DESIGN AND DEVELOPMENT OF PULMONARY TUBERCULOSIS DIAGNOSING SYSTEM USING IMAGE PROCESSING TECHNIQUES AND ARTIFICIAL NEURAL NETWORK IN MATLAB

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ABSTRACT

In this paper we are presenting a system which has been designed to detect the presence of pulmonary tuberculosis (PTB). Using image processing techniques and Artificial Neural Network (ANN) the system is designed. These toolkits are available in Matlab. So, the whole system is designed on the Matlab platform. The toolkit ANN with Back Propagation (BP) is used as classifier. For the detection of PTB X-ray images are used as input. On these X-ray images segmentation & enhancement algorithms are implemented. From the resultant image shape and texture features are extracted. These features are fed to the neural network for training. Along with these features a clinical examination (sputum) result is also considered. Once training of the ANN is over, testing is done by giving an unknown X-ray image. The first two stages which have occurred while training the ANN will also occur for testing stage i.e. segmentation & enhancement. The extracted shape & texture features from test image are compared with the trained features. ANN, the classifier classifies whether the case is TB or NON-TB. Along with the classified result severity check is also made. The ANN is designed with the architecture (135-40-10-2). A GUI has been designed for the user which displays the result, informations about the intermediate stages, etc. of the system. The designed system is verified for 110 X-ray images of which 59 were NON-TB and 51 were PTB. 55 were detected as NON-TB and 49 as TB by our designed system. Thus the detection accuracy is found to be 94.5%.

Keywords: Pulmonary Tuberculosis, Neural Network, Back Propagation, TB Symptoms, X-ray, ANN
1. INTRODUCTION

Worldwide Tuberculosis (TB) has become one of the most important public health problems. There are 9 million new TB cases and nearly 2 million TB deaths each year [1]. Diagnosis and the management of pulmonary tuberculosis is an essential target of tuberculosis control programs. However, pulmonary tuberculosis (PTB) is becoming more and more a serious problem, particularly in countries affected by epidemics of human immunodeficiency virus (HIV) [2]. The diagnosis of PTB using prompt and accurate methods is a crucial step in the control of the occurrence and prevalence of TB. However, the diagnosis of PTB is quite complex, so there is no unified standard at present. Frequently, there is over diagnosis and missed diagnosis and it is a thorny question in the field of TB control. Some of the methods used earlier are based on distance or pair wise distance measurement and their performance is around 60% to 65% [3].

Artificial neural network (ANN) is theoretical mathematical model acting like human brain which is one kind of information management system based on the imitation of cerebrum neural network architecture and the function [4]. ANN has the functions of self-learning, the associative memory, and highly parallel, fault-tolerant and formidable non-linearity handling ability [5] and can make rational judgment to complex questions according to obtained knowledge and the experience of handling problems. ANNs have been applied in the fields of signal processing, pattern recognition, quality synthetic evaluation, forecast analysis, etc. [6] This study seeks to develop a diagnostic model of PTB that is based on ANN to explore the feasibility of it in diagnoses with the support of the image processing techniques such as image enhancement, segmentation, data compression. An algorithm called embedded zero wavelet (EZW) frameworks is used for the image compression. The compression technique is used to just send the Lung suppressed image from one place to another.

In the earlier techniques either X-ray images or clinical methods are used for the diagnosis of PTB. S.A Patil et.al made texture analysis by using image processing techniques where only lung field segmentation is used [3]. K. Veropoulos et.al studied an Automated Identification of Tubercle Bacilli using Image Processing and Neural Computing Techniques. They are detecting the Tubercle bacilli using clinical specimens [7]. The drawback of this method is that a high resolution image for the process is needed. In our work along with lung suppression Rib suppression is also made. And along with texture features shape features are also taken which has increased the accuracy of detecting PTB. In our system both X-ray and clinical results are used for the diagnosis. Using X-ray image two types of features are extracted i.e. shape and texture. Along with these features sputum examination results are also added. By Incorporating Shape, Texture & Sputum as features to the system has increased the accuracy to 94.5%.

2. METHODOLOGY

Figure 1 shows the block diagram of the overall system designed for the diagnosis of PTB. The total system is divided in to two parts i.e. Training phase & testing Phase. From the block diagram it is evident that artificial neural network is the core for this system. Figure 2 shows the flowchart representation of working of the overall designed system. The X-ray image is read which then undergoes image segmentation and enhancement. From the resulting image the required features are collected. These features are then fed to the neural network. This procedure is called as Training. In testing, same image processing techniques
are used to extract the features. These collected features along with sputum examination results are compared with the available trained features by the ANN. Depending on the comparison result, the classifier gives the as TB or NON-TB with severity.

**Figure 1:** Block Diagram of the Overall PTB Detection System
The whole work is divided into three important stages. The stages are mentioned as follows:

- Image Processing Techniques
- Designing of Neural Network
- Development of GUI

### 2.1 Image Processing Techniques

In this stage, three image processing techniques are being used. The techniques are enhancement, segmentation, and compression. The first two techniques are used in the diagnosis of PTB. The third technique is used to transmit the processed image from one place to another.

#### 2.1.1 Image Acquisition

The Dicom formatted X-ray images are read by converting them into MATRIX format. Then these read images are taken as input images for further analysis. These images then undergo enhancement, Segmentation.

#### 2.1.2 Enhancement in Image Processing

Once the image is read, before proceeding to another image processing application enhancement process is employed. Image enhancement is the process of adjusting digital images so that the results are more suitable for display or further analysis. For example, noise can be removed or brighten an image, making it easier to identify key features. Basically, the idea behind enhancement techniques is to bring out detail that is obscured, or simply to highlight certain features of interest in an image. It is important to keep in mind that enhancement is a very subjective area of image processing [8].

Before extracting the features we are using the Image processing enhancement technique to detect the tuberculosis cavities from the X-ray image. Several algorithms have been proposed to enhance the signal-to-noise ratio and to eliminate noise speckles. These filters include but are not limited to: Fractal Analysis [9], Fuzzy Logic approach [10], and wavelet analysis [11]. Here the two best algorithms are implemented. The adopted algorithm is a hybrid image enhancement technique that simultaneously smoothens and sharpens the image to achieve optimal contrast [12]. And Edge enhancement using Laplacian smoothing approach [13].

The developed technique involves contrast enhancement using sequentially iterative (repetitive) smoothing filters, histogram equalization, and simultaneous application of two types of edge detection processes namely, maximum-difference edge detection [12] and Canny’s edge detection [14].

The post processed image is combined with the original image to accentuate the edges while eliminating noise. Finally, Smoothing is implemented because of its effect to reduce specific types of noise signals in the digitized image. Figure 3 shows the adopted algorithm for repetitive smoothing & sharpening process in enhancement [12].
Figure 2: Flowchart for the Overall System

In spite of the characteristic noise, the low pass filter and high-pass filter could not directly reveal tuberculosis cavities from the image. So, the Laplacian smoothening operator is used, which highlights gray level discontinuities in an image with slowly varying gray level. To recover the edges, the gradient image is segmented using a local adaptive threshold operator.
2.1.3 Image segmentation

Segmentation means the grouping of neighbouring pixels into regions (or segments) based on similarity criteria (digital number, texture). Image objects in image data are often homogenous and can be delineated by segmentation. Thus, the number of elements, as a basis for a following image classification, is enormously reduced if the image is first segmented. The quality of subsequent classification is directly affected by segmentation quality.

In computer vision, image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze.

Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics [15]. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image (see edge detection). Each of the pixels in a region is similar with respect to some characteristic or computed property, such as colour, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic(s). Figure 4 shows the lung segmented image.
2.1.4 RIB Suppression
The density of the ribs affects the image by changing the luminance values of the underlying textures. This can affect the detection of nodules. A method for suppressing the contrast of the ribs and chest clavicles may be implemented using an algorithm such as the one suggested by Clifton et al. [16]. The generated bone structure is then used to train a classifier and suppress the ribs in a lung radiograph.

2.1.5 Region of Interest
This concept reflects the fact that images frequently contain collections of objects each of which can be the source for a region. In a sophisticated image processing system it should be possible to apply specific image processing operations to selected regions. Thus one part of an image (region) might be processed to suppress motion blur while another part might be processed to improve color rendition. The amplitudes of a given image will almost always be either real numbers or integer numbers. The latter is usually a result of a quantization process that converts a continuous range (say, between 0 and 100%) to a discrete number of levels. In certain image-forming processes, however, the signal may involve photon counting which implies that the amplitude would be inherently quantized. In other image forming procedures, such as magnetic resonance imaging, the direct physical measurement yields a complex number in the form of a real magnitude and a real phase [17].

2.1.6 Feature Extraction
When the input data to an algorithm is too large to be processed and it is suspected to be notoriously redundant (e.g. the same measurement in both feet and meters) then the input data will be transformed into a reduced representation set of features (also named features vector). Transforming the input data into the set of features is called feature extraction. If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input. Algorithms include edge detection, corner detection and shape level. Figure 5 shows the flow chart of the top level flow for feature extraction [16].
2.1.6.1 Canny’s Edge Detection Algorithm

The purpose of edge detection in general is to significantly reduce the amount of data in an image, while preserving the structural properties to be used for further image processing. However, experienced radiologists still feel difficulties due to the high noise, low contrast, and eye-fatigue. Hence, it is important to diagnose the image which will help in increasing the diagnostic reliability by reducing noise effects in X-ray images. This algorithm mainly focuses on the probability of detecting real edge points and maximizing it while the probability of falsely detecting non-edge points should be minimized. Secondly, the detected edges should be as close as possible to the real edges. Finally, one real edge should not result in more than one detected edge. The process of Canny’s image detection is simple. Determining ROI (Region of Interest) that includes only white background besides the pump, and cropping the image to this region. Conversion to gray-scale to limit the computational requirements next to blur the image to remove noise then identify the potential edges by thresholding and finally, it should be made mandatory that the edges should be marked where the gradients of the image has large magnitudes[18].

![Flow chart for Feature Extraction](image)

**Figure 5:** Flow chart for Feature Extraction
2.1.6.2. Shape Level Features

Here we are using 8-Neighbour connectivity algorithm to group the nearest-neighbour connected pixels to describe the shape features. These shape descriptors are invariant to rotation, translation, skew transformations and scale. The extracted shape level features are rectangularity, circularity, sphericity, convexity and convex perimeter. The typical values for TB shapes are as follows shown in the table 1. These features discriminate true TB shape.

<table>
<thead>
<tr>
<th>Shape Features</th>
<th>Tb</th>
<th>Non-Tb</th>
<th>Shape Descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangularity</td>
<td>0.15 To 0.6</td>
<td>0.6 To 1.0</td>
<td>Actual Area/Area Of Bounding Box</td>
</tr>
<tr>
<td>Circularity</td>
<td>0.3 To 1.0</td>
<td>0.1 To 0.3</td>
<td>Mean Distance/Standard Distance</td>
</tr>
<tr>
<td>Sphericity</td>
<td>0.1 To 0.9</td>
<td>0.9 To 1.0</td>
<td>Radius Of The Inscribed Circle/Radius Of Circumscribed Circle Of Boundary</td>
</tr>
<tr>
<td>Convexity</td>
<td>0.1 To 0.8</td>
<td>0.8 To 1.0</td>
<td>Actual Area/Convex Hull’s Area</td>
</tr>
<tr>
<td>Convex Perimeter</td>
<td>0.1 To 0.9</td>
<td>0.9 To 1.0</td>
<td>Actual Perimeter/Convex Hull’s Perimeter</td>
</tr>
</tbody>
</table>

Table 1: Shape Level Features.

2.1.6.3. Texture Level Features

Here we are using Log Gabor Wavelet Transformation to find the texture features on the validated region of interest (ROI) after resizing it to 128x128. Totally we are calculating 128 texture features on real part of wavelet coefficients.

2.2 Design of Artificial Neural Network

2.2.1 Feature Classification

The selected features are used for classification. For classification of samples, we have employed the ANN, a matlab based Machine Learning package. The Back-Propagation (BP) Network is a multi-layered feed forward network for the weight training of non-linear differentiable functions. The BP network mainly is used for approximation of functions, pattern recognition, classification, the data compression. In the practical application of ANN, 80%-90% of the ANN model adopted the BP network or its variations. Three-layered (including input layer) BP network may complete the random n dimension to m dimension mapping. Therefore this analysis uses a three-layered BP network with one hidden layer, in accordance with TB features.

An artificial neural network, often just called a neural network, is a mathematical model inspired by biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. The inspiration for neural networks came from examination of central nervous systems. In an artificial neural network, simple artificial nodes, called "neurons", "neurodes", "processing elements" or "units", are connected together to form a network which duplicates a biological neural network.
2.2.2 The Network Type and the Layer

The Back-Propagation Network is a multi-layered forward feed network for the weight training of non-linear differentiable functions. The BP network mainly is used for approximation of functions, pattern recognition, classification, the data compression. In the practical application of ANN, 80%-90% of the ANN model adopted the BP network or its variations. The BP network is also central to the forwarding network and constitutes the most vital element of the ANN. ANN with one hidden layer can be used for approximation for any closed interval, continuous function. Therefore, a three-layered (including input layer) BP network may complete the random n dimension to m dimension mapping. Therefore this analysis uses a three-layered BP network with one hidden layer.

2.2.3 Input and Output Variable Choice

Training samples were analyzed using single factor Logistic regression, screening significant parameters for TB diagnosis as input variable. Parameters identified in this analysis included the shape variables and symptoms. The network output has two kinds: the first kind is the TB group, for which the expected export value is 1; the second kind is the non-TB group, for which the expected export value is 0.

2.2.4 Number of Hidden Layer Neurons

Determining the number of hidden layer neurons is a very complex issue. Because of the lack of a strong analytical formula for calculating this value, in the past, this was often determined simply according to designer's experience and repeated trials. To address this the research, the BP network is designed with a hidden layer with variable neuron in order to determine best number of hidden layer neurons through comparisons of errors.

2.2.5 Activation Function

Activation function is central to both the neuron and the network. The capacity and efficiency of a network to solve questions depends on the activation function which is used in the network to a great extent beside related to the network architecture. The Sigmoid activation function has the function of nonlinearity magnification to coefficient; it can transform the signal from an input of -8 to 8, to an output of -1 to 1. Because the magnification coefficient is smaller for larger input values and bigger for smaller input values. As such, we chose to use the sigmoid activation function.

2.2.6 The Pre-Treatment of Clinic Data

Different parameters used in diagnoses had different expression methods and dimensions, and there was a significant difference between their ranges. If raw data were directly input into the neural network, the network would adjust weight primarily in accordance with data whose numerical values are greater. So the frequency of error did not reflect the data whose numerical values were smaller. So raw data had to be changed into those fit for neural network by means of pretreatment to improve the learning ability and astringency function of the neural network. It was also important to normalization, pretreated input data for the network, which used the ‘sigmoid’ excitation function and error back-propagation learn algorithm for raising their learning ability and generalization performance. The input data of network should be in the interval (0, 1), so 1 and 0 were used to indicate “YES” and “NO” for the binary variable data, and texture variances were transformed to 0~1 variables. Normalization treatment widely used for selection of quantitative data:
Where, $x_i$ raw data. The data collected were used for the raw data matrix of the ANN diagnostic after they were quantitative and normalized according to this principle [1].

2.3 Data Sharing and Image Compression

Here the compression technique is used to send the information from one place to another which helps in the analysis of the segmented image on the other side. Medical databases are considered valuable to many parties including hospitals, practitioners, researchers, insurance companies, etc. Hospitals and practitioners used their patients medical records to support their services. Data sharing or information sharing is necessary for distributed systems, and much works have focused on designing a specific information sharing protocols [19]. However, the privacy of the shared data and data transmitting becoming a challenging issue [16]. In Telemedicine system, each collaborator (hospital) needs to share their private local database with other collaborators. The data sharing in healthcare industry is different from other domains. Medical data is useful, but also harmful to a patient if it’s not accurate or real. The shared data received from other collaborators under the Telemedicine system can affect the decisions made by the practitioners.

Image compression is an application of data compression that encodes the original image with few bits. The objective of image compression is to reduce the redundancy of the image and to store or transmit data in an efficient form. The main goal of such system is to reduce the storage quantity as much as possible, and the decoded image displayed in the monitor can be similar to the original image as much as it can be.

2.3.1 The Embedded Zero-tree Wavelet algorithm

Image compression is very important in many applications, especially for progressive transmission, image browsing and multimedia applications. The whole aim is to obtain the best image quality and yet occupy less space. Higher compression ratios can be obtained if some error, which is usually difficult to perceive, is allowed between the decompressed image and the original image. This is lossy compression. In such a case, the small amount of error introduced by lossy compression may be acceptable. Most popular standards for image and video compression (MPEG, JPEG, and H.261) are based on the Discrete Cosine Transform (DCT), a mathematical tool that transforms the signal domain from space to frequency [20]. The Discrete Wavelet Transform (DWT) is another mathematical tool that offers very good results when it is applied to image and video coding algorithms, improving significantly the performance of DCT-based codec’s.

2.3.2 Discrete Wavelet Transform

The transform of a signal is just another form of representing the signal. It does not change the information content present in the signal. The Wavelet Transform provides a time-frequency representation of the signal. It is easy to implement and reduces the computation time and resources required. The signal to be analyzed is passed through filters with different cutoff frequencies at different scales [21].

2.3.3 The Embedded Zero-tree Wavelet Algorithm (EZW)

The Embedded Zero-tree Wavelet (EZW) algorithm is considered the first really efficient wavelet coder. Its performance is based on the similarity between sub-bands and a
successive-approximations scheme. Coefficients in different sub-bands of the same type represent the same spatial location, in the sense that one coefficient in a scale corresponds with four in the prior level. This connection can be settled recursively with these four coefficients and its corresponding ones from the lower levels, so coefficient trees can be defined. The EZW algorithm is performed in several steps, with two fixed stages per step: the dominant pass and the subordinate pass. In Shapiro's paper [22] the description of the original EZW algorithm can be found.

3. GUI (GRAPHICAL USER INTERFACE)

A GUI has been designed for the user sake i.e. for the display of the result. Figure 6 shows the designed GUI where the informations about results. Severity, intermediate results, graphs etc. are available.

A GUI program is a graphical based approach to execute the program in a more user friendly way. It contains components such as push buttons, text boxes, radio buttons, pop-up menus, slider etc. with proper labels for easy understanding to a less experienced user. These components help the user to easily understand how to execute or what to do to execute the program. When an user responds to a GUI’s components by pressing a pushbutton or clicking a check box or radio button or by entering some text using text box, the program reads the necessary information for that particular event, hence GUI programs are also known as event driven programs. MATLAB provides a tool called GUIDE (GUI Development Environment) for developing GUI programs. GUI approach is employed in various fields. In some systems GUI is built to facilitate users to apply the developed system and understand hierarchy. GUI that acts as an intermediate media creates a form of communication between users and the developed object detection system.

![Automatic TB Diagnostics](image)

Figure 6: Front Panel (GUI)

3.1 Matlab

The whole system is designed on the Matlab platform. MATLAB, which stands for matrix laboratory, is a very powerful technical language for mathematical programming. It has a very extensive library of predefined programs or functions designed to help engineers and scientists to solve their problems in a faster and less painful way. In MATLAB having over number of toolboxes has made it easy for different subjects of study. A toolbox of a particular subject contains mainly the functions or programs required to solve problems
related to the subject. The present day professional version of MATLAB is having graphical and GUI features. Writing programs in MATLAB is much easier compared to other programming languages like FORTRAN, C, C++ or Java. This is because when writing a program in MATLAB, there is no worry about the declaration of variables, types, sizes and memory requirements, which are the main sources of troubleshooters in other programming languages. [23].

4. RESULTS AND DISCUSSIONS

In the designed ANN, the objective error is found to be 0.01 with the training rate of 1000. Figure 7 shows the ANN under training. The ‘Performance plot’ button in the training window can be used to see a plot that resembles Figure 8, the Semi-Logarithmic Line Graph of Training Performance of the neural network. The plot shows the mean squared error of the network starting at a large value and decreasing to a smaller value. In other words, it shows that the network is learning.

The designed system is verified for 110 X-ray images of which 59 were NON-TB and 51 were PTB. 55 were detected as NON-TB and 49 as TB. Accuracy, sensitivity, and specificity of our diagnosis were 94.5% (94/100), 96.49% (55/57), and 92.45% (49/53), respectively. Table 2 shows the diagnostic results of the X-ray images taken for testing.

![Figure 7: ANN Training Network](image)

![Figure 8: Semi-Logarithmic Line Graph of Training Performance](image)
Due to the complexity of TB diagnosis, there is no unified standard for the diagnosis. Over diagnosis and missed diagnosis are formidable problems in the process for TB control. The cost of new diagnostic methods, such as nucleic acid amplification tests is very high and the effectiveness of these tests has not been confirmed in developing countries. To aim directly at uncertainty information and artifacts in clinical diagnosis, the limitation of regression modeling can be overcome by the use of ANNs. Reasonable judgment, satisfactory predictions and ideal forecasts can be achieved by ANN based on existing knowledge and experiences in solving problems. It is found that the accuracy of TB diagnosis is 94.5% by the (135-40-10-2)-BP network. These results indicate that the validity of diagnosis was good and the (135-40-10-2)-BP network could be further extended to new patient data. The results indicate that this could be used as a new diagnosis method for the diagnosis of PTB.

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