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RESEARCH ARTICLE

Noise Removal Techniques for Lung Cancer CT Images

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Abstract

Objectives: To analyze various filtering methods to eliminate noises present in the lung CT images and to enhance the image, which help in further evaluation of CT images for accurate lung cancer detection. To compare the proposed method with existing filtering techniques and to find the best filtering technique. **Methods:** For input lung CT images noises like salt along with pepper noise and speckle noise are added. For noisy images different filtering methods like Median filter, Wiener filter, Gaussian filter and Guided filter are applied. The performances of different filters are computed in terms of metrics for evaluation like PSNR, SSIM, MSE, and SNR. Based on the performance metrics the best filter is selected to remove noise in the lung CT images. **Findings:** The results of the experiment shows that the median filter is more efficient in comparison to other filtering methods in eliminating noises that exist in lung CT images by owning fewer mean square error (MSE) value of 4.065604, a high SNR value of 36.5931, a high SSIM value of 0.983545, and high PSNR value of 42.0395. **Novelty:** Different filtering methods are analyzed for different noise densities from 5% to 50% and chosen best filter by considering different evaluation metrics. The proposed method is compared with existing filtering techniques. The method can be used for elimination of noise in the other imaging modalities.

Keywords: Filtering; Median filter; Wiener filter; Gaussian filter; Salt and Pepper noise; Speckle noise

1 Introduction

Lung cancer is one of the most common life-threatening diseases in today's society, and the mortality rate is constantly rising as a result. The influential challenging task is the recognition of tumors in the lung. Medical imaging is the method through which detailed information about various parts of the human body are collected with the help of different technology for clinical evaluation and medical encroachment. Various types of imaging modalities like plain X-ray, Computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound scanning are used for the recognition of lung tumors.

The CT scan method uses a small dose of ionizing radiation to produce CT images. It creates 360-degree images. The CT scan method is utilized as an efficient medical screening test because of its low cost, short imaging time, higher clarity, and reduced distortion over other imaging modalities[(1)].

Noise and Outliers are common in any medical image. During the acquisition of lung CT images, various types of noise like salt with pepper noise and speckle noise are added. These noise and outliers hide many minor details in a lung CT image. Snowy, Grainy, and blotchy looks are results of the presence of noise. These noises have an impact on the quality of lung CT images and degrade the performance of the segmentation stage and feature extraction stage of lung cancer detection. In a CT image, unwanted elements may be added during the acquisition process which can be referred to as noise. The appearance of low-contrast images decreased due to noise. Image quality is affected by radiation dose crucially. The number of corrupted pixels defines the intensity of the noise in an image. For further processing of the image noise removal is a critical thing[(2)]. Hence the primary purpose of medical image processing is to remove these noises and artifacts using image pre-processing techniques. It eliminates some regions of CT image such as the background and surrounding tissues or vessels. It enhances the quality of an image and improves detection accuracy. Hence the elimination of noise has a significant impact on the diagnostics and analysis of the CT scan images. Hence image preprocessing techniques like various filtering and enhancement techniques are used which helps in further analysis of lung cancer detection.

The different researchers used different filtering techniques to remove noise in the lung CT images. In the preprocessing a wiener filter is used to remove the noise which is added to the lung CT scan images during image acquisition[(3)]. For preprocessing, proposed the Gabor filter to renovate the observation of information included in the image for normal vision or to find better input for other stages of image processing methods[(4)]. According to author, for pre-processing, the median filter and Gabor filter are used. The median filter removes salt as well as pepper noise and the Gabor filter improves the image's quality[(5)]. In the processing stage, proposed image enhancement and noise filtration techniques on the images collected from the LIDC dataset. For Image enhancement histogram equalization method has been proposed and the median filter has been proposed two times for the enhanced image to remove the noise[(6)]. The wiener filter is very slow in filtering noise and also very hard to obtain the restoration of noise in random nature. The Gaussian filter require lot of time to reduce noise and image details are reduced after filtering. The guided filter fails to remove noise when it doesn't have the clear guidance image. The Gabor filter requires large computation time to remove noise and also to extract features. Because of these limitations of filtering techniques, it is very much necessary to analyze the filters.

This paper attempts to compare various filtering methods and analyze them to prove the best method for accurately remove noise in the lung images. The proposed method analyses the noises of different kinds in the CT images and different noise removal techniques which help in improving the accuracy of segmentation and feature extraction as they remove unwanted noise and contribute to the accurate detection of lung cancer. Since there is no standard filtering technique to remove noise in the CT images, it is very much essential to find the best filter which remove noises in the lung images.

The following is a summary of the remainder of this paper: Section 2 describes the proposed methodology. Section 3 describes results and discussions. Section 4 describes the conclusion of the research work.

2 Methodology

First input lung CT images are collected from the LIDC dataset in DICOM format. Different types of noise, such as speckle noise, salt noise as well as pepper noise, are applied to the input CT images, ranging from 5% to 50% noise density. The existing methods are not analyzed for different noise densities but the proposed method applied for all noise density to all filtering methods. For noisy images, different filters like Gaussian filter, median filter, wiener filter, and guided filter are applied. The performance of each filter is analyzed in terms of the MSE, the PSNR, the SSIM, and the SNR. Based on the value of the above image quality performance metrics the best filter which removes the noise in lung CT images is selected. The proposed methodology is shown in Figure 1.

2.1 Filtering techniques

The denoising technique must preserve very microscopic details of CT images as they are crucial in medical diagnostics. Usage of filters is the most common technique. Filters are divided into linear and non-linear. Linear filters are those in which the output pixel value is the linear combination of pixel values from adjacent pixels in the input[(7)]. The Wiener filter, the median filter, the gaussian filter, and the guided filter are some of the filters used to eliminate noise from lung CT images.

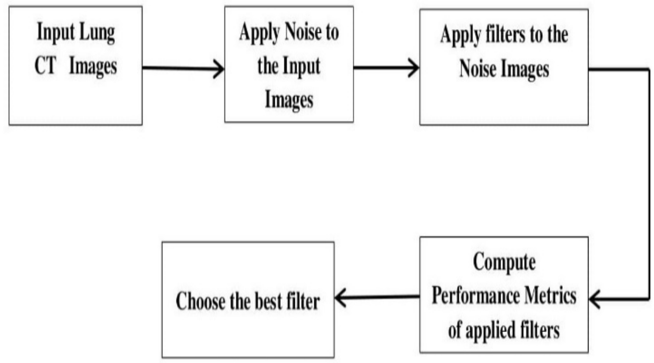

Fig 1. Proposed Methodology

2.1.1 Wiener filter

A linear filter with a low mean square error is the wiener filter. A Wiener filter can be used to reduce picture distortion caused by linear motion or unfocused optics[8]. This filter can be used to clean up image information that's been corrupted by noise. This is a trade-off between noise smoothing and also inverse filtering. In inverse filtering and noise smoothing, it lowers the total mean square error. It is utilized to get rid of poisonous and speckle noise[9].

2.1.2 Median filter

A median filter is a non-linear approach for removing noise from image data. It's mostly used to eliminate salt & pepper noise. When it is applied to an image, the median value of nearby pixels is substituted for each pixel. The window is the name given to this neighbor's floor plan. By sorting all of the pixel values in the window into numerical order and then replacing them with the median pixel value, the median is calculated. The major benefit of the median filter is that it keeps the image's edges, and sharpness, and reduces noise, hence it's commonly used in digital image processing[10].

2.1.3 Gaussian filter

It's a non-uniform linear low pass filter for blurring images within certain parameters. This aids in noise reduction. It operates by employing a point–spread function based on a 2D distribution. The 2D Gaussian distribution function is used to confound the image. The Gaussian function should be approximated with a discrete approximation. Because the Gaussian distribution is non-zero at all points, it necessitates an infinite convolution[11].

2.1.4 Guided filter

The fastest edge-preserving filter is the guided filter. It's calculated using a linear model. It works by calculating the values of nearby pixels in the guide image, which is also the input image. The pixel values from the guidance image are used to calculate the output pixel. If the input and guide images are identical, the edges of the output image are identical to those of the input image[12].

2.2 Image quality performance metrics

To find the best filter out of the four filters, image metrics such as signal to noise ratio (SNR), the peak-signal to noise ratio (PSNR), the structural similarity index (SSIM), and mean square error (MSE) were calculated.

2.2.1 Mean Square Error (MSE

The mean square error is the accumulative squared error between the compressed image and the original image[13]. The MSE is calculated using the following equation (1).

$$MSE = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]^2}{M*N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

2.2.2 PSNR

The term PSNR refers to the relationship between a signal's greatest possible value and the ability to distort noise that degrades image quality. The PSNR is measured in decibels because several signals have a wide range (dB) [14]. The psnr is calculated using the following equation (2).

PSNR =$10log_{10}(\frac{R^2}{MSE})$ ………………….. (2)

Where R is the Information Rate.

2.2.3 SSIM

It is an intuitive parameter that evaluates image quality deterioration produced by the data compression process or data transmission losses. Since SSIM is a full reference metric it needs two images for evaluation. Such images are a reference image and a processed image that is taken from the same image [15].

3 Results and Discussion

The filters are analyzed by applying different types of noise at various noise densities. For each filter the value of PSNR, MSE and SSIM are calculated. Based on the image quality metrics the best technique for noise removal process is selected. The obtained method is compared with the existing methods to remove noise accurately.

3.1 Preprocessing using a filter with speckle noise

In an image, speckle noise is undesirable and random. In medical images, speckle noise is also known as spatial variation of pixel intensities. The amount of scatters per resolution cell of the scatter density distribution determines the type of speckle structure [16]. For experimentation, lung CT images are collected from the LIDC-IDRI database. For experimentation, Matlab R2021a is used to analyze different filters in terms of PSNR, MSE and SSIM.

The median filter has filtered the noise and has achieved the highest PSNR which is a sign of improving the image quality. It has obtained a PSNR value of 24.8094 at 5 % noise density which is better than other filters applied. Figure 2 shows the graph plotted between PSNR values and noise densities, which shows that the median filter has filtered the maximum amount of noise. The mean square error has been calculated using the input image as a reference at all noise densities. The median filter has the lowest MSE which shows its excellence in filtering the images. At 5% of noise density, the median filter has obtained an MSE value of 214.8522.

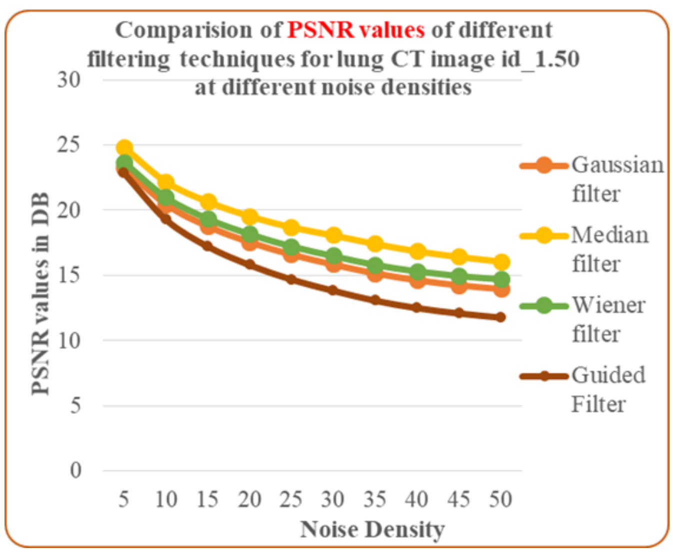

Fig 2. Noise density v/s PSNR values

Figure 3 shows the graph plotted between MSE values and noise densities, which shows that the median filter has the lowest MSE which shows its excellence in filtering the images. Figure 4 shows the graph plotted between SSIM values and noise densities, which shows that the Median filter is a step ahead of the Wiener filter at all noise densities. Median filter has obtained

0.645698 of SSIM at 5 % noise density which is slightly better than a Wiener filter. The output images of all filters for different noise densities are shown in Figure 5.

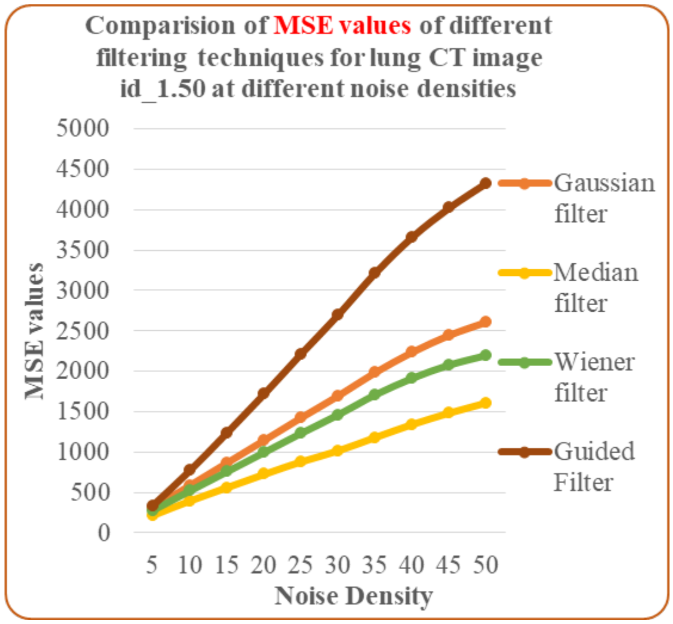

Fig 3. Noise density v/s MSE values

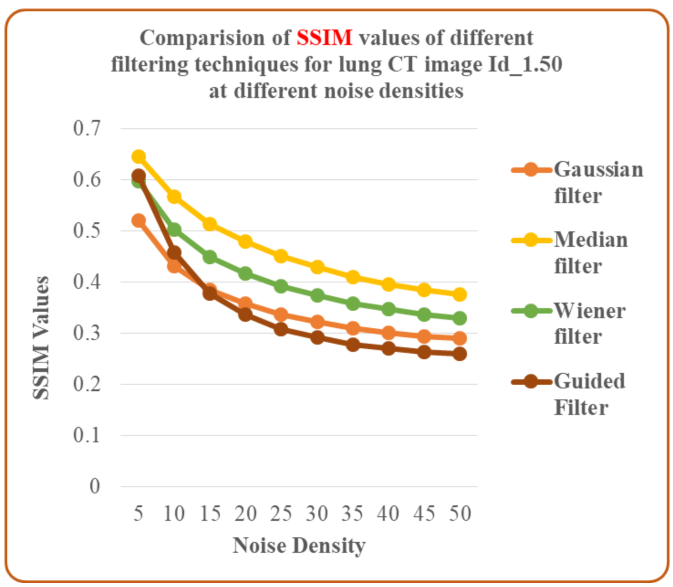

Fig 4. Noise density v/s SSIM values

From the experimental results it is concluded that median filter removes speckle noise effectively compared to other filters.

3.2 Preprocessing using a filter with salt and pepper noise

Salt, as well as pepper noise, is a type of image noise that occurs in the lung CT image. This is considered impulse noise. It can be caused by image disruptions that are abrupt and sharp. It manifests as white and black pixels that are irregularly distributed. Noisy pixels in salt, as well as pepper noise, have either a salt value (255 grey levels) or a pepper value (zero grey levels), resulting

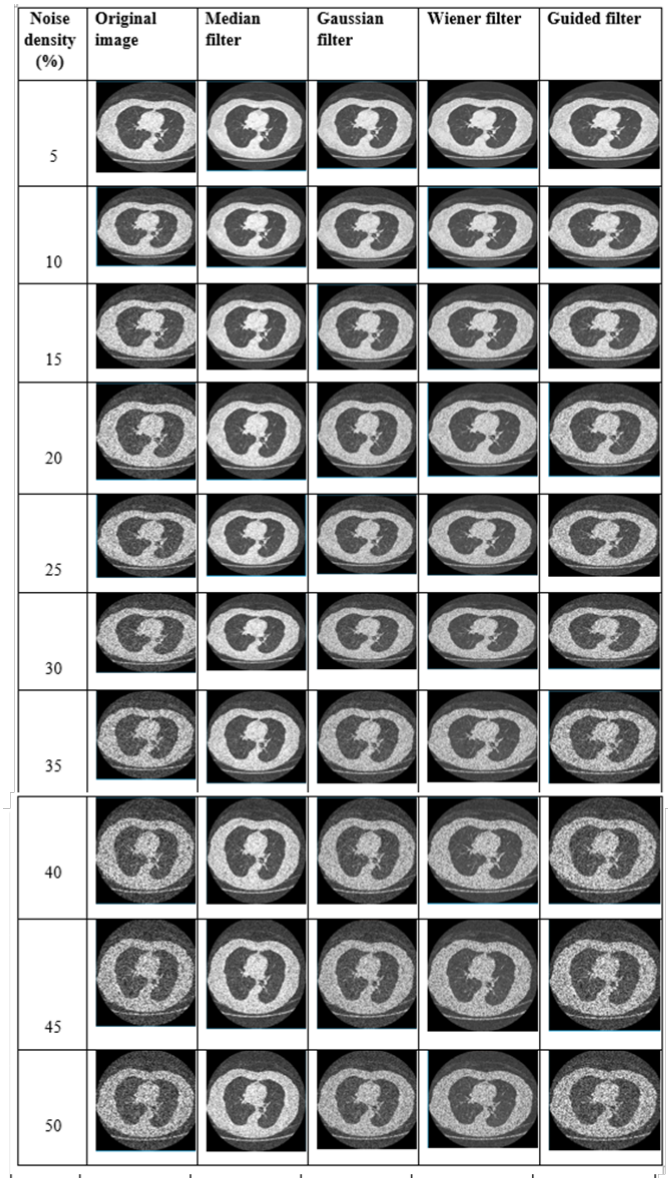

Fig 5. Original lung CT images, output lung CT images after applying various filters for different noise densities with Speckle noise

in black and white patches in the images. It is critical to remove this noise from the lung CT imaging for further analysis. The noise importantly harms the information in the image which tends to create problems in the different stages of image processing such as segmentation of an image and feature extraction[(17)].

After filtering salt and pepper noise at various noise densities, PSNR values are calculated. The median filter has outperformed well compared to all other filters. The median filter improved the quality of the image and obtained a PSNR value of 42.03955 which is the best value of PSNR. Figure 6 is a graph depicting the relationship between PSNR values and noise densities, which shows that the median filter has filtered the maximum amount of noise.

MSE for an image must be as low as possible and the median filter has obtained the lowest MSE value which is 4.065604 at 5 % noise density. Figure 7 is a graph depicting the relationship between MSE values and noise densities, which shows that the median filter has the lowest MSE which shows its excellence in filtering the images. It has obtained a ssim value close to 1.0 which is an indication of a better quality of the image.

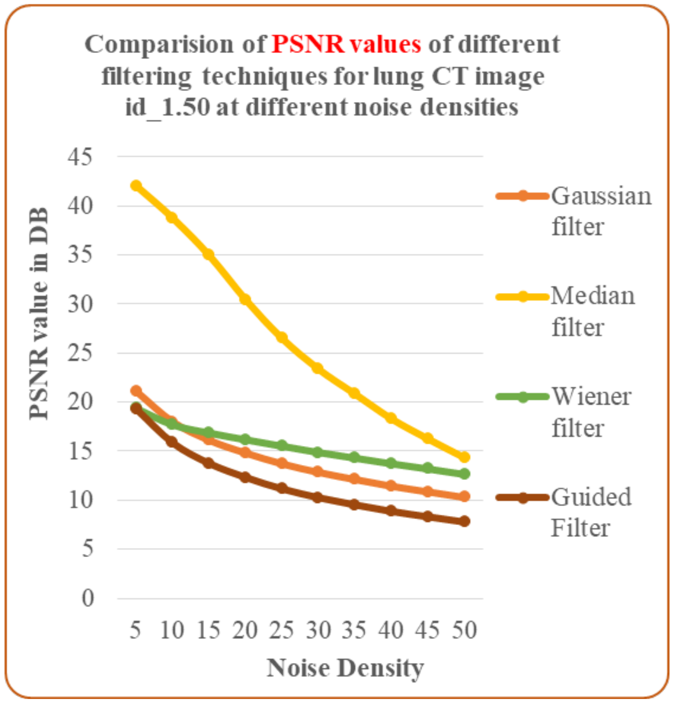

Fig 6. Noise density v/s PSNR values

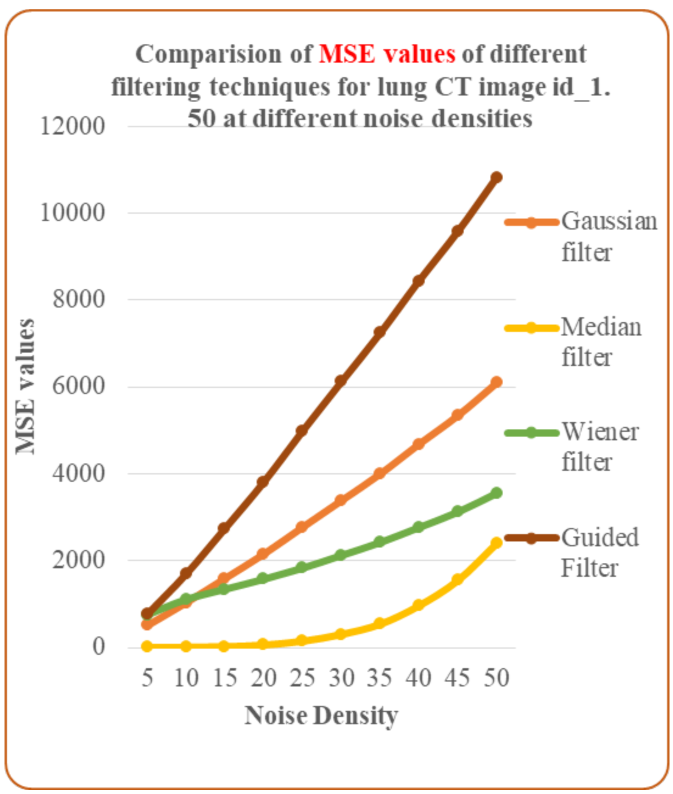

Fig 7. Noise density v/s MSE values

Figure 8 shows the graph plotted between ssim values and noise densities, which shows that the median filter wiener filter achieved high ssim values at all noise densities compared to other filters. . Median filter has been obtained 0.983545 of SSIM at 5 % noise density which is better than the other filters. The output images of all filters for different noise densities are shown in Figure 9.

From the results obtained in the section 3.1 and 3.2 it is concluded that median filter remove the different noise occur in the CT images effectively.

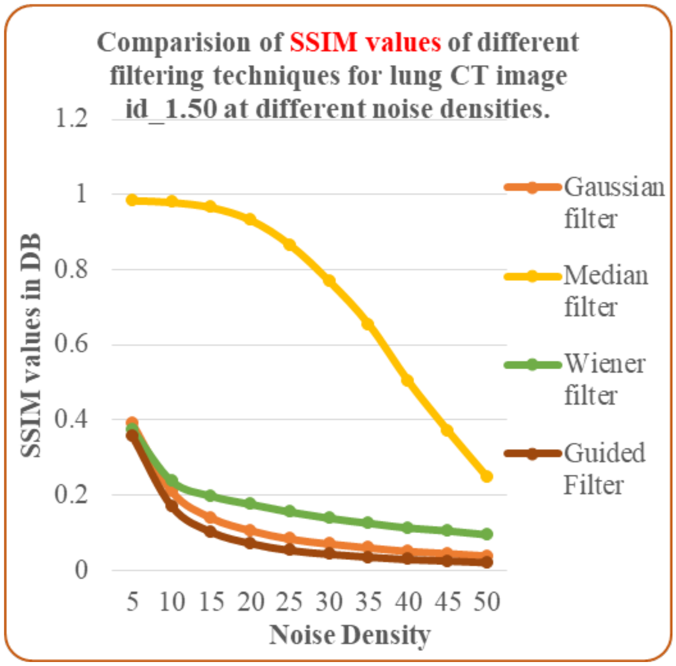

Fig 8. Noise density v/s SSIM values

3.3 Comparison

The method used to remove noise using self-guided filter obtained very less PSNR value and SSIM value compared to our proposed method. This method obtained a PSNR value of 25.75 and a SSIM value of 0.916 [18].In the proposed method, the median filter obtained PSNR value of 42.039 and a SSIM value of 0.98354.The method obtained a very high value compared to the existing method.

The noise in the CT images is removed using adaptive Gaussian filter [15]obtained a PSNR value of 15.6710 and a SSIM value of 0.3788, which is very low compared to our proposed median filter.

The Gabor filtering method used in the paper attained a highest PSNR value of 35.72 [18] which is very low compared to our proposed method results. The Gabor filter requires large computation time to remove noise and also to extract features and compared to Gabor filter median filter remove noise very effectively. The comparison results is shown in Table 1.

Table 1. Comparison of proposed method with existing method

Sl.No	Techniques Used	PSNR
1	Self-guided filter for image denoising [12]	25.75
2	Image enhancement filtering techniques toenhance CT images of lung cancer [18]	35.72
3	Reduce Noise in Computed Tomography Image using Adaptive Gaussian Filter [15]	15.67
4	Proposed Method	42.039

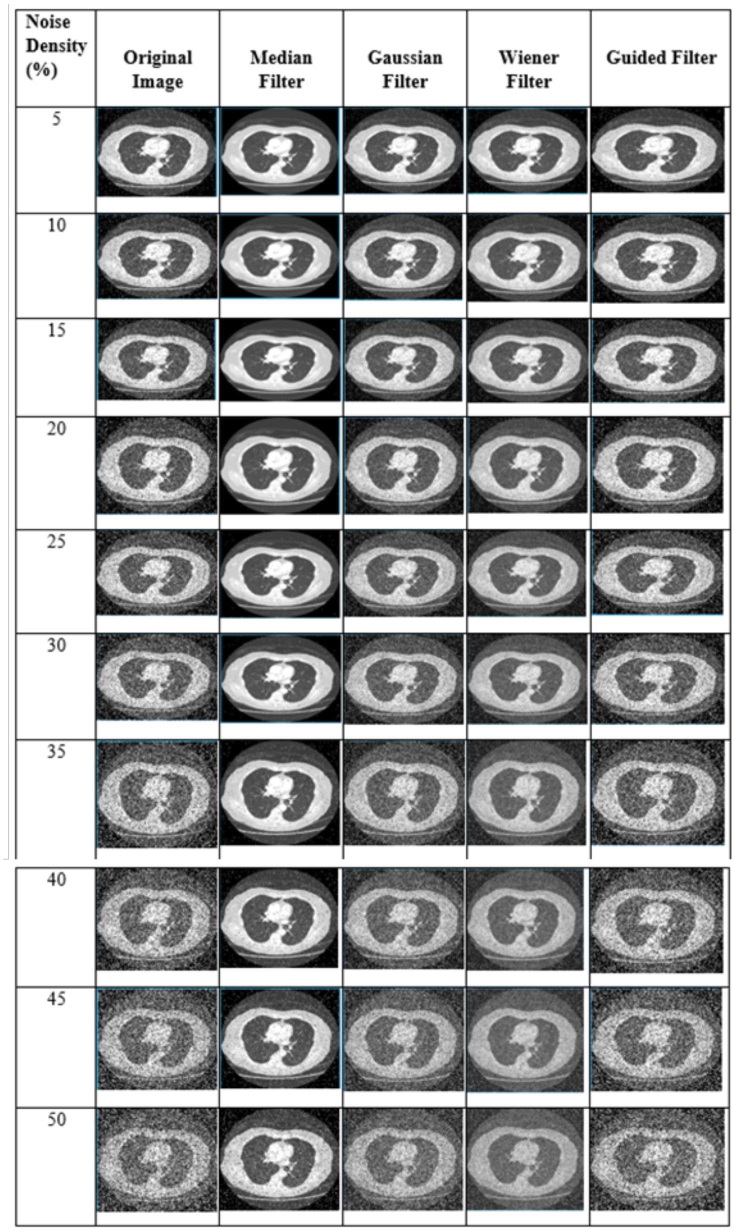

Fig 9. Original lung CT images, Output lung CT images after applying various filters with Salt as well as Pepper Noise for various noise densities

4 Conclusion

The proposed study analyses various filtering methods to eliminate noises present in the lung CT images. The performances of different filters are computed in terms of metrics for evaluation like PSNR, SSIM, and MSE. The filters are applied for different noise densities from 5% to 50%. The results of the experiment shows that the median filter is more efficient in comparison to other filtering methods in eliminating noises that exist in lung CT images by owning fewer MSE value of 4.065604, high SSIM value of 0.983545, and high PSNR value of 42.0395. From the results, it is concluded that the median filter removes noises effectively compared to other filtering techniques. It helps in improving the accuracy of segmentation and feature extraction as they remove unwanted noise and contribute to the accurate detection of lung cancer. The method can be used for elimination of noise in other imaging modalities.

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