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Research paper



Lung Lesion Enhancement Using Adaptive Median Filter with Curvelet Transform

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Abstract

Lung cancer is one of the major troubles of cancer in the worldwide among people. Initial identification of lung cancer will highly decreases the mortality rate to save the patient lifetime. To detect the lung nodule, the lung image must be enhanced, thus a novel method is proposed for improving image quality, which is the combination of adaptive median filter and Curvelet transform. During image acquisition, the noise content also include in the image. In order to eliminate the noise, the following steps are carried out; first the input image is changed into grayscale image for reduce the processing delay. Then adaptive median filter is performed along the image to remove the noise and histogram equalization is used to improve the image contrast. Finally, the curvelet transform is applied for sharpening the image edge. Performances are analyzed based on the PSNR, MSE, SNR and SSIM values.

Keywords: *Histogram equalization, Adaptive median filter, Curvelet transform*

1. Introduction

Lung cancer is one of the common diseases affecting the people, due to the abnormal cell growth occur in the lung tissues , it is also known as lung carcinoma which is a harmful lung tumor. If the cancer cells are present in the tumor region then it is said to be a malignant tumors and if it is absent in the tumor region, considered as benign tumors [2]. If this disease is not known initially, this cancer get enlarge and extend to other parts. This is a harmful disease which is mainly affecting the lungs pulmonary nodule. Initial Identification is important because it increases the survival rate when compared to other cancer. This cancer begins in the main passageway of the lung, and then it develops rapidly and extends to other organs including lymph nodes. Various scanning schemes are used for detecting the tumors at initial stage. CT scan is mainly used since it gives high quality image, low noise, and less expensive. In order to examine the tumor growth inside the lungs CT scan images is used to gather more details about the patient. Generally, the CT scan image contains some noises which decrease the object views.Noise occurs due to hardware problems, Radiation dose, transmission and acquisition which highly affect the image quality, so that filtering and de-noising technique is used to avoid noise. Filtering is mainly used for image enhancement. Image de-noising is a method of obtaining accurate information. Transform and filtering techniques are used for image enhancement and de-noising the CT image

Yadav et al., proposed discrete wavelet transform to remove noise in an ultrasound image. This is best technique, but it is not effective for Gaussian noise image [19]. Hua et al. explained the best preprocessing techniques using gray level thresholding [7]. This is an easy method but this take more time for computation. Pu et al. [9] explained the image enhancement technique here, the lung air pockets are eliminated by Gaussian smoothing and the outer region of lungs is extracted by graylevel thresholding. The unwanted lung regions are eliminated using flood fill algorithm. This method takes more time for computation. Diwakar et al. proposed [5] Wavelet transform method for edge sharpening, but this method doesn't gives the clear edges. Lilik et al. [10] explored preprocessing methods, initially the grayscale conversion and binarization is performed then for removing noise median filter is used, and finally adaptive histogram technique is applied to improve the brightness in an image. In this method denoising is poor because if the noise high the median filter does not work properly. Selin et al., [15] explained noise reduction technique using the erosion and median filters after that thresholding technique is applied to remove the unwanted components presented in the lung region.

Oulhaj et al., [11] identified various types of technique are used in medical images for denoising purpose, non local means and wavelet theory techniques are commonly used. These techniques are performing well but it will spoil the image sharpness. Nowadays noise elimination depends on wavelet thresholding or partial differential equations. Pandey et al., [12] suggested an effective noise removal technique, the main target of the Independent Component Analysis (ICA) is to separate the unwanted components in an image. However, the separation of the unwanted component technique is quite complex and improve the quality require many tools. Salsabil et al. [14] proposed a preprocessing technique based on contrast stretching, this method is more complex to segment the lung nodules because of lack enhancement. Thomas et al. [13] explained enhancing technique based on the morphological operation. Here the selection of size and shape of the morphological structuring element is tedious process. The above studies proposed a different technique but they have some disadvantages. To overcome this introduced a novel preprocessing technique, based on adaptive median filter with

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curvelet transform. Inorder to remove noise adaptive median filter is used, the contrast are enhanced by histogram equalization technique. Clear edges are obtained by using curvelet transform. The remainder of this paper is organized as follows. Section 2 illustrates the methodologies and performances metrics are explained in section 3. Section 4 describes the details experimental results and discussion. Finally, the conclusion is given in the Section 5.

2. Methodologies

The proposed preprocessing technique starts with image acquisition, Gray scale conversion, Adaptive median filtering, Histogram equalization, and Curvelet transform for de-noising. Here Matlab2016 software is used for implementation. The block diagram of novel method is shown in figure 1.

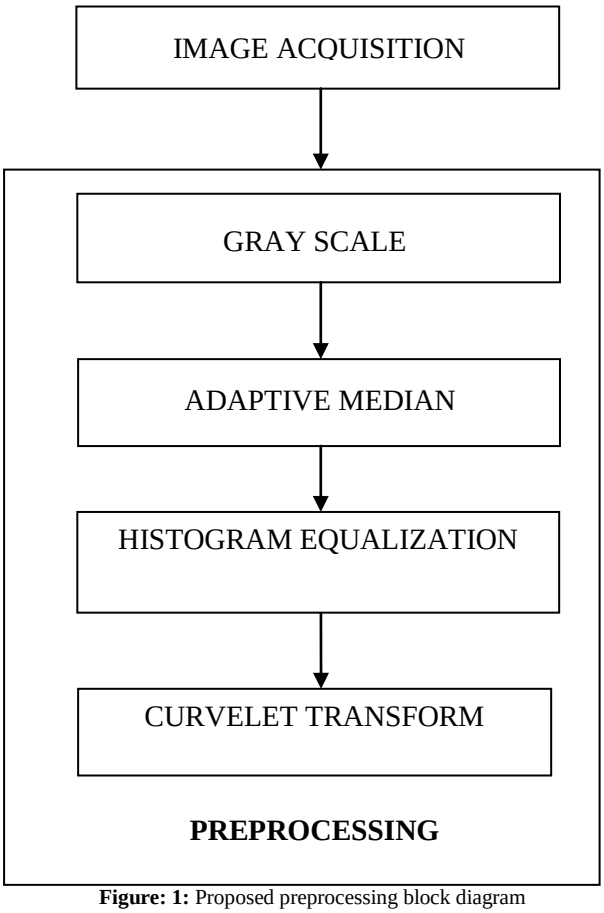


Figure: 1: Proposed preprocessing block diagram

2.1 Image Acquisition

Image acquisition is the process of obtaining medical images using imaging modalities. Various lung screening schemes are used, among which CT has more advantages, as it allows screening the whole lung area with high contrast and better details. The Lung Image Database Consortium (LIDC) provided by the National Cancer Institute (NCI) is one of the largest public databases. In this database the datasets are in DICOM format. For the next process covert the DICOM images into JPEG using dicom converter. Here 10 images used for enhancing; it includes 5 cancerous images and 5 noncancerous images.

2.2 Pre-Processing

Image pre-processing is mainly used for enhancing the qualities of the images by changing the pixel's quality, contrast levels and gray values. The distortion and noise of the acquired data's are eradicated by the following preprocessing steps.

2.2.1 Gray Scale Conversion

In a binary image the accurate image extraction is performed. Normally the image is in Red Green Blue (RGB) form, which is a logical representation of 3matrixes. The image dimension is usually 1×m, m represents number of pixel. The image in matrix format is complex to process, so the transformation is performed. In a gray scale image each pixel having a discrete level of o to 255. The dark color (black) represents the minimum value and the bright color (white) represents the maximum value. The dimension of the matrix in the image is represented interms of pixel value. Usually the medical image is in the form of gray scale, inorder to remove the unwanted component present in the image the gray scale transformation is performed. This conversion will eliminate the hardware error occurred during the scanning process.

2.2.2 Adaptive Median Filter

The adaptive median filter is widely used compared with the standard median filter, if the noise is higher than 0.2dB the standard median filter performance is poor. This filter determines impulse noise in an image by using spatial processing. This detect noisy pixel by comparing neighborhood pixel value and threshold value. If a pixel exceeds the threshold value it classifies as noise. These noise pixels are replaced by neighborhood pixel median value, which has already passed the noise classification. Working principles of the adaptive median filter is described below.

- fxy represents the size of the neighborhood pixel it will changed during the operation.
- Symbols

Amin = minimum gray (intensity) value in fxy

Amax = maximum gray (intensity) value in fxy

Amed = median of gray (intensity) levels in fxy

Axy = gray (intensity) at coordinates (x, y)

fmax = maximum size of fxy

- Algorithm

Step X: X1 = Amed - Amin

X2 = Amed - Amax

if X1 > 0 && X2 < 0, go to step Y

else increase the filter size

if filter size < Smax, repeat step X

else output Axy

Step Y: Y1 = Axy - Amin

Y2 = Axy - Amax

if Y1 > 0 && Y2 < 0, output Axy

else output Amed

2.2.3 Histogram Equalization

The histogram of an image is a plot (or) graph drawn between gray level values (0-255) in the x- axis and the number of pixels having the corresponding gray levels in the y axis. Histogram equalization is the method of improving contrast of image by distributing the values uniformly on intensity scale. In an intensity scale the dark image components are concentrated on the low side

similarly bright image in the high side. Low contrast images have narrow histogram, located in middle of the intensity scale. For a high contrast image the components are distributed over the wide range of intensity scale. Compared with the original image it provides bright images. The histogram equalized image has high dynamic range and high contrast.

2.2.4 Curvelet Transform

The curvelet transform is a novel multi-scale transform follow on wavelet transform. Dimension, location and orientation are the basic elements of curvelet transform. It has good orientation characteristic. For eliminating noise the curvelet transform is best method compared to the wavelet transform. It clearly represents the curved shapes, so it can be used in the graphical application. The main use is detecting edge and image de-noising. A curvelet coefficient t (j, l, k) is given by,

$$t\,(a,b,c): < f, \varphi_{a,b,c} > \quad (1)$$

Where,

a = 0, 1.. - Scale limit; b= 0, 1 ... - orientation limit;

c = (c1, c2), c1, c2 ∈ Z - translation limit.

A curvelet coefficient is the inner product between elements f ∈K2 (M2) and curvelet $\varphi_{a,b,c}$ as

$$t(a,b,c) = < f, \varphi_{a,b,c} > \quad \int_{M2} f(X)\,\overline{\varphi_{A,B,C}(X)\,dX}$$

$$= \frac{2}{(2\pi)^2} \int \hat{F}(y) U_a(M_\theta, y) e^{i<X_c^{(A,B),y}>} dy \quad (2)$$

The curvelets with a scale of 2-a, orientation θ_1 and position XC (A,B) = $R_{\theta 1}^{-1}$(c1.2a,c2. 2-a/2) can be represented as:

$$\varphi_{a,b,c} = \varphi_{a,}(R_{\theta 1}(X - X_c^{A,B})) \quad (3)$$

Where,

$\theta_1 = 2\pi . 2^{\lfloor a/2 \rfloor} . 1$, With l = 0, 1… $0 < \theta_1 < 2\,\pi$,

R_θ - Rotation by $\theta_1$radians.

The algorithm of the cuvelet transform is described as follows. Here the image is taken as I.

First the image 'I' is split in to 3 subbands they are s1, s2, s3 using additive wavelet transform.

In subband s1 and s2 performs the tiling process.

Then ridgelet transform is calculated on each tiling subbands s1 and s2.

It mainly focuses the sharpening of curves. The basic theory of curvelet transform depends on partition of the given image into small overlapping tiles then applies a ridgelet transform. This mainly used in the medical application. . One of the most important properties of the curvelet is

$$L = W\text{^}2 \quad (4)$$

Where,L = length = 2^-A, W = width = 2^-(2*A), (A = scale,).

In a tiling process the subbands s1 and s2 of the transformed images are divided in to overlapping tiles and resulted into smaller dimension, then transform curved line into straight line this will avoids the edge effects. Segmentation is performed to approximate the curved line into overlapping tiles. Discrete Ridgelet transform is applied on the segmented tiles. This ridgelet transform used for shape detection. The calculation of ridgelet transform is quite complex because it involves more steps but now a days the calculation is simple because it does not use ridgelet transform so the time complexity greatly reduced.

The waveform φa(x) is defined as FT $\varphi_a(y)\ U_a(y)$

Let the frequency window Ua defined in the Fourier domain by

$$U\,(p,\theta) = 2 - \frac{2a}{4M}(2\,p)N\frac{\left(2\left\lfloor\frac{a}{2}\right\rfloor\theta\right)}{2\pi} \quad (5)$$

Where,

M - radial window; N -angular window;

$\lfloor a/2 \rfloor$ is the truncated integer of a/2.

3. Performance Metrics

This Following performance measures are analyzed for lung cancer CT images. The main metrics PSNR, MSE, SNR, and SSIM are considered and the values are obtained

3.1 Peak Signal to Noise Ratio

PSNR is defined as the ratio of maximum possible power and the power of corrupting noise. PSNR is represented as

$$PSNR = 10\log10\left(\frac{MAX^2}{MSE}\right) \quad (6)$$

Where, MSE - Mean Square Error

MAX-maximum pixel value of image

3.2 Mean squared error

MSE is the quality of the estimator. MSE is calculated as

$$MSE = \sum_{i=1}^{K} p_i\ (x_i - t)^2 \quad (7)$$

3.3 Signals to Noise Ratio

SNR is the ratio of signal power to the noise power. SNR is expressed interms of following equation.

$$SNR = 20\log\frac{\text{rms signal}}{\text{rms noise}} \quad (8)$$

3.4 Structural Similarity Index (SSIM)

SSIM is a method for measuring the parallelism between two images. The based on the initial distortion SSIM measure the image quality. The ssim values ranges from -1 to 1. It is represented as follows.

$$SSIM = \frac{(2\mu_x\ \mu_y + l_1)\ (2\sigma_{xy})l_2)}{(\mu_x^2 + \mu_y^2 + l_1)\left(\sigma_x^2 + \sigma_y^2 + l_2\right)} \quad (9)$$

Where, μ_x is the average of x

μ_y is the average of y

σ_x^2 is the variance of x

σ_y^2 is the variance of y

σ_{xy} is the covariance of x and y

L1= (K1c)2 and L2 = (K2c)2 are two variables stabilize the division with weak dominator. c represents the dynamic range of the pixel value k1 = 0.01 and K2 = 0.03 by default.

4. Results and Discussion

VR In this section, the obtained results for lung preprocessing are discussed. The novel adaptive median filter and curvelet transform are used for enhancing.

4.1 Implementation Environment

The proposed CAD system is implemented with the help of MATLAB 2016 software. The MATLAB code is embedded with statistical and image processing tools. The Lung CT images of 10 patients obtained from LIDC database are analyzed and examined to obtain the preprocessing results of the proposed system.

4.2 Experimental Results

The following steps show the results obtained by giving the original lung CT image from the database. Preprocessing techniques are applied to obtain the best quality images. The resultant extracted performance metrics from the sample images are given in the table.

Take an image from the database: Images are obtained from LIDC. Here some of the images are analyzed and are given into the CAD system.

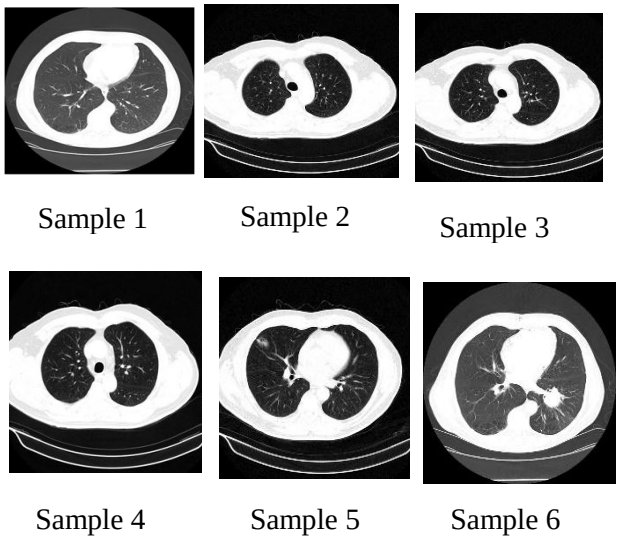


Figure 2: Dataset samples

Figure.2 shows the sample datasets obtained from LIDC. It consists of both benign and malignant lung image. Some samples (sample 1, sample 2) are taken to show that it is been used for analyzing the output of the proposed system.

The figure 3 shows the result of the benign image and fig 4 shows the results of the malignant image. Same processing is applied for both the image. Initially the image is given as input to preprocessing techniques to remove the noise and improve the quality. Basically medical images are grayscale by default in order to remove the unwanted hardware noise the grayscale conversion is performed. The CT scan image is converted into Gray scale image for further processing which is shown in figure 3 & 4 (b). The converted images are filtered to remove noise and filtering is done using the adaptive median filter. This filter detects noise pixel value and replaced by median pixel value. Adaptive Median filter output for the corresponding input image is shown in figure 3 & 4 (c). Histogram equalization is applied on these filtered images to increase the pixel quality of the images. Figure.3 & 4 (d) shows the histogram equalized images of the sample, given as the input to the processed preprocessing techniques. In this step, the input image is preprocessed using Histogram equalization technique to increase the contrast. Histogram equalized curve for a processed preprocessing technique and grayscale image histogram value is shown in figure 3 & 4 (e), (f). In this histogram the dark image components are concentrated on the low side of the gray scale; similarly the components of bright images are concentrated on the high side of the gray scale.

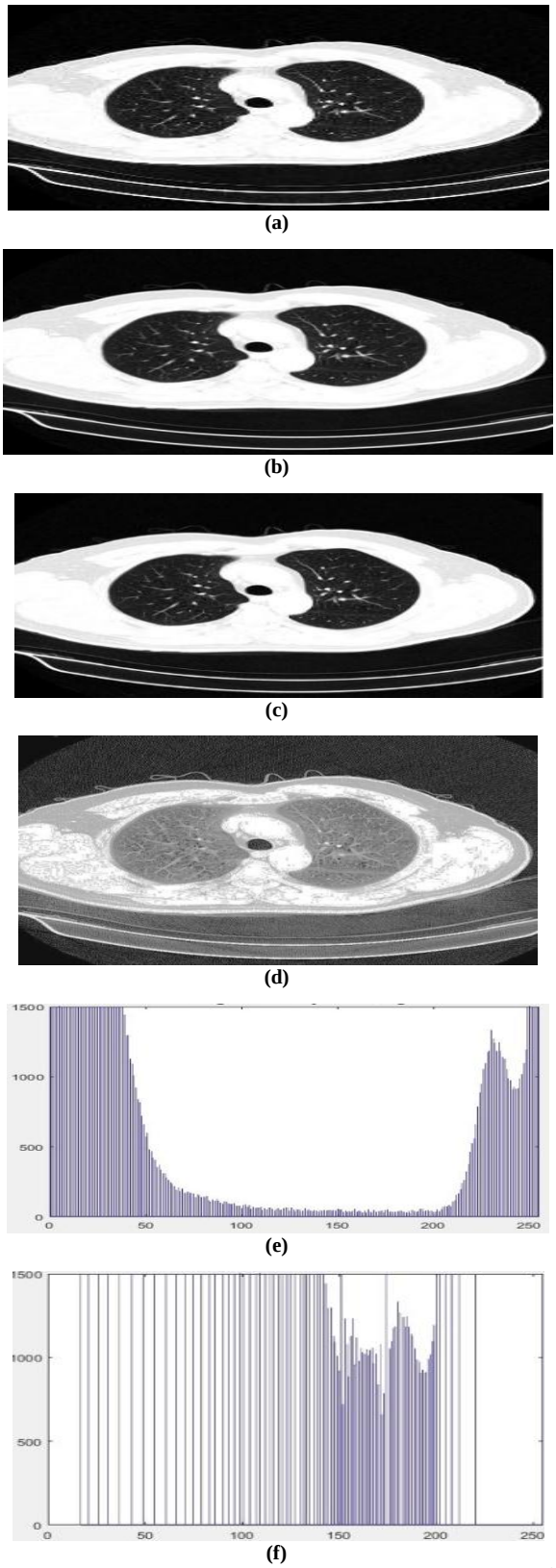
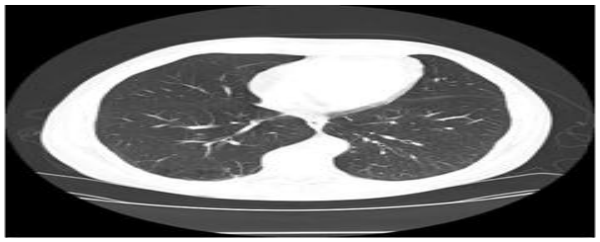
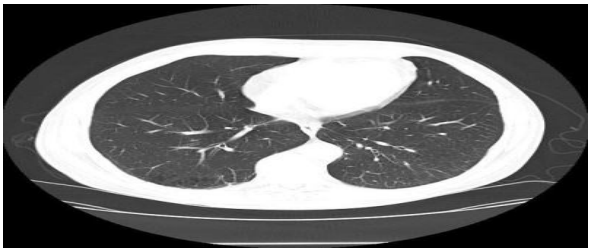


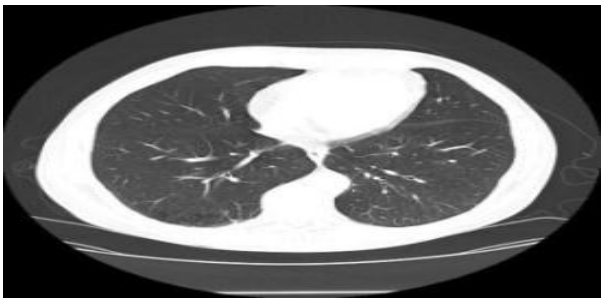
Figure: 3: (a) Input image (b) Gray scale image (c) adaptive median filter image (d) Histogram equalized image (e), (f) Histogram plots



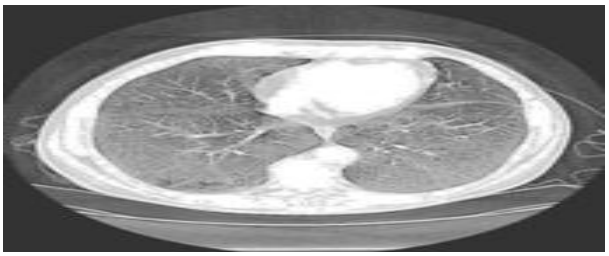
(a)



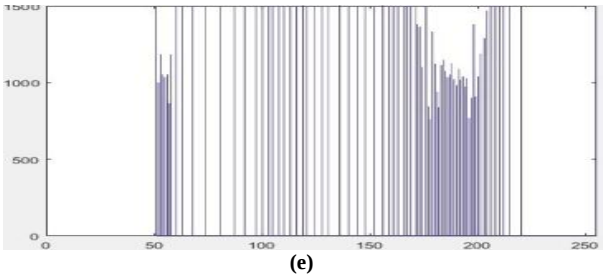
(b)



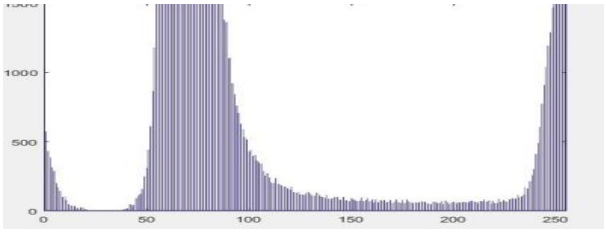
(c)



(d)



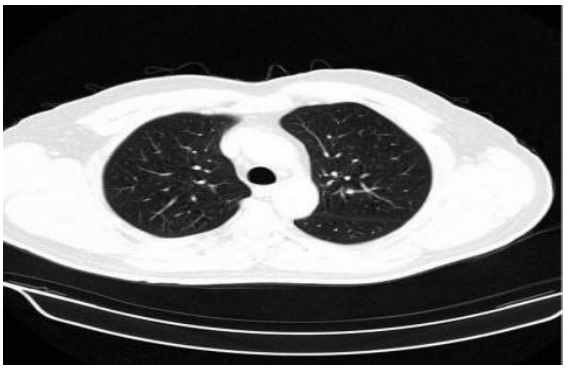
(e)



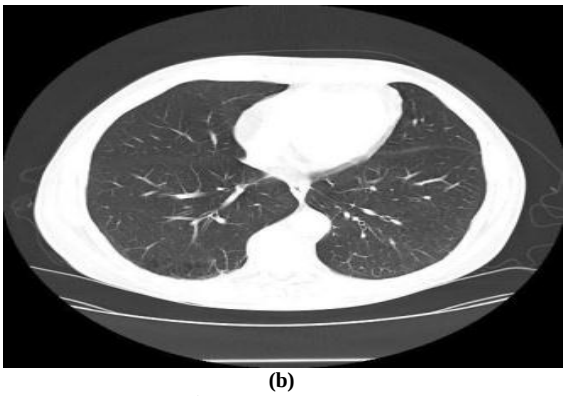
(f)

Figure: 4: (a) Input image (b) Gray scale image (c) adaptive median filter image (d) Histogram equalized image (e), (f) Histogram plots

Finally the original CT lung image curves are more sharply recovered and de-noised using curvelet transform to obtain the cancerous region. The final de-noised output of both benign and malignant image is shown in figure 5 (a), (b).



(a)



(b)

Figure: 5: Curvelet transformed (a) Benign image (b) Malignant image

Table: 1: Performance values of the database images

Metrics	MSE	PSNR	SNR	SSIM
Sample 1	59.1	35.66	30.41	0.9756
Sample 2	38.57	36.17	32.26	0.9735
Sample 3	69.76	35.45	29.69	0.9733
Sample 4	25.07	36.66	34.13	0.9766
Sample 5	43.17	36.04	31.77	0.9740
Sample 6	40.91	36.10	32.01	0.9742

The PSNR, MSE, SNR, SSIM calculation values for corresponding de-noised images are represented in table 1. In sample 4th, the PSNR and SSIM values are high when compared to other samples present in the database. The PSNR, SNR and SSIM are indirectly proportional to MSE values. The MSE value for sample 3 is 69.76 and the corresponding SSIM value is 0.9733 which is lowest one.

5. Conclusion

Rapid growth of cells inside the lung tissues is said to be Lung cancer. This type of cancer is cured if it is detected in an earlier stage and reduces mortality rate. The pre-processing steps for CT Lung images was done by adaptive median filter with curvelet transform, using this accurately removes the noise in the images. Initially the grayscale conversion was done; then the adaptive median filter performs the detection of noise in an image, further the image was enhanced by histogram equalization. Finally the curvelet transform de-noised the image and accurately find the curves of the images. By using proposed method the obtained results in terms of PSNR, MSE, SSIM and the corresponding values are 36.66, 25.07 and 0.9766.

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