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Artifact removal techniques for lung CT images in lung cancer detection

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ABSTRACT

Lung Cancer in today's world is one of the major widespread dangerous diseases which is the subject of maximum deaths every year. Accurate detection of lung cancer could boost the endurance rate. Medical image processing has a significant impact on the recognition of lung tumors using Computer Tomography (CT) scan images. Images from a CT scan are widely used because they provide comprehensive imaging of tumor progression inside the lungs. Although different types of noise might be experienced while doing CT scans, producing it a monotonous task for recognizing tumors in the lung. Elimination of noise in CT images is a challenging task for medical diagnoses. The presence of noise in an image is inevitable. Hence reducing noise from the CT scan image is critical for further analysis. Hence various filtering techniques have been used that denoise and enhance the image and help in further evaluation of CT images for accurate lung cancer detection. This paper 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. The various filtering methods are analyzed with salt along with pepper noise and speckle noise. The performances of different filters are computed in terms of metrics for evaluation like PSNR, SSIM, MSE, and SNR. The experimental results show 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 values of 214.8522, high SNR value of 19.36304, SSIM value 0.595997, and high PSNR value of 24.80941.

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1. INTRODUCTION

In today's society, lung cancer is one of the major widespread life-threatening diseases, because of which the mortality rate is increasing rapidly. 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 is 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[1]. The CT scan method uses a small dose of ionizing radiation to produce CT images. It creates 360-degree images. Because of its low cost, short imaging time, better clarity, and less distortion CT scan method is used as an efficient medical screening test over other imaging modalities.

Noise and Outliers are common in any medical image. During the acquisition of lung CT images, various kinds of noise like salt pepper noise and speckle noise are added. These noise and outliers hide many minor details in a lung CT image[2]. 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[3]. 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 is 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[4]. 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 the 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 pre-processing 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[5].

For noise removal, Sayali Satish Kanitkar et al. proposed a Gaussian filter for smoothing and a Gabor filter for enhancement of an image[6]. Gabor filter is proposed by Bariqi Abdillah et al. to enhance the quality of lung CT images in the pre-processing stage which helps in accurate lung cancer recognition[7]. In the pre-processing stage, S. Kalaveni et al. proposed RGB to grayscale conversion to change an RGB CT image into a grayscale image. Histogram equalization has been proposed to smoothen the image by increasing the dynamic range and increasing contrast. Binarization is also proposed in the image pre-processing stage for enhancement of the image[8]. Mithuna B.N et al. proposed foreground and background separation techniques and image enhancement methods to remove unwanted information and enhance an image[9].In the pre-processing stage, K. T. Navya et al. proposed Histogram Equalization for image enhancement and median filter as noise removal techniques[10]. For pre-processing Prenitha Lobo et al. have proposed Contrast Limited Histogram Equalization (CLAHE) technique. The contrast of the lung CT input images is enhanced using CLAHE to increase image quality and reduce noise amplification [11]. In the pre-processing Loveneet Kaur et al. have proposed filtering and enhancement techniques. The input images were converted into grayscale images then the Median filter was used to reduce the amount of noise in CT images, later the images were enhanced using the log Gabor filter[12]. In the pre-processing Manikandan T et al. proposed a wiener filter to remove the noise which is added to the lung CT scan images during image acquisition[13]. For pre-processing Mehdi Hassan Jony et al. proposed a 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[14]. According to Mahmudual Islam et al. for pre-processing, the median filter was proposed for smoothing an image, and the Gabor filter was proposed for enhancement. The median filter removes salt as well as pepper noise and the Gabor filter improves the image's quality [15]. In the processing stage, Nikita Banerje et al. 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[16].

This paper analyses 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.

The following is a summary of the remainder of this paper: Section 2 explains the various filtering techniques used to eliminate the noise present in the CT images. Section 3 describes various image quality performance metrics. Section 4 describes pre-processing using the filter with speckle noise. Section 5 describes pre-processing using the filter with salt and pepper noise. Section 6 describes the conclusion of the research work.

2. METHODOLOGY

First input lung CT images are collected from the LIDC dataset in DICOM format. For input, CT images speckle noise is applied ranging from 5% to 50% noise density to create a noisy image. For noisy images, different filters like the Gaussian filter, Median filter, Wiener filter, and Guided filter are applied. The performance of each filter is analysed 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. This helps to detect lung cancer more accurately by increasing the accuracy of segmentation and feature extraction. The proposed methodology is shown in figure 1.

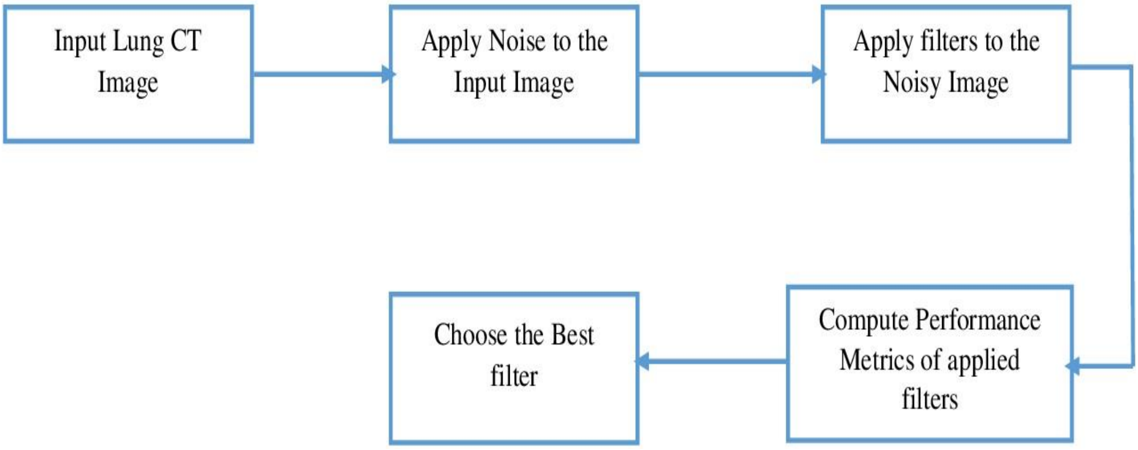


Figure 1: Proposed Methodology

2.1. Filtering Techniques

The denoising Technique must preserve very microscopic details of CT images as they are crucial in medical diagnostics. The 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[17]. 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.

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. 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 speckled noise[18].

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. '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 a median filter is that it keeps the image's edges, and sharpness, and reduces noise, hence it's commonly used in digital image processing[19].

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[20].

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[21].

Different filters used to remove noise from lung CT images are explained in this section. Each filter is analyzed in terms of various performance parameters to find the best filter which improves the accuracy.

3. RESULTS AND DISCUSSIONS

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[22].

For experimentation, images are collected from the LIDC-IDRI database. For experimentation, Matlab R2021a is used to analyze different filters in terms of PSNR, MSE, SSIM, and SNR.

Table 1: PSNR value after applying filters on lung CT images

Noise Density	Gaussian filter	Median filter	Wiener filter	Guided Filter
5	23.23813	24.80941	23.66589	22.83313
10	20.44488	22.16231	20.97204	19.26562
15	18.7597	20.64827	19.33966	17.20898
20	17.54489	19.53134	18.15492	15.78548
25	16.59324	18.68406	17.22243	14.67929
30	15.83744	18.06308	16.48195	13.82123
35	15.15432	17.40793	15.80275	13.05771
40	14.63453	16.85014	15.30962	12.49499
45	14.24453	16.41578	14.95185	12.08482
50	13.96546	16.06233	14.71262	11.7675

In the above table 1 shows the PSNR value calculated after applying the 4 filters to different noise densities. 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.

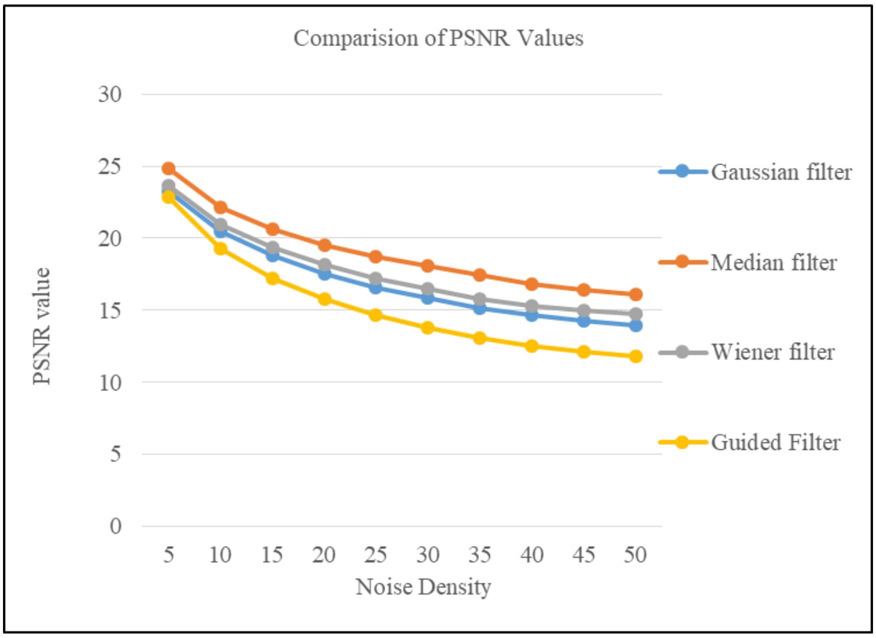


Figure 2: Noise density v/s PSNR values

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.

Table 2: MSE value after applying filters on lung CT images

Noise Density	Gaussian filter	Median filter	Wiener filter	Guided Filter
5	308.509	214.8522	279.5706	338.6629
10	586.9378	395.2294	519.8477	770.0491
15	865.1878	560.0842	757.0326	1236.468
20	1144.437	724.3465	994.4627	1716.061
25	1424.807	880.388	1232.642	2213.865
30	1695.651	1015.717	1461.792	2697.474
35	1984.487	1181.102	1709.249	3215.949
40	2236.803	1342.969	1914.777	3660.844
45	2446.96	1484.233	2079.198	4023.443
50	2609.364	1610.081	2196.942	4328.426

In the above table 2, 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.

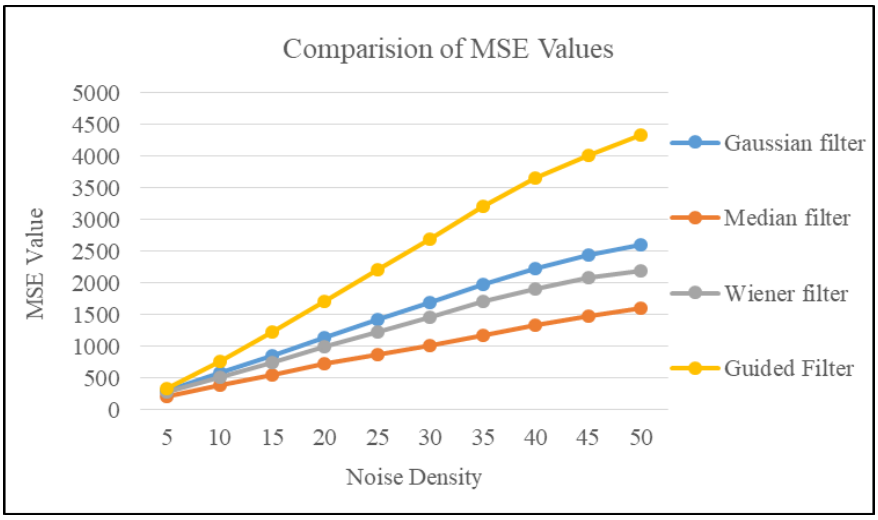


Figure 3: Noise density v/s MSE values

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.

Table 3: SSIM value after applying filters on lung CT images

Noise Density	Gaussian filter	Median filter	Wiener filter	Guided Filter
5	0.520073	0.595997	0.645698	0.606598
10	0.431182	0.502694	0.565888	0.457566
15	0.384659	0.4497	0.513803	0.377933
20	0.357187	0.417626	0.478372	0.336024
25	0.336655	0.392499	0.450353	0.308691
30	0.321737	0.374105	0.428511	0.291466
35	0.309379	0.358664	0.409118	0.278486
40	0.301709	0.347921	0.396321	0.270657
45	0.294166	0.337314	0.384646	0.263771
50	0.289829	0.330149	0.37651	0.259541

In the above table 3 shows that the Wiener filter is a step ahead of the Median filter at all noise densities. Wiener filter has obtained 0.645698 of SSIM at 5 % noise density which is slightly better than Median Filter.

Figure 4 shows the graph plotted between SSIM values and noise densities, which shows that the Wiener filter is a step ahead of the Median filter at all noise densities. Wiener filter has obtained 0.645698 of SSIM at 5 % noise density which is slightly better than Median Filter.

Table 4: SNR value after applying filters on lung CT images

Noise Density	Gaussian filter	Median filter	Wiener filter	Guided Filter
5	17.79176	19.36304	18.21952	17.38676
10	14.99852	16.71594	15.52568	13.81925
15	13.31333	15.2019	13.89329	11.76261
20	12.09852	14.08497	12.70855	10.33911
25	11.14687	13.2377	11.77607	9.232925
30	10.39107	12.61671	11.03558	8.374864
35	9.707954	11.96156	10.35638	7.611345
40	9.18816	11.40378	9.863254	7.048625
45	8.798168	10.96942	9.505478	6.638458
50	8.519089	10.61596	9.26625	6.321137

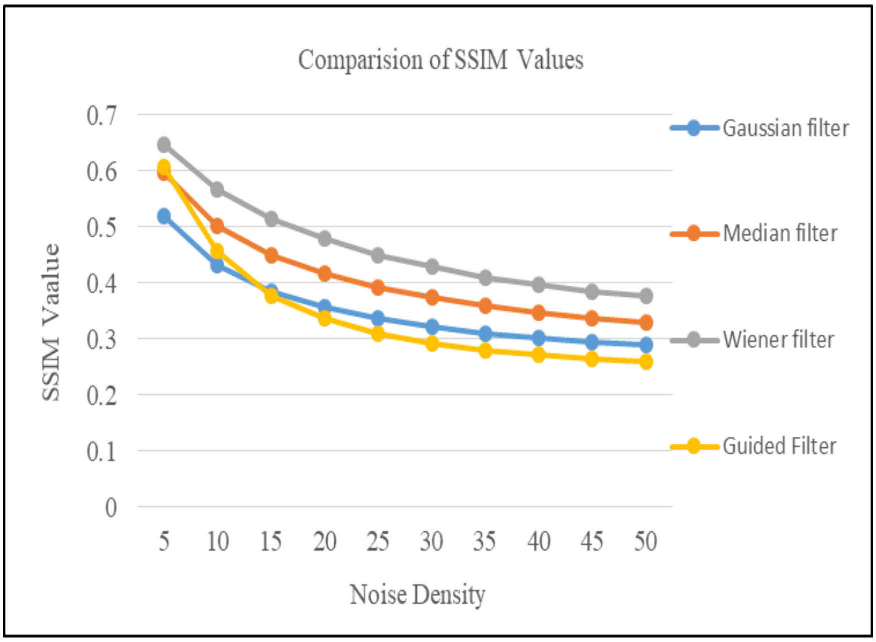


Figure 4: Noise density v/s SSIM values

In the above table 4 shows the SNR values of each filter. From Figure 5 the results, it is concluded that the median filter has obtained the highest values at all densities. Median Filter has obtained an SNR value of 19.36304 at 5 % noise density.

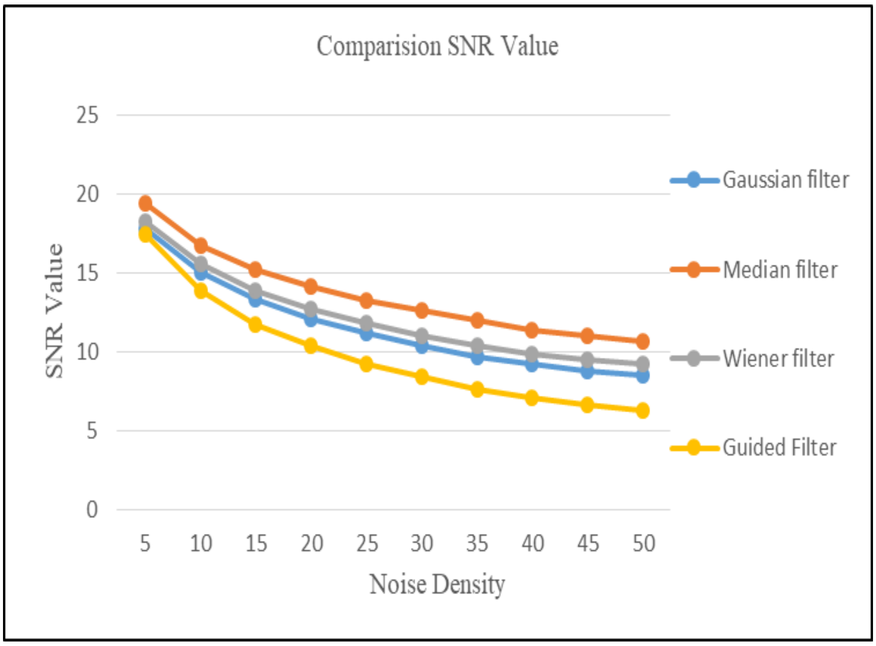
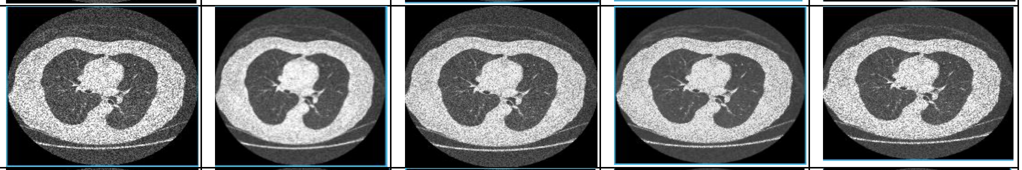
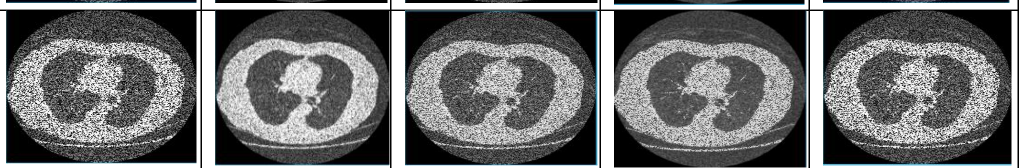
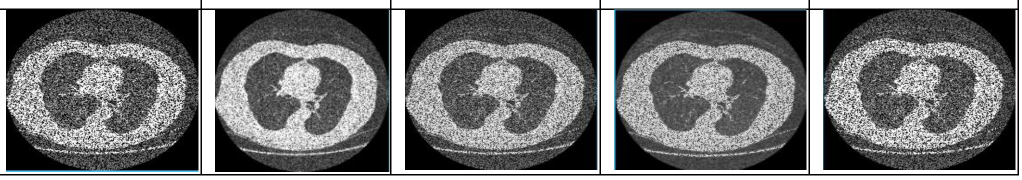


Figure 5: Noise density v/s SNR values

In this research work, in the first step for input CT images speckle noise is applied ranging from 5% to 50% noise density to create a noisy image. For noisy images, different filters like the Gaussian filter, Median filter, Wiener filter, and Guided filter are applied. The performance of each filter is analysed 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. This helps to detect lung cancer more accurately by increasing the accuracy of segmentation and feature extraction. The experimental results show 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 values of 214.8522 , high SNR value of 19.36304, SSIM value 0.595997, and high PSNR value of 24.80941.

Table 5: Original lung CT images, Output lung CT images after applying various filters for different noise densities with Speckle noise.

Noise Density (%)	Original Image	Median Filter	Gaussian Filter	Wiener Filter	Guided Filter
5					
10					
15					
20					
25					
30					
35					
40					
45					
50					

4. CONCLUSION

Detection of lung cancer accurately flattens the mortality curve and increases the chance of survival of lung cancer patients. The work which is performed through this research work mainly emphasizes removing noise in the lung's CT images for the accurate detection of lung cancer. Various filtering methods are applied on CT scans of lungs image to remove noise that is added during image acquisition. The filters are compared and analyzed in terms of PSNR, MSE, SSIM, and SNR. The experimental results show 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 values of 214.8522, high SNR value of 19.36304, SSIM value 0.595997, and high PSNR value of 24.80941.

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