Modeling Pulmonary Tuberculosis using Adaptive Neuro Fuzzy Inference System

Ajay Kumar Shrivastava, Akash Rajak, Niraj Singhal

Abstract— **The problem of health monitoring has been taken as it is one of the challenging problems in rural areas where people many times do not get proper treatment and are not financially sound to visit doctors in city. Tuberculosis is an infectious disease and many lives are lost due to lack of proper treatment which in turn can be saved if proper prognosis is done in time. In this paper, a detailed study has been done to design a system for diagnosing tuberculosis using adaptive neuro fuzzy inference system (ANFIS).**

Index Terms—**Adaptive neuro fuzzy inference system, fuzzy system, neural networks, tuberculosis.**

I. INTRODUCTION

During the late 1980s, the number of researchers and engineers interested in neural networks (NNs) and fuzzy logic (FL) increased, dramatically introducing the NN and FL technologies into several application fields. Both technologies are widely used and are considered fundamental engineering technologies. Within several years, NN and FS fusing technologies were already being used in commercial products and industrial systems. Today these techniques are very popular in biomedical field like medical diagnosis. This paper illustrates a reliable prediction methodology to diagnose tuberculosis disease and classify between different stages of tuberculosis using Adaptive Neuro Fuzzy Inference System (ANFIS) classification techniques [1].

Despite the reduction in incidence and prevalence of tuberculosis (TB) through efforts worldwide, TB remains a global health problem. In 2013, 9.0 million new cases of TB, 1.5 million deaths among HIV-negative people with TB, and 360 000 deaths among HIV-positive people with TB were reported [7].

The ANN classification technique approach is based on the supervised Multi-Layer perceptron (MLP) with sigmoidal feed forward network and standard Back-propagation algorithm. The attractiveness of ANNs comes from their capability to "learn" and/or model very complex systems and from the possibility of using them in classification. This approach is employed as a forecaster for stages of tuberculosis disease. The ANN is a self-learning technique with the ability to identify multi-parameter relationship and perform classification in nonlinear domain. In the medical field, ANNs have been used since the late 1980s, initially as an aid to diagnosis and treatment, and lately as a tool for the analysis of survival data.

Adaptive Neuro Fuzzy Inference System (ANFIS) is a kind of hybrid of neural network and fuzzy logic and is based on fuzzy inference system. In ANFIS, we combine both the learning capabilities of a neural network and reasoning capabilities of fuzzy logic in order to give enhanced prediction capabilities [5]. Since it integrates both neural networks and fuzzy logic principles, it has potential to capture the benefits of both in a single framework. Its inference system corresponds to a set of fuzzy IF–THEN rules that have learning capability to approximate nonlinear functions. Hence, ANFIS is considered to be universal approximator. The ANFIS model is very suitable and can generate excellent classification results provided that the right type and number of Membership Functions (MFs) are used in the classification task [4]. In the classification two different classification techniques are employed: an artificial neural network-based classifier and a hybrid ANFIS classifier. A neural classifier can learn from data, but the output does not lead itself naturally to interpretation. An ANFIS classifier is based on a three-layer feed-forward neural network and combines the merits of both neural and fuzzy classifiers while overcoming their drawbacks and limitations. The developed Adaptive Neuro Fuzzy Inference System (ANFIS) classifier exhibits high levels of accuracy, consistency and reliability, with acceptably low computational time and is a promising new development in the field of diagnosis of tuberculosis.

ANFIS and ANN architecture has been designed and implemented. System design includes training of data in ANN and ANFIS which is then subjected for implementation.

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Ajay Kumar Shrivastava, Department of IT, Krishna Institute of Engineering & Technology, Ghaziabad, India, +919873657877, (e-mail: ajay@kiet.edu).
Akash Rajak, Department of CA, Krishna Institute of Engineering & Technology, Ghaziabad, India,, +919873718407, (e-mail: akashrajak@gmail.com).
Niraj Singhal, Faculty of Engineering & Technology, Shobhit University, Meerut., India, +919897037210, (e-mail: sonia_niraj@yahoo.com).

II. PULMONARY TUBERCULOSIS

Tuberculosis (TB) is caused by infection with Mycobacterium tuberculosis, which is transmitted through inhalation of aerosolized droplets. TB mainly attacks the lungs, but can also affect other parts of the body (extra pulmonary tuberculosis).The disease is among the leading causes of mortality in India. India accounts for 1/5 of the global TB burden.

Practitioners should identify all pulmonary tuberculosis suspects and get their sputum tested from a quality assured microscopy center. Under the Revised National Tuberculosis Control Program (RNTCP) more than 13,000 such quality-assured microscopy centers are available across the country wherein sputum sample may be sent for examination. Two sputum samples (one sample preferably early morning sample) need to be sent to quality-assured microscopy center. A patient with one or two sputum samples being positive for acid fast bacilli (AFB) by direct microscopy is diagnosed as having smear positive pulmonary tuberculosis (Fig. 1).

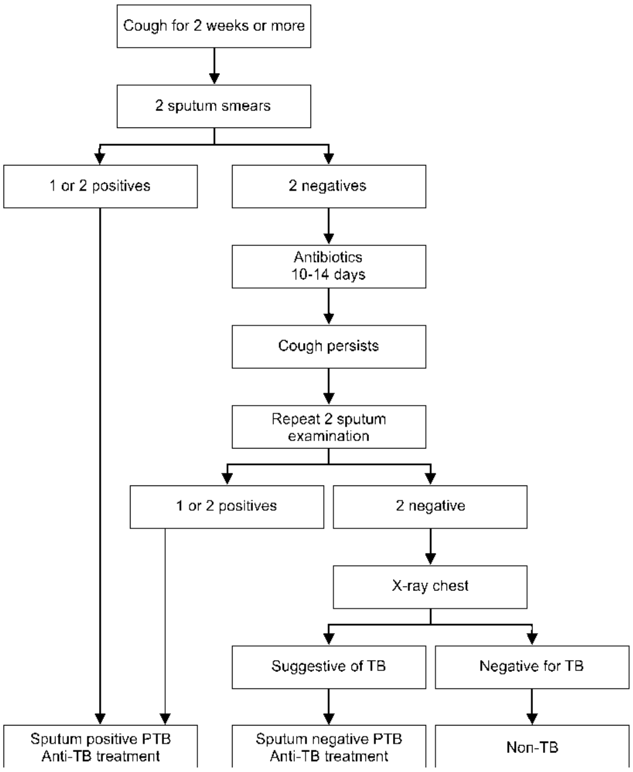

Fig. 1. Flowchart for diagnosis of Pulmonary TB

A. Drug-resistant Tuberculosis

The diagnosis of drug resistant tuberculosis is laboratory based from quality assured, culture and drug susceptibility testing (C & DST) laboratory. Under RNTCP, 43 quality-assured C & DST laboratories are available across the country for diagnosis. Following categories of patients are considered as multidrug resistant tuberculosis (MDR-TB) suspects: all patients who have failed first line treatment, all previously treated patients; all HIV-TB co-infected patients, any smear positive follow-up new or previously treated patients and all pulmonary tuberculosis cases who are contacts of MDR-TB.

With the worldwide re-emergence of TB, multi-drug resistant (MDR-TB) and extensively drug resistant (XDR-TB) strains have become an even greater threat. According to the WHO Global Tuberculosis Control Report 2009, there may be more than 500000 cases of MDR-TB worldwide. Current testing for drug resistance can take more than 4 weeks, leading to higher mortality and the further spread of MDR strains.

B. Treatment

The goal of treatment of tuberculosis is to ensure high cure rates, prevent emergence of drug resistance, minimize relapses and cut the chain of transmission through early diagnosis and treatment. TB can be treated effectively by using first line drugs (FLD) isoniazid (INH), rifampin (RIF),pyrazinamide (PZA), ethambutol (EMB) and streptomycin (SM). However, this first line therapy often fails to cure TB for several reasons. Relapse and the spread of the disease contribute to the emergence of drug resistant bacteria. The emergence of multidrug resistant TB (MDR-TB), i.e. which is resistant to at least isoniazid (INH) and rifampicin (RIF), is of great concern, because it requires the use of second-line drugs that are difficult to procure and are much more toxic and expensive than FLDs [3].Therefore, the detection and treatment of drug susceptible or single drug resistant TB is an important strategy for preventing the emergence of MDR-TB [6]. M. tuberculosis strains with extensively drug resistant-TB (XDR-TB), that is resistant to either isoniazid or rifampicin (like MDR tuberculosis), any fluoroquinolone, and at least one of three second-line anti tuberculosis injectable drugs—i.e., capreomycin, kanamycin,and amikacin have also been reported [2].

C. Monitoring the Treatment of TB

Patients should be monitored closely for signs of treatment failure. Monitoring response to treatment is done through regular history taking, physical examination, chest radiograph and laboratory monitoring. The classic symptoms of TB – cough, sputum production, fever and weight loss – generally improve within the first few weeks. Cough and sputum production can persist after sputum conversion in patients with extensive lung damage, but even in those with extensive lung damage improvement is often seen within a month or two of effective treatment. Persistent fever, weight loss or recurrence of any of the classic symptoms of TB should prompt investigation of treatment failure or untreated comorbidities. The recurrence of TB symptoms after sputum conversion may be the first sign of treatment failure. The chest radiograph may appear unchanged in the first few months of treatment or show only slight improvement, especially in patients with chronic pulmonary lesions. Chest radiographs should be taken at least every six months to document progress and to use for comparison if the patient's clinical condition changes.

III. DESIGN OF INTELLIGENT SYSTEM

In this section, we will describe the designing of intelligent system based on Adaptive Neuro Fuzzy Inference System (ANFIS). The system will detect pulmonary tuberculosis stages based on various input parameters. A system diagram describing the various blocks and flowchart will be designed for the intelligent system. The intelligent system will be rule based and rules are formulated for the diagnosing the various stages of tuberculosis.

A. Input Parameters

In this study, the following parameters has been discussed:

Sputum

A lab will use a microscope to look at any sputum (phlegm) that you cough up. If there are TB germs in your sputum, you have tuberculosis of the lungs or throat (pulmonary TB). This test also helps doctors to understand how infectious you may be. The sputum test result can be positive (1) or negative (0).

Culture

This test uses your sputum or tissue sample to grow any TB bacteria that may be there. It tells doctors how infectious you are and also whether your TB is resistant to any antibiotics. This helps ensure they put you on a combination of drugs that will cure you. As TB culture grows slowly, it may take up to eight weeks to get some of the results. The system defines the culture test as positive (1) or negative (0).

Chest X-Ray

A chest x-ray can show damage in your lungs, but you might need further tests to prove you have TB, such as sputum and culture tests or scans. The cavity in chest X-ray can be of four categories. They are no cavity, low (1-25%), high (20-75%) and severe (70% and above).

Weight Loss

Tuberculosis patients often suffer from severe weight loss, which is considered to be immunosuppressive and a major determinant of severity and outcome of disease. The system defines four categories for weight loss i.e severe (>10kg), high (>5), low (>1) and no loss.

Duration of Symptoms

The doctor may suggest for sputum test if the TB symptoms are from more than two weeks. The duration of symptoms are categorized as short (>15 days), medium (>1 month) and long (>2 months).

Drug Susceptibility Test (DST)

Drug susceptibility test means testing to find out which drugs the TB bacteria in a person are sensitive to, and therefore whether the person has got drug resistant TB. It is essential that if a person might possibly have drug resistant TB, that this is discovered as soon as possible, in order that the patient can be provided with effective TB treatment. Historically drug susceptibility testing has needed specific laboratory facilities and trained personnel, and in addition has been a very lengthy process

Drug susceptibility tests for TB are basically of two different types, phenotypic or genotypic. Phenotypic meaning the observable characteristic of an organism, whereas genotypic is the genetic characteristics of the organism. The DST result gives the resistance of anti-tuberculosis drugs. The resistance can be following type: No Resistance, Isoniazid (H), Ethambutol (E), Parazinamide (Z), Rifampcin (R) and Fluoroquinolones (FQs) along with Second line injectibles.

A neurofuzzy functional block diagram is shown in Fig. 2.

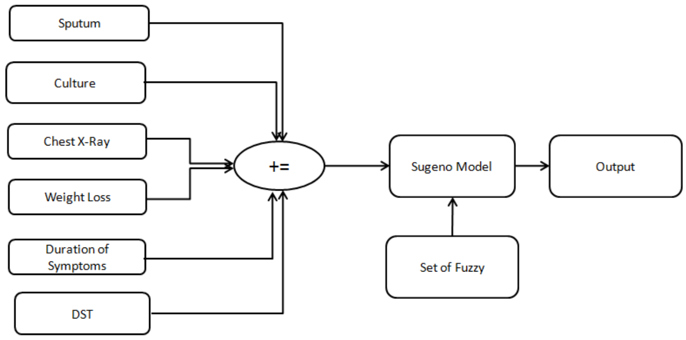

Fig. 2: Block diagram of ANFIS for tuberculosis

B. Formation of Rules

The fuzziness of a fuzzy membership permits us to handle the problem of disease prognosis, various membership functions based upon the factors that are responsible for respective diseases have been defined. Combining the various research data about the diseases have laid down linguistic fuzzy rules which are based on the Fig. 3.

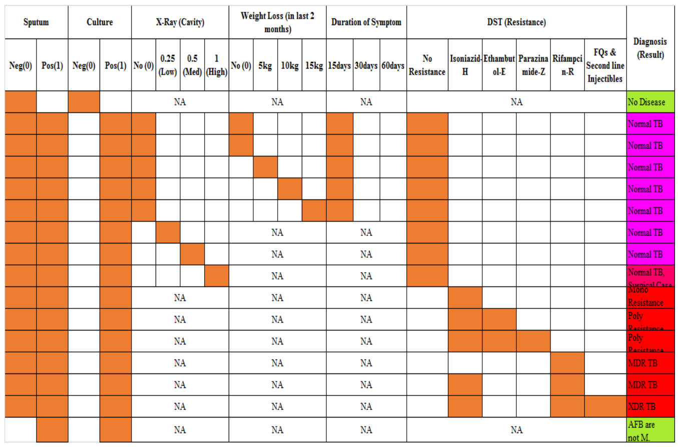

Fig. 3: Formation of rules for detecting tuberculosis

IV. CONCLUSION

In this paper neurofuzzy system for tuberculosis has been proposed. Rule-based fuzzy system has contain symptoms as its input variables in certain specified ranges & possible cures or referrals to doctors as its output. The proposed work for automated diagnosis, which have performed by using the realistic causes of tuberculosis disease are effective. A good level of agreement with doctor's opinions using neurofuzzy systems has been achieved. The proposed research has wide application in many fields, like noisy speech recognitions, noisy image filtering, medical science, intelligent agents, nonlinear adaptive control and performance analysis of dynamical systems. In remote areas, this proposed research work is under consideration where there is no easy availability of a doctor.

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Ajay Kumar Shrivastava has done his Ph. D. from Dr. H S Gour University, Sagar. Presently he is working as Associate Professor in Krishna Institute of Engineering & Technology, Ghaziabad, India. He is the life member of Computer Society of India (CSI). He is also life member of Association of Computer, Electronics and Electrical Engineers (ACEEE) and International Association of Computer Science and Information Technology (IACSIT) and International Association of Engineers (IAENG). He is also reviewer of various ACEEE organized conferences. He has published various research papers in Journals and conferences.

Akash Rajak is working as Associate Professor in Krishna Institute of Engineering and Technology, Ghaziabad. He completed Ph.D in computer science from Barkatullah University, Bhopal in the field of temporal data mining. He has more than 13 years of teaching and research experience. He is a life member of various professional societies like ACEEE, IACSIT, IAENG, CSTA etc. He is a reviewer of various international conferences, journals and books. He also served as program committee chair of various ACEEE conferences.

Niraj Singhal is working as Associate Professor in faculty of Engineering and Technology Shobhit University, Meerut. His areas of interest are web information retrieval, system software and software agents. He has published various research papers in reputed journals and conferences.