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Analysis of Lung cancer images using Neural Networks

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Abstract: Among all the cancer types, lung cancer has been proved to be the dangerous one. It is because of the absence of symptoms even in the advanced stages of the disease. And the symptoms start appearing in the final stages of the cancer, thus making it hard to treat. In this paper, lung cancer detection by both visual means and neural networks are proposed. The X-ray images of Chest AP(Anterior Posterior) are analyzed using various image processing techniques for enhancement and edge detection.With the data set acquired, neural network architecture is created and trainedfor detecting whether the abnormality is benign or malignant.

Keywords--Lung cancer, Image processing, Edge detection, spatial and frequency domain, neural network

I.INTRODUCTION

Lung cancer detection at an early stage is very important as it can cause a great impact in the treatment of the patient.Worldwide, lung cancer kills over 1 million people a year[4].Lung cancer is the uncontrolled growth of abnormal cells that start off in one or both lungs; usually in the cells that line the air passages. The abnormal cells do not develop into healthy lung tissue, they divide rapidly and form tumors. Tumors are of two types.

i) Tumors that remain in one place and do not appear to spread are known as "benign tumors".

ii) Malignant tumors, the more dangerous ones, spread to other parts of the body either through the bloodstream or the lymphatic system.

Around 90% of lung cancers arise as a result of tobacco,Carcinogens and Genetic reasons. Both Spatial and frequency domain image techniques are employed for the lung image analyses. Spatial domain techniques operate directly on pixels. The spatial techniques used are Histogram Equalization, Median Filter, and average filter. The frequency domain technique used is Wiener filter. The mean square error and PSNR for the enhanced image are found and their efficiency is compared. Edge detection algorithms are used on the enhanced image. The algorithms used are Sobel and Prewitt. Edge detection is also carried on using Wavelet Transforms with the help of One of Stephane Mallat's many papers, Characterization of Signals from MultiscaleEdges [2]. Artificial Neural Networks are a system of interconnected neurons that can compute values from inputs by feeding information to the networks[5]. Using the acquired data set on lung cancer images, a neural network is trained and the performance is plotted and the confusion matrix is obtained.

II. IMAGE ENHANCEMENT

Spatial domain techniques are those which act directly on the pixels of the image.

A.Histogram Equalization.

The histogram plots the number of pixels in the image (vertical axis) with a particular brightness value (horizontal axis). Algorithms in the digital editor allow the user to visually adjust the brightness value of each pixel and to

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dynamically display the results as adjustments are made. Improvements in picture brightness and contrast can thus be obtained.

Suppose that for every pixel with level *r* in original image we create a pixel in the enhanced image with level S=T(r). The probability of an occurrence of a pixel of level I in the image is

$$P_x(i) = P(x = i) = \frac{n_i}{n}, 0 \le i < L \ (1)$$

L being the total number of gray levels in the image (typically 256), *n* being the total number of pixels in the image, and $P_x(i)$ being in fact the image's histogram for pixel value i, normalized to [0,1]. Fig 2.1(a) represents the original image and Fig 2.1(b) represents the histogram equalized image.
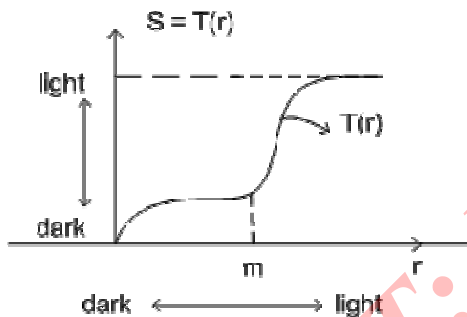

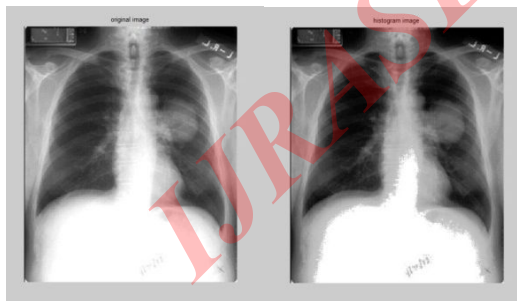Fig 1 Histogram graph manipulation

Fig 2(a) Original Image   Fig 2(b) Histogram

Normalized Image

III. SMOOTHENING:

A. Median Filtering

One such method is known as median filtering. In median filtering, the neighboring pixels are ranked according to brightness (intensity) and the median value becomes the new value for the central pixel. Median filters can do an excellent job of rejectingcertain types of noise, in particular, "shot" or impulse noise in which some individual pixels have extreme values.In the median filtering operation, the pixel values in theneighborhood window are ranked according to intensity, and the middle value (the median) becomes the output value for the pixel under evaluation.Fig 2.2(a) represents the original image and Fig 2.2(b) represents the median filtered image.
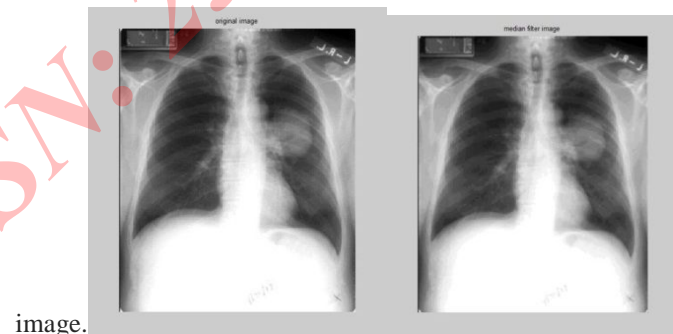

Fig 3(a) original image   Fig 3(b)median filtered image

B.Average Filtering

Take the average of intensity values in a *M X N*region of each pixel (usually M = N). Take the average as the new pixel value. The normalization factor MN preserves the range of values of the original image. It is a simple filter and is the same for all types of noises. But a big disadvantage is that it blurs the image and considerable amount of detail is lost.

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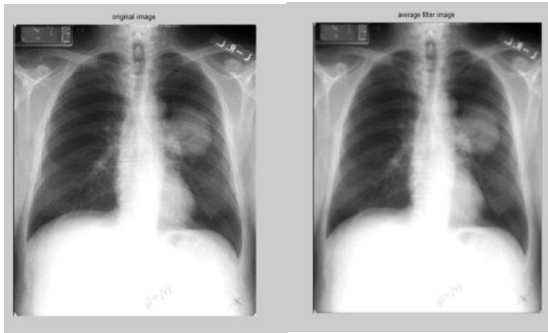

Fig 4(a) Original image   Fig 4(b) Average filtered image

C. Frequency Domain

1)Weiner Filter:

The Wiener filter is the MSE-optimal stationary linearfilter for images degraded by additive noise and blurring.Calculation of the Wiener filter requires the assumption that the signal and noise processes are second-order stationary (in the random process sense).Wiener filters areoften applied in the frequency domain.Given a degraded imagex(n,m), one takes the Discrete Fourier Transform (DFT) to obtain X(u,v). The originalimage spectrum is estimated by taking the product of X(u,v) with the Wiener filterG(u,v):

$$G(u,v) = \frac{P_n(u,v)}{P_s(u,v) + \sigma_n^2} \ (2)$$

Where

P_n(u,v) = Powerspectrum of the noise process, obtained by taking the fourier transform of the noise correlation.

P_s(u,v) = Power spectrum of the signal process, obtained by taking the fourier transform of the signal correlation.
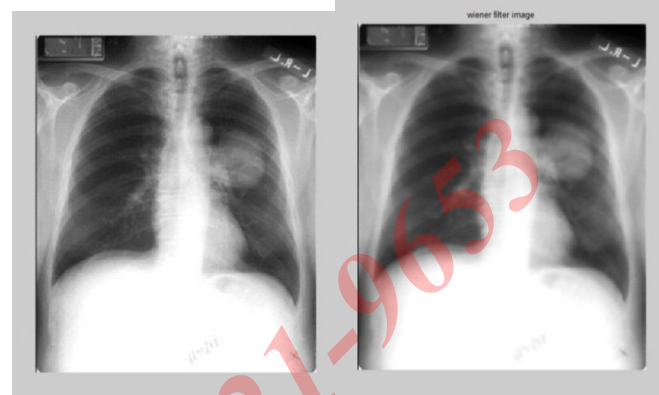
σ_n^2 = Noise variance.

Fig. 5(a) Original Image   Fig 5(b)Wiener filtered image

IV. COMPARISON OF ENHANCEMENT AND FILTERING TECHNIQUES:

A. Peak Signal to Noise Ratio (PSNR):

Peak Signal-to-Noise Ratio (PSNR), Signal–to-noise ratio (SNR) is a mathematical measure of image quality based on the pixel difference between two images [3]. The SNR measure is an estimate of quality of reconstructed image compared with original image. PSNR is defined as in

$$PSNR = 10log\frac{s^2}{MSE} \ (3)$$

where s = 255 for an 8-bit image. The PSNR is basically the SNR when all pixel values are equal to the maximum possible value.

B. Mean Square Error:

Mean Square Error (MSE), MSE is computed by averaging the squared intensity of the original (input) image and the

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resultant (output) image pixels MSE measures the average of the squares of the "errors." The error is the amount by which the value implied by the estimator differs from the quantity to be estimated

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \quad (4)$$

C. Structural Similarity Index Measure (SSIM):

The structural similarity (SSIM) index is a method for measuring the similarity between two images. The SSIM index is a full reference metric; in other words, the measuring of image quality based on an initial uncompressed or distortion-free image as reference. SSIM is designed to improve on traditional methods like peak signal-to-noise ratio (PSNR) and mean squared error (MSE), which has been proven to be inconsistent with human eye perception.

The SSIM metric is calculated on various windows of an image. The measure between two windows x and y of common size $M{\times}N$ is:

$$SSIM(x,y)$$
$$= \frac{(2\mu_x\mu_y + c1)(2\sigma_{xy} + c2)}{(\mu_x^2 + \mu_y^2 + c1)(\sigma_x^2 + \sigma_y^2 + c2)} \quad (5)$$

with

- μ_x the average of x;
- μ_y the average of y;
- σ_x^2 the variance of x;
- σ_y^2 the variance of y;
- σ_{xy} the covariance of x and y ;
- $c1 = (k_1L)^2$, $c2 = (k_2L)^2$ two variables to stabilize the division with weak denominator;

- L the dynamic range of the pixel-values (typically this is $2^{\#bits\,per\,pixel} - 1$);
- $k_1 = 0.01$ and $k_2 = 0.03$ by default.

In order to evaluate the image quality this formula is applied only on luma. The resultant SSIM index is a decimal value between -1 and 1, and value 1 is only reachable in the case of two identical sets of data.

D.Universal Image Quality Index:

Let $X = \{x_i | i = 1,2,….,N\}$ and $Y = \{y_i | i = 1,2,……,N\}$ be the original and test image signals, respectively. The universal quality index is defined as

$$Q = \frac{4\sigma_{xy}\bar{x}\bar{y}}{(\sigma_x^2 + \sigma_y^2)[(\bar{x})^2 + (\bar{y})^2]} \quad (6)\ ,$$

Where

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \ , \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i\ ,$$

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2 \ , \sigma_y^2$$
$$= \frac{1}{N-1}\sum_{i=1}^{N}(y_i - y)^2\ ,$$

$$\sigma_{xy}$$
$$= \frac{1}{N-1}\sum_{i=1}^{N}(x_i - x)(y_i - y) \quad (7)$$

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In order to understand this, the definition of Q as a product of three components:

$$Q = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \cdot \frac{2\bar{x}\bar{y}}{(\bar{x})^2 + (\bar{y})^2} \cdot \frac{2\sigma_x \sigma_y}{\sigma_x{}^2 + \sigma_y{}^2} \tag{8}$$

TABLE I

COMPARISION OF FILTERING TECHNIQUES

Types of filters	MSE	PSNR	SSIM	UIQI
Histogram Equalization	24650	4.33	0.8548	0.8635
Average filter	664.62	19.44	0.8490	0.8632
Median filter	27.16	33.83	0.9610	0.9754
Wiener filter	20.96	34.95	0.9848	0.9949

Based on the above results, we can confirm that the error is low and the peak signal to noise ratio is high in the wiener filter. Also the SSIM and UIQI are nearest to the maximum value 1 in the Wiener filter. So among the other techniques, wiener filter is the better technique for noise reduction.

V. EDGE DETECTION

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene.Classical methods of edge detection involve convolving the image with an operator (a 2-D filter), which isconstructed to be sensitive to large gradients in the image while returning values of zero in uniform regions.

A. Sobel's Edge detection:

The 3X3 convolution mask smoothens the image by some amount , hence it is less susceptible to noise. But it produces thicker edges. So edge localization is poor.

Convolution Mask

$$G(x) = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$G(y) = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$
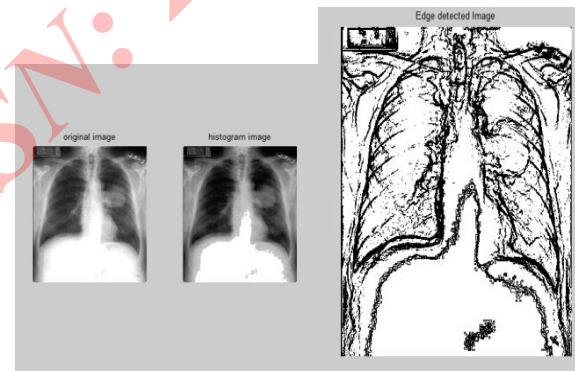

Fig 6(a) Original Image   Fig 6(b) After Sobel's Algorithm

From the above result, it is confirmed that the Sobel's method produces thicker edges.

B. Prewitt's Edge detection:

Prewitt Edge detection is nearly the same as sobel edge detection method except that they use different operational matrices for convolution.

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$$G(x) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \qquad G(y) = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$
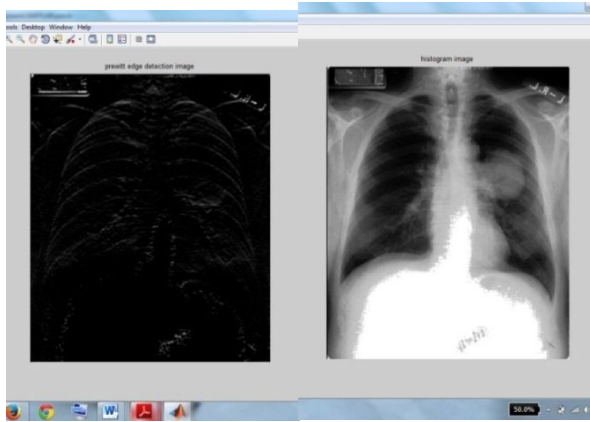

Fig 7(a) Edge detected image   Fig 7(b) original image

C. Edge detection using 2-D Wavelet Transform

Conventional Filters such as Sobel, Prewitt and Robert's Edge detection have a disadvantage that these gradient-based and zero-crossing finding algorithms are very sensitive to noise. They may misjudge the noise points as the part of real edges and miss some real edges because of the noises' interference. Furthermore, the masks' sizes are fixed and cannot be dilated for the need of varieties of problem domains.

The method uses only horizontal and vertical coefficients values
(LowHigh and HighLow coefficients 1) from each level of wavelet decomposition.
Wavelet transform modulus is defined by Eq. (9)

$$Mf(u,v,2^j) = \sqrt{|W^1 f(u,v,2^j)|^2 + |W^2 f(u,v,2^j)|^2} \quad (9)$$

for each pair of horizontal and vertical coefficients at $|W^1 f(u,v,2^j)|^2$ and $|W^2 f(u,v,2^j)|^2$ the same position in matrices.

A matrix of the gradient angles for the same pairs of coefficients is evaluated according to Eq. (9)

$$\alpha = \arctan\left(\frac{W^2 f(u,v,2^j)}{W^1 f(u,v,2^j)}\right) \quad (10)$$

Points in the original image for which values of $Mf(u,v,2^j)$ are local maxima in one-dimensional neighborhood in the direction of gradient are supposed to be edge pixels. These points are distributed according the boundary of important structures in the image. To recover edges, found individual maxima are chained.
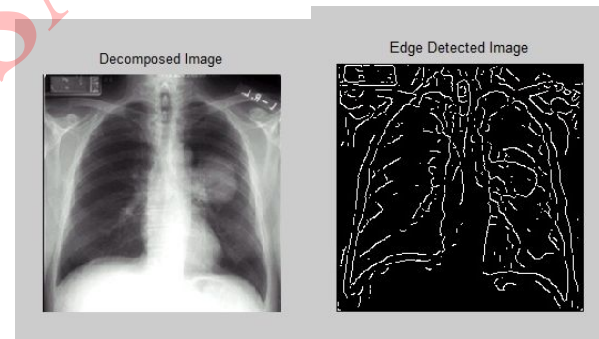

Fig: 8(a) Original Image   Fig 8(b) Edge Detected image using Wavelet Maxima

It is found that the Edge detection using Wavelet local maxima is better than Prewitt's and Sobel's algorithm as the latter takes noises into account. And we can see that the edges are thicker in Sobel's method. And finally the edge detected images are visually investigated.

VI. THRESHOLDING

Thresholding is a non-linear operation that converts a gray-scale image into a binary image where the two levels are assigned to pixels that are below or above the specified threshold value.This method gives satisfactory results for bimodal histogram images. Threshold values based on this method will be between 0 and 1, after achieving the threshold value; image will be segmented based on it.

VII. FEATURE EXTRACTION

The features should carry enough information about the image and should not require any domain-specific knowledge for their extraction. Sequence of stages started from image enhancement, image segmentation and cropping, finally feature extraction get introduced. Feature extraction is an essential stage that represents the final results to determine the normality or abnormality of an image. And 9 features are extracted from the lung cancer image. These attributes are made into a .xls file and it is used in training the Artificial Neural Network.

VIII. ARTIFICIAL NEURAL NETWORKS

An Artificial Neural Network (ANN) is an information processing system which contains a large number of highly interconnected processing neurons. These neurons work together in a distributed manner to learn from the input information, to coordinate internal processing, and to optimize its final output. We use ANN to classify the images containing benign and malignant tumors by training with the acquired datasets.

The datasets used contains 9 attributes that are related to the lung nodule. Lung cancer detection is done by interpreting the output .xls file. The output consists of two rows where one corresponds to benign and the other to malignant. Based on the values in each column, we can declare if the tumor is benign or malignant.

The Network type used is Feed-Forward network and the algorithm used is Back-Propagation algorithm.The type of training used in this network is Supervised learning. Here the network is trained by providing it with input and matching output patterns. These input-output pairs can be provided by an external teacher, or by the system which contains the neuralnetwork.
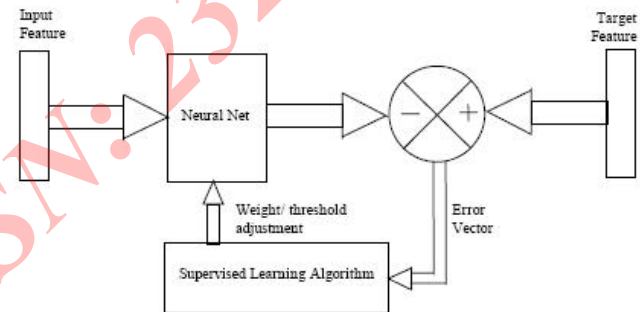

Fig 9 Training Algorithm

The artificial Neural Network consists of 3 layers.

The three layers are

- ➢ Input layer
- ➢ Hidden layer
- ➢ Output layer

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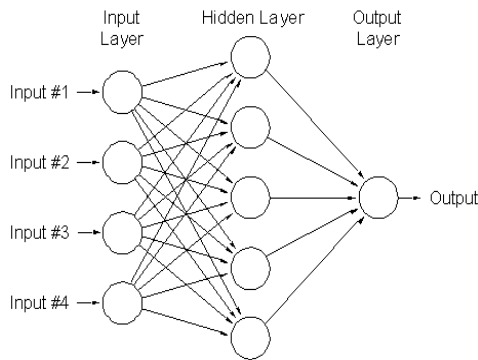

Fig 10 Artificial Neural Network Architecture

The performance graphs are plotted and the confusion matrix is obtained. The diagonal cells show the number of cases that were correctly classified, and the off-diagonal cells show the misclassified cases. The blue cell in the bottom right shows the total percent of correctly classified cases (in green) and the total percent of misclassified cases (in red).
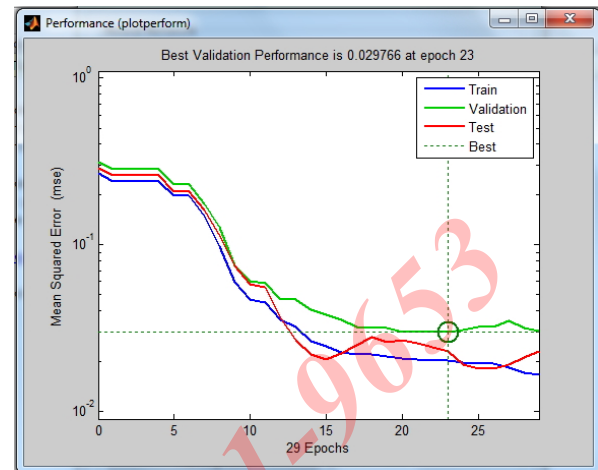

Fig 11 Confusion Matrices

Fig 12 Performance Plot

IX. ANALYSIS OF THE RESULTS

This project has implemented many types of filtering techniques and edge detection techniques with a lung cancer X-ray image as the input. The histogram equalization was successfully implemented but the resultant imagewas noisy. In order to eliminate the noise to a certain level, many filtering techniques were used.

Both spatial and frequency domain techniques were compared with each other. It was found that wiener filter techniques had the least Mean Square Error (MSE) and the highest Peak signal-to-noise ratio. So, we can conclude that wiener filter is the most efficient technique among all other techniques used. Even the edge detection techniques were compared but using visual recognition. All the edge detection algorithms except Wavelet 2-D maxima didn't respond well to the noise in the input image. The wavelet method produced better results than the other algorithms and the edges were clearly seen irrespective of the noise in the input image.
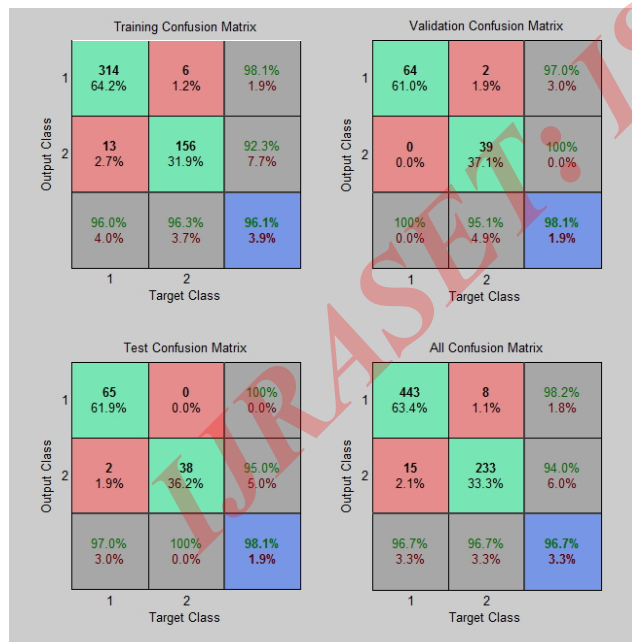
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Using segmentation and feature extraction methods, 9 different attributes were found. These attributes related to the lung cancer nodule are used as inputs to the neural network. The attributes obtained are made into a spreadsheet file and given as the input for training the neural network. The supervised network is the best method for training the network as it is more accurate than the unsupervised training. After training, the output file is obtained which is of the spreadsheet format. The spreadsheet consists of 699 columns and 2 rows. The rows represent whether the cancer is benign or malignant. The values on each column are used to identify whether the cancer is benign or malignant. Then the performance graph is obtained. Performance graph is used to know at which point the performance is maximum. It is found that the performance is optimum at epoch 23. And the confusion matrix is obtained. This matrix is used to know the accuracy of classification of both correctly classified and misclassified data during the training. The green and the blue colored boxes in the confusion matrix represent the correctly classified data, while the rest of the boxes represent the percentage of misclassified files. As we can see, the accuracy of correctly classified data is 96.7 % which is high. Thus early detection of cancer is possible using a Lung cancer X-ray.

X. CONCLUSION

The Chest X-ray images have been enhanced and smoothened by various methods whose performances are compared. Later edge detection is carried out on the enhanced image, for a better visual operation. And we conclude that Wavelet Edge detection is better than Prewitt's and Sobel's edge detection because the latter two takes the image noise into account and they do not respond well to noisy images. Then using image segmentation and feature extraction, 9

attributes of the images are obtained which are used as the input data for the Neural Network. And in the Neural network part, it is observed that an accuracy of 96.7% is achieved for the dataset. Although for some reasons this network cannot be a substitute for a human doctor, but they could be used for retesting the images.

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