Gaussian low pass filter.	
	PSNR	RMSE	PSNR	RMSE	PSNR	RMSE	PSNR	RMSE
I1	19.50	0.1060	19.64	0.1042	19.54	0.1054	19.39	0.1073
I2	19.09	0.111	19.32	0.1081	19.36	0.1076	19.00	0.1122
IM	18.76	0.1153	19.18	0.1099	19.23	0.093	19.05	0.1115
IM1	19.00	0.1122	19.31	0.1082	19.04	0.117	18.68	0.1164

TABLE 2: FILTER RESPONSE FOR IMAGE CORRUPTED BY SALT AND PEPPER NOISE

	Wavelet Filter		Adaptive Filter		Median Filter		Gaussian low pass filter.	
	PSNR	RMSE	PSNR	RMSE	PSNR	RMSE	PSNR	RMSE
I1	23.09	0.0705	19.98	0.1005	34.32	0.0192	24.29	0.0611
I2	22.38	0.0760	19.56	0.1052	35.52	0.0168	23.70	0.0653
IM	21.77	0.0816	19.40	0.1072	32.06	0.0249	22.63	0.0738
IM1	22.1	0.784	19.56	0.1052	28.60	0.0372	22.83	0.0722

TABLE 3: FILTER RESPONSE FOR IMAGE CORRUPTED BY POISSON NOISE

	Wavelet Filter		Adaptive Filter		Median Filter		Gaussian low pass filter.	
	PSNR	RMSE	PSNR	RMSE	PSNR	RMSE	PSNR	RMSE
I1	122.3	7.7e-7	38.06	0.0125	35.92	0.16	28.66	0.0369
I2	125.87	5.1e-7	39.02	0.0112	38.61	0.0117	28.05	0.0396
IM	54.71	0.0018	35.16	0.0175	34.20	0.0195	29.88	0.0321
IM1	123.62	6.5e-7	38.36	0.0121	29.16	0.0348	25.98	0.0502

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IV. Conclusions

We applied different algorithms on different CT images of abdomen which are utilized for test purpose. The results were compared with the statistical parameter like PSNR and RMSE. To obtain significantly better De-noised image, with retaining the region of interest (i.e., tumors or stone). The PSNR value should be high and the value of RMSE should be low to obtain better quality of de-noised image. Wiener filter restores Image corrupted by Gaussian Noise and wavelet filter gives better result for Poisson Noise. If image is corrupted by salt and pepper noise median filter shows better performance. The preprocessing technique does not affect the image characteristics, but removes only noise pixels from the original image. The histogram analysis and visual quality of the image holds the result.

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