Early Detection and Clustering of Lung Cancer in X-Ray Images through Fuzzy - ART Nueral Ntwork

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ABSTACT: *Cancer is the most familiar disease that affects human body. The time factor is very important to discover the abnormality issues in target patients, especially in various cancer tumors such as lung cancer, breast cancer etc., To increase the survival rate of cancer patients, as it is extremely poor, recently, image processing techniques have been used widely for earlier detection and treatment with reduced risk. This paper presents a Fuzzy-Adaptive Resonance Theory (ART) neural network based approach for early detection of lung cancer from raw chest X-ray images. Image quality and accuracy in predicting the presence of nodules and clustering them into one of the four stages of cancer are the core factors of this paper. Removal of noise using various filters and segmentation of the lung to detect abnormal regions in the X-ray images has been carried out. Relying on extracted features like area, perimeter, shape of the detected nodules, a clustering method is used to cluster the nodules appropriately to verify whether a region is a malignant nodule or not in consent with the domain expert knowledge.*

Keywords: Fuzzy-ART, Lung Cancer, Image Processing, Segmentation

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1. Introduction

Lung cancer was rare at the beginning of the 20th century, is now a global problem, which is most frequent cancer in the world. The survival rate can be improved by discovering the existence of cancer in early stage. Early stage can be performed in inhabitants screening. Chest projection radiography is the most common screening mode [1]. It has been exposed in the Early Lung Cancer Action Projects that the conventional chest X-ray used for the finding of nodules. The nodule appears in lung as a spherically shaped mass, which is distorted by surrounding anatomical structures [12]. The complexity for detecting lung nodules in X-ray radiographs are nodule sizes, density and contrast alteration [15]. The diameter of a nodule can be in between a few millimeters up to several centimeters. Some nodules are rather denser than the neighboring lung tissues. Hence, the visibility on a X-ray radiograph is reduced. The nodule can be found anywhere in the lung field as a result of contrast variation to the background.

1.2 Lung Cancer

Abnormal cells multiplying and developing into a tumor causes lung cancer. Cancer cells can be taken away from the lungs in blood, or lymph fluid that surrounds lung tissue. Metastasis spread has occurred to any distant organs or lymph nodes awayfrom the chest through the bloodstream. Common distant organs are opposite lung, brain, liver, bones and adrenal glands. Cancer that originates in the lung is called primary lung cancer [15]. There are basically two types of Lung cancers: Small Cell Lung Cancer (SCLC) and Non Small Cell Lung Cancer (NSCLC). SCLC type cancerous is diagnosed about 20 out of every 100 lung cancers. These cancer cells are small in size that caused by smoking and is very rare for someone who has never smoked. This type of lung cancer often spreads very early. NSCLC are collected together because they act in a similar way and respond to behavior in a different way to small cell lung cancer.

2. Related work

The lung regions extraction comes up into two different categories; either *rule-based* or *pixel classification based* category [7]. Most of the proposed methods belong to *rulebased* category [9,10], where a progression of phase, tests and rules are used in the extraction process. Dynamic programming techniques are used for thresholding, region growing, edge detection and ridge detection, morphological operations, fitting geometrical models or functions. On the other hand, there is one more approach employed in lung regions extraction process based on pixel classifications, where each pixel in the X-Ray is classified into lung or its background using classifiers, usually the neural networks, trained with a variety of local features including intensity, location and texture measures [7]. Computer aided diagnosis systems are divided into two groups [9] *density-based* and *model-based* approaches. Taking into considering the fact that lung nodules have relatively higher densities than those of lung parenchyma, *density-based* detection methods employ techniques such as multiple thresholding, regiongrowing, locally adaptive thresholding in combination with region growing, opening and closing, using the histogram. The top 20% gray values are considered as preliminary cancerous candidate regions. Using the histogram, the normal tissues are removed, then ellipticalshaped regions, which is in general characterize abnormalities, are detected, and fuzzy clustering is used to identify nodule andidates in the lungs. For the *model-based* detection approaches, the relatively compact shape of a small lung nodule is taken into account while establishing the models to identify nodules in the lungs [11]. Techniques such as morphological filters and the anatomy based generic model have been proposed to identify sphere shaped small nodules in the lung. Nodule candidates are detected using template matching or a modified Hough transform in which edge pixels vote for circles that could cause these edges. After getting segmentation results, different features are extracted, to be used in the diagnosis phase, where sets of rules are put together to distinguish between true and false cancerous candidates. Different features were extracted by the various researchers in the diagnosis phase. In some methods, uniformity, connectivity and position features were extracted [13]. The features such as size, circularity and mean brightness of Region of Interests (ROIs) were extracted [14]. Area, thickness, circularity, intensity, variance, localization and distance from the lung wall are the extracted features in [8]. The underlying idea of developing a nodule diagnosis system is not to hand over the diagnosis to a machine, but rather that a machine algorithm take action as a support to the radiologist and points out spots of suspicious objects, so that the overall sensitivity is boosted.

Problem Statement:

"*Given the chest X-ray image of the patient, the objective is to develop diagnosis system that detects the presence of cancerous nodules in the lungs and also to further detect the appropriate stage of the cancer on par with domain expert"*

The proposed diagnosis system aims at improving the quality and accuracy of diagnosis, thereby increasing therapy success by early detection of cancer, avoiding unnecessary biopsies and reducing radiologist interpretation time [16,17]. The system makes use of efficient image processing techniques to detect as well as diagnose the stage of the cancer by means of fuzzy-ART neural network based clustering algorithms so that appropriate treatment can be provided to the patient.

3. Nodule Diagnosis Dystem

A nodule appears in lung X-Ray as a spherically shaped mass which can be distorted by surrounding anatomical structure and there are no limitations on size or distribution in lung tissue [5]. The nodule is classified into certain categories; nodule is connected to pleural surface, other connection to neighboring vessels by thin structure [16]. Pre-diagnosis approaches help to locate the risk of lung cancer disease in very early stage [2]. Some of the approaches used in pre-diagnostic are artificial neural network based learning process [3], Rule Based Learning Technique, Supervised Learning Methods, Fuzzy System, Expert System and Genetic Algorithms. In this paper, we use Fuzzy-ART ANN based learning method, where the original JPEG X-ray image of 30 cases in various size and contrast are used for both healthy and cancerous patient, that are collected from reputed medical diagnosis centre CLUMAX Bangalore and it is further to classify the tumor as *benign* or *malignant* [16].

The entire process of lung nodule diagnosis system is shown in Figure 1. It uses resizing, cropping and filters like median & Gaussian to smooth the X-ray images and to enhance the contrasts. The lungs in the images are then segmented by applying the Otsu's thresholding method that uses gray thresholding function which compute global image threshold. After binary conversion, nodule detection system works-out morphologic technique to extract features include the perimeter, area and shape. After this, cancerous identification of a lung nodule is employed to analyze those features to evaluate whether cancer cells exist or not along with their type.

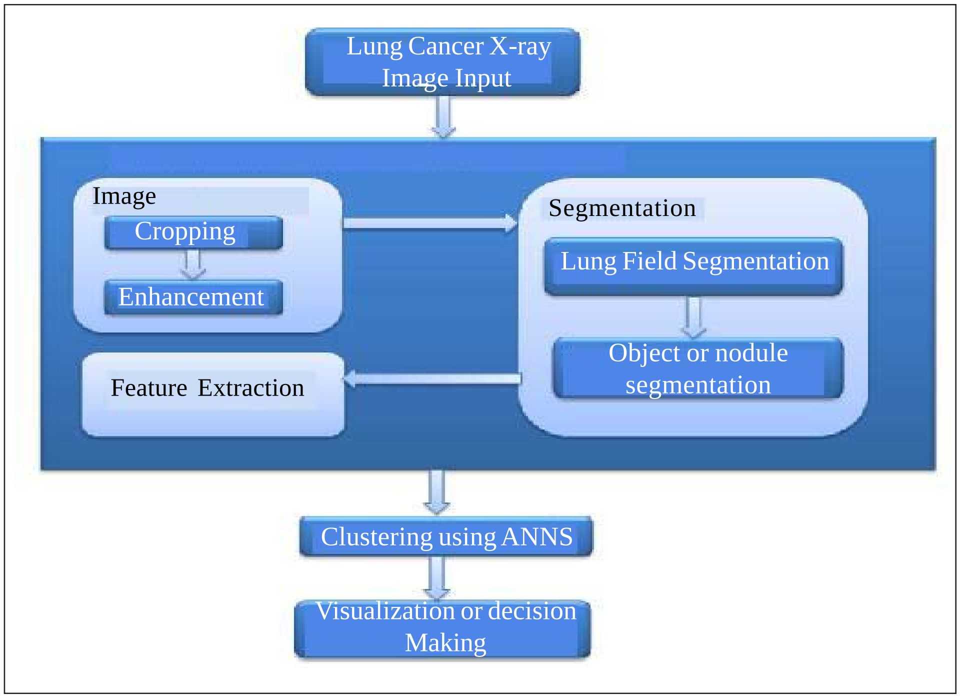


Figure 1. Lung Nodule Diagnosis System

3.1 Image Pre-processing

The original image format can be in jpg, bmp, tif and the image can vary in sizes and contrast. Therefore, all the images have to undergo several pre-processing steps in order to standardize the image characteristics. Image pre-processing involves cropping, resizing, and contrast adjustment. Histogram equalization is used to enhance the contrast of the image [4]. Before any procedures are carried out, all the images have to be converted into grey scale images having only 256 grey levels, as to facilitate intensity analysis. The Figure 2(a) shows the original X-ray image of the chest and Figure 2(b) shows that the image is enhanced in terms of contrast after pre-processing.

It is necessary to improve the quality of X-Ray image by denoising and enhancement of its structure & contrast. Mean, Median, Laplacian and Gaussian filters are used for denoising after resizing and cropping of X-Ray images.

The input X-ray image may contain noises such as white noise, salt and pepper noise etc., White noise is the most common problem hence it is eliminated through median filters. Median filtering is a nonlinear common enhancement digital filtering technique for removing noise without reducing the sharpness of the image [6]. It is usually applied for smoothing of the lung boundaries in thresholding. We applied filtering by assigning 5x5 pixels.

3.2 X-ray Image Enhancement

Histogram manipulation is able practice for X-ray image enhancement. Histogram of X-ray divides the interval between the minimum and maximum pixel values into equally spaced bins. The shapes of histogram are depending on the size of intervals. Histogram equalization is done so that all the image intensities are with equally divided bins [16]. To calculate value of *k* for each brightness level *j* in the original X-ray image, we use the formula

$$k = \sum_{i=0}^{j} \frac{N_i}{\tau} * I_{max}$$

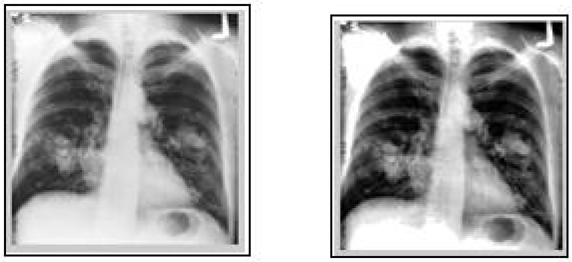


Figure 2. a) Original Image b) enhanced Image

Binary conversion is then applied the process of enhancement as 8-bit X-ray image altered into 2-bit gray scale image. If the pixel value in image is greater than threshold (τ) value, it shows 0 (black) else it shows 1 (white).

3.3. Thresholding

The cancerous nodules in the X-ray image appear in low contrast and the non-nodule area show neither too bright nor too dark. we use a multi-level thresholding to classify any point (x, y) in the image $f(x, y)$ as belonging to object class if $\tau_1 < f(x, y) \leq \tau_2$ to the other object if $f(x, y) > \tau_2$ and to the background if $f(x, y) \leq \tau_1$, where τ_1 and τ_2 are two threshold values and limits $\tau_1 = 120$ and $\tau_2 = 170$. Upon observing all the X-ray images in database, pixels within cancerous nodule are in range 125 to 158. The pixel value less than τ_1 and greater than τ_2 as background set to zero. The pixels whose values lie between τ_1 and τ_2 refer to foreground pixels. After this process, the image is converted into binary form by setting all the foreground pixel values equal to 255.

3.4 Lung Segmentation

3.4.1 Lung field Segmentation

Lung segmentation procedures have been proposed due to the approximate intensity value between the lung cancer nodule and the unwanted background region. The approximation of this intensity value makes it difficult to perform perfect nodule detection. The most important step for this process is morphological operations to remove unwanted noise. Firstly opening by reconstruction is carried out in order to remove all objects below a certain size by choosing the appropriate structural element size. Later closing by reconstruction is used in order to fill the small gaps and obtain smooth boundaries. Both involve series of dilations and erosions. These operations help in obtaining the foreground and background markers. A mask image is obtained out of this as shown in Figure 3(a) and finally, mask image is overlaid on the original image to obtain the segmented lung. Lung segmentation is very useful to extract the features from lung X-Ray. It may classify image pixel into anatomical regions such as bone muscles and blood vessels. In X-Ray image, segmentation has been done through pixel by pixel multiplication o f lung mask. Lungs can be easily separated from other anatomic structure by binary thresholding $m1(x, y) = \tau(f(x, y))$. After thresholding, the background is eliminated by suppressing all adjacent to image edges by flood filling. The matrix value put on view as 1 used for lungs and 0 for background. Figure 3(b) shows the segmented lungs.

3.4.2 Nodule Segmentation

Once the lungs have been segmented from the image, the presence of nodule has to be detected. For lung nodule detection, several operations are again applied such as the *thresholding* and the *morphological* operations for removing unwanted pixels in the image. A threshold value is obtained and fine-tuned to obtain the foreground image of the nodules. Other morphological operations such as *erosion* and *dilation* operations are also have been implemented. Erosion operator makes a region smaller, while dilation operator enlarges a region. The use of these operations eliminates linear gaps and also makes the objects smooth. All the nodules that are segmented need not be cancerous in nature. Hence only the candidate nodules are selected based on the minimum area that a nodule should have to be called cancerous. Figures 4 (a) and 4(b) shows all the nodules that are segmented and the cancerous nodules that are selected.

3.5 Edge Detection

It is a set of connected pixels that lie on the boundary between two regions and detected by sobel methods because of its accuracy. Convolve the image g (r, c) to get smooth image and apply the threshold values to find the edge.

3.5 Lung Nodule detection

In this, several operations are applied such as thresholding and morphological operators like erosion and dilation. Erosion operator makes a region smaller while dilation operator enlarges a region [16]. Lung mask is smoothed by morphological closing with line element.

$$e\,(x_0, y_0) = \begin{cases} 1, \ for \ \sqrt{(x-x_0)^2 + (y-y_0)^2} \leq 4.5\, mm \\ 0, \ otherwise \end{cases}$$

The values in pixels are different. The smooth mask is $s\,(x, y) = m\,(x, y) * e\,(x, y)$. Image $f\,(x, y)$ is multiplied by smooth mask $s\,(x, y)$ element by element $g\,(x, y) = f\,(x, y) * s\,(x, y)$. From segmented lung X-Ray image, a nodule candidate is detected, high densities appears as zero value (black) irregularities on the lung edge after thresholding. Now, subtraction of threshold image $t\,(x, y)$ and smoothed mask $s\,(x, y)$ is done for getting result $j_0\,(x, y) = s\,(x, y) - t\,(x, y)$. Here, nodule candidates that are not located on lung boundary are eliminated from $j_0\,(x, y)$.

Lung boundary is generated from the smoothed mask by morphological dilation and addition of X-Ray, where e is a line element. The mask $j_0 = s\,(x, y)$ is then multiplied element by element by boundary mask $b\,(x, y)$ which is given by

$$b\,(x, y) = s\,(x, y) + (s\,(x, y) \oplus e\,(x, y))$$

$$\text{and } j\,(x, y) = g\,(x, y)\, b\,(x, y)$$

3.6 Feature Extraction

The features extracted would act as input vectors for the clustering process. Regional properties are used to extract the features. Three features would be considered for extraction: *area, shape and perimeter*. *Area*, *perimeter* and *shape* are the scalar values. *Area* allocate the actual number of overall summation of pixels (value 1) and *perimeter* provide the real number of inter-connected outline of the nodule pixel in the binary X-Ray image. After getting the values from area and perimeter, *shape* can be calculated by the formula:

$$Shape = \frac{4\pi + Area}{(Perimeter)^2}$$

These features as shown in Table 1 are streamed onto a file for future analysis and also to facilitate the clustering process.

4. Fuzzy-Art based clustering

The concept of Neural Networks (NN) is being used to achieve clustering. An unsupervised neural network is a net which clusters input patterns into categories. Every output node in an unsupervised network represents a category. The neural network has to decide to which category the input belongs most likely. Every category is related to features which can possibly occur in the input. The network has to extract features from the input in order to decide to which category the input belongs. Several researchers establish that NN techniques that are accurate for predictive inference with potential to support clinical decision making.

Adaptive Resonance Theory (ART) NN implements a clustering algorithm where in, an input is presented to the network and the algorithm checks whether it fits into one of the already stored clusters. If so, the input is added to this cluster. If not, a new cluster is formed. ART NN is used in modeling such as invariant visual pattern recognition. Fuzzy-ART has been used to cluster the shapes of the nodules found out into categories like Stage1, Stage2, Stage3 and Stage4.

Fuzzy-ART is an unsupervised learning algorithm and it uses structure calculus based on fuzzy logic. The algorithm is based on ART NN. In Fuzzy-ART, the generalization of learning both analog and binary input patterns is achieved by replacing the appearance of the logical AND intersection operator '$\cap$' in ART-1 by the MIN operator '$\wedge$' of fuzzy set theory. Fuzzy-ART NN involves several differences according to ART-1: (1) non-binary input vectors can be processed; (2) there is a single weight vector connection; and (3) in addition to vigilance and threshold, two other parameters have to be specified: a choice parameter and a learning rate.

5. Results and Discussions

Experiments have been conducted on the lung X-Ray images dataset consists of 30 images obtained from CLUMAX diagnostic centre. The training dataset of X-ray images of lung cancer are processed in three stages to attain more quality and accuracy in the observed results. The results are then visualized to provide the appropriate treatment to the patient. On one hand, we have developed a nodule diagnosis system for early detection of lung cancer in X-Ray images, wherein a high level of sensitivity has been attained. This prevents the system from hindering the radiologist's diagnosis. On the other hand, the proposed system is capable of detecting nodules with *area*, *perimeter* and *shape*. This shows that the system is capable of detecting lung nodule in primarily stagesas shown in Figures 6 (a), 6 (b), 6 (c), 6 (d), 6(e) and 6 (f) from the cropped X-ray of Figure 5, so that the patient's survival rate will improve because of early diagnosis.

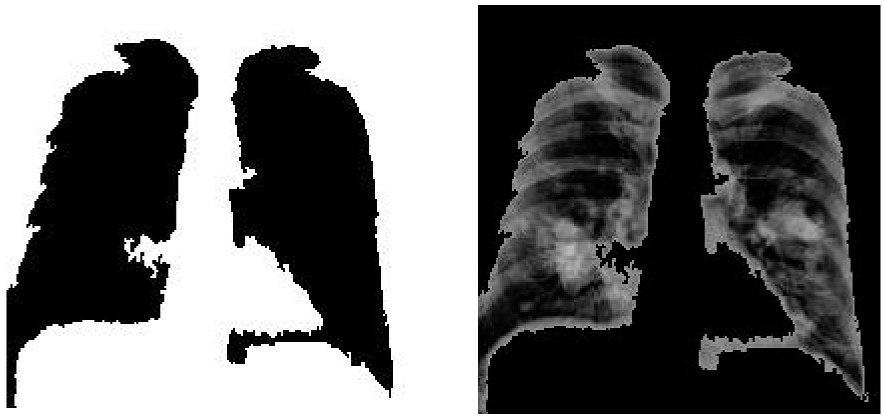


Figure 3. a) Mask Image b) Segmented Lungs

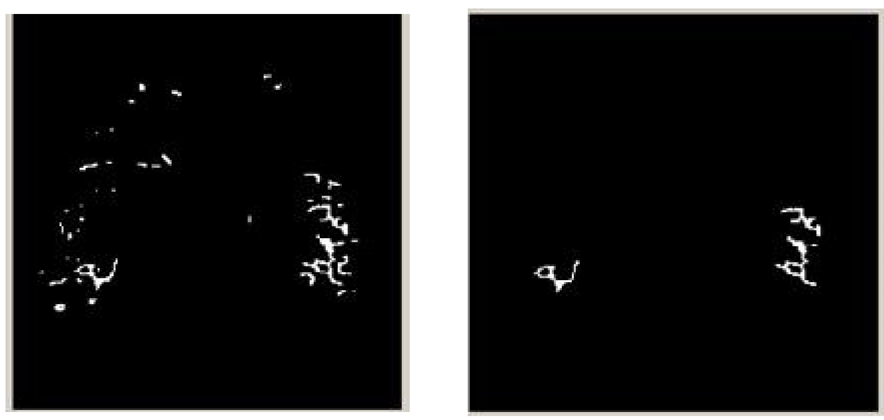


Figure 4. a) Segmented Nodules b) Candidate Nodules

	Nodule Number	Area	Perimeter
1	1	89	83.5980
2	2	137	119.6399
3	3	83	86.4264

Table 1. Extracted features of the candidate Nodules

6. Conclusion

The proposed system successfully detects the presence of cancerous nodules in the lungs of the X-Ray images being provided as inputs to the system. Image processing techniques that are applied to the supplied image would ensure the efficient detection of the presence or absence of nodules (cancerous cells) in the lung segments. The detected nodules would also be grouped into one of the stages of the cancer based on the various features extracted from the nodules. Effective clustering method based on Fuzzy-ART NN has been applied in order to achieve this.

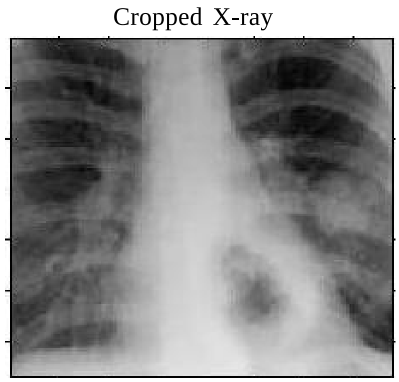
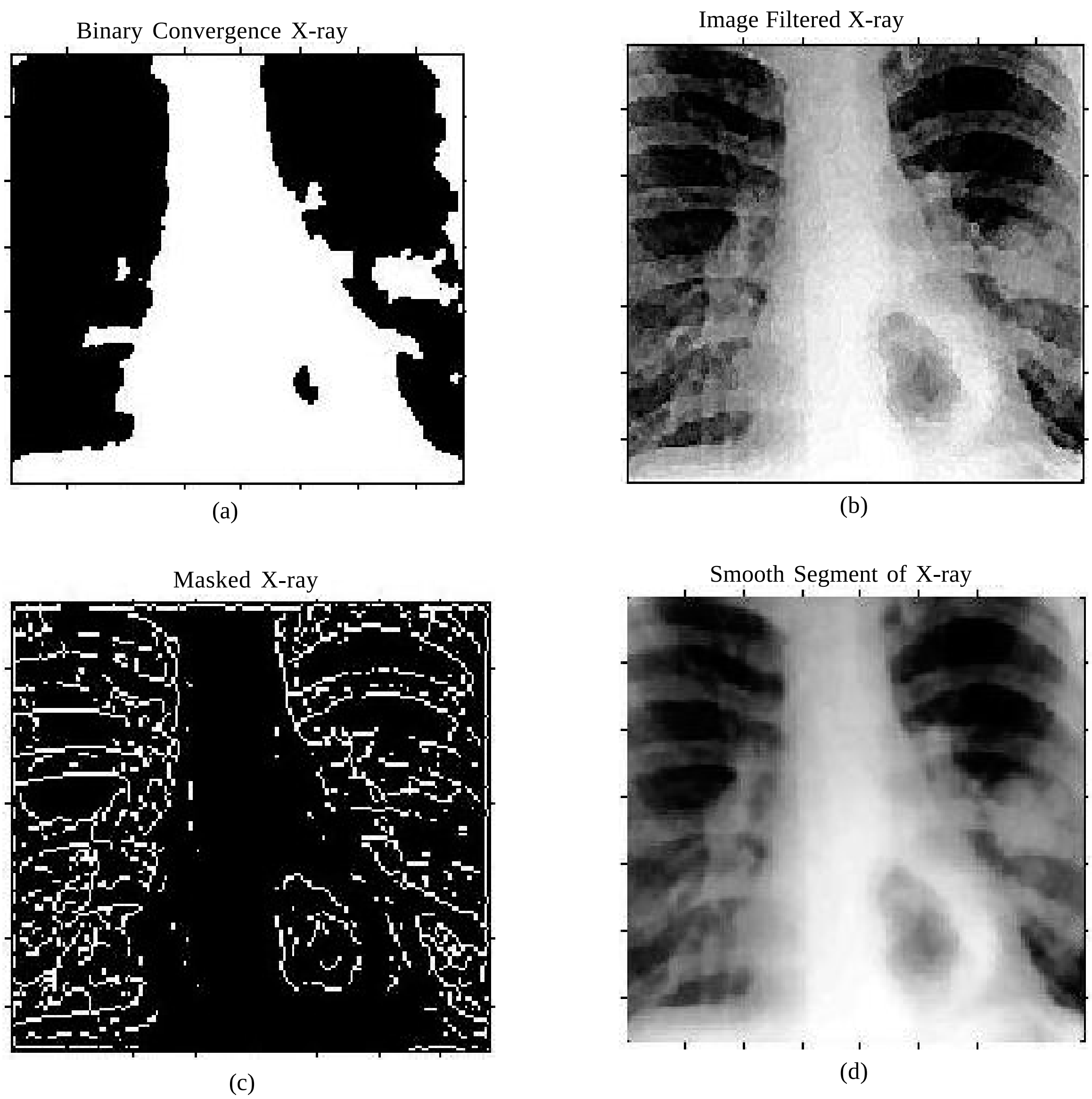
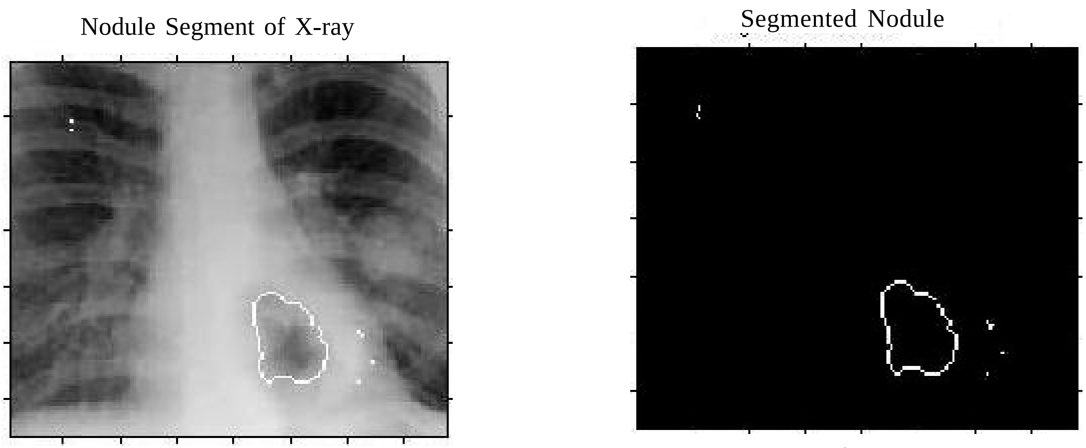


Figure 5. Cropped X-ray Image





(e) (f)

Figure 6. Results of Proposed Diagnosis System

ART NNs are known for their plastic and stable learning of categories, hence providing an answer to the so called stability-plasticity dilemma. As the input environment changes in time, the accuracy of the older back propagation network method will rapidly decrease because of the weights are fixed thus preventing the network from adapting to the changing environment.

It has been noted that results of Fuzzy ART NN depends critically upon the order in which the training data are processed. The effect can be reduced to some extent by using a slower learning rate, but is present regardless of the size of the input data set. Hence Fuzzy ART NN estimates do not possess the statistical property of consistency.

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