RESEARCH ARTICLE OPEN ACCESS

Tuberculosis Detection Using Artificial Intelligence - A Literature Review

[1]Aurtiselvi. K,[1] Suvathi. B,[1] Padmanaban. K, [1]Ganesh. R, [2]Gowrishankar. K
[1] UG Students, Department of Biomedical Engineering , Rajiv Gandhi College of Engineering and Technology, Puducherry.
[2] Associate Professor and Head, Department of Biomedical Engineering, Rajiv Gandhi College of Engineering and Technology, Puducherry.

ABSTRACT
Tuberculosis is a highly infectious disease that primarily affects the lungs. The main cause of TB is mycobacterium tuberculosis. According to World Health Organization (WHO), it is one of the top 10 causes of death worldwide. In many cases, TB can be preventable and treatable under the right conditions. Diagnosis of active TB is based on chest X-rays, as well as microscopic examination and culture of body fluids. The development in artificial intelligence algorithm provides an easy way for detecting tuberculosis. In this paper we have conducted a brief survey on various methods of detecting tuberculosis using artificial intelligence. Our aim is to overcome the existing limitations and to develop a mobile application for both Android and IOS to detect TB and produce the result stage-wise which is easy to use and provide higher accuracy.
Keywords - Android, Artificial intelligence, Chest X-ray, IOT, Tuberculosis.

Date of Submission: 20-06-2020 Date of Acceptance: 07-07-2020

I. INTRODUCTION

Tuberculosis has existed since antiquity. Much archaeological survey has evidences that it was prevalent in Egypt. Source case and susceptible individuals increase the risk of transmission [1]. Host related determinants of disease risk TB was called as white plague which means "Consumption". Consumption is a Latin word which means ‘‘wasting’’ [2]. The Greek Physician Hippocrates observed tubercles in cattles and pigs [3]. The tubercle bacillus was first identified by Robert Koch in 1882. Koch was awarded Noble prize for his contribution in Tuberculosis [4]. The mycobacterium tuberculosis is slow growing mycobacteria with doubling time under optimal condition. *M.tuberculosis* is a agent of TB in human. The mycobacteria have an outer layer which is waxy in nature spreads around the lungs [5]. The probability that an individual with tuberculosis will transmit *M.tuberculosis* to others is determined by many factors. Individuals with more severe pulmonary tuberculosis may emit higher numbers of infectious droplet nuclei by producing droplets at an elevated rate [6] [7].Closer proximity and longer duration of contact between an infectious include HIV infection [8], diabetes [9], smoking [10], excess alcohol use [11] and malnutrition [12]. Several studies conducted in Africa have estimated the proportion of transmission occurring within households [13].

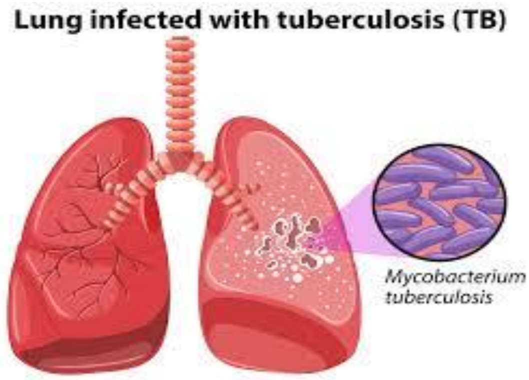

Fig.1 Lung infected with tuberculosis (TB)

1. Types of tuberculosis

TB is an airborne infectious disease that affects the lungs, though it can also affect other parts of the body. When it affects the lungs, it's called pulmonary TB and that of outside the lung is called extra-pulmonary TB. It can also be classified as active or latent. Active TB is contagious and causes symptoms. Latent TB doesn't cause symptoms and isn't contagious. Pulmonary TB is active TB that involves the lungs. Extra-pulmonary TB involves parts of the body outside the lungs such as the bones or organs. TB lymphadenitis is the type of extra pulmonary TB which affects the lymph nodes. Skeletal TB affects the bones, spine and joints and it does not cause any symptoms. Genitourinary TB is the type of extra-pulmonary TB which affects the urinary tract and kidneys [14].

2. Symptoms and Risk factors of TB

The symptom of TB varies under two conditions. Latent TB*:* The person affected by latent TB will have no symptoms and no damage is seen in chest X-rays. They can be detected only by blood test. Active TB*:* The person affected by active TB will have cough with phlegm, fatigue, fever, chills, loss of appetite and weight. This can also spontaneously go away and return [15]. The person who has weak immune system and the person who has HIV infection have the risk of developing TB disease much higher than normal persons. About 5 to 10% of TB patients who do not take treatment will develop TB disease at some time in their life [16].

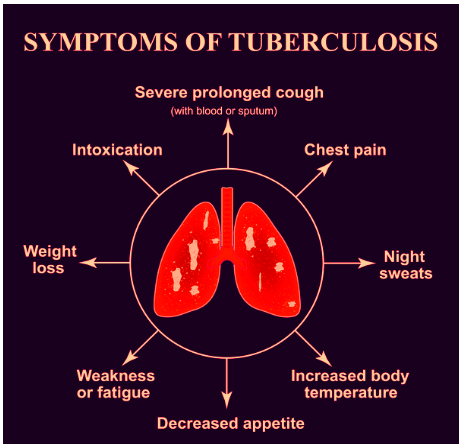

Fig.2 Symptoms of tuberculosis

3. Death rate of TB patients

TB is a global epidemic that causes the death of 1.8 million people worldwide annually. In 2016 the World Health Organization said that there are 9 million new cases formed all over the world. In 2018, 1.1 million children fell ill with TB globally, and there were 205,000 child deaths due to TB. Eight countries account for two thirds of the total, with India leading the count, followed by China, Indonesia, Philipines, Pakistan, Nigeria, Bangladesh and South Africa [17].

4. Diagnosis method of TB with artificial intelligence

Diagnosis of pulmonary TB is established using chest X-ray, sputum microscopy, culture in both liquid and solid media, and nucleic acid amplification. Patients with smear-negative pulmonary TB go for chest computed tomography, biopsy samples and new molecular diagnostic tests [18]. The term "Artificial Intelligence"(AI) was coined by John McCarthy in 1956[19]. In Artificial Intelligence various Machine Learning algorithm have found the interest in Computer-aided Detection and diagnosis methods. Advances in AI algorithm has developed the method of identifying the presence and absence of TB using various methods like Convolutional Neural Network(CNN), Artificial Neural Network(ANN), Deep learning, Genetic algorithm, Fuzzy logic and Neural network with multiple layer[20].

II. METHODS

1. Artificial Neural Network

Artificial Neural Network is based on computing system designed to stimulate human brain analysis and process information. Artificial Intelligence is formed from Artificial Neural Network. It is the information processing technique. It works like the human brain which processes information [21].

ANN is used to detect the prevalence of TB by checking radiographic findings, constitutional symptom and measuring variability caused due to demography using General Regression Neural Network. The evaluation was done using a tenfold cross validation approach. This showed the sensitivity of 100% and specificity of 72% [22]. The ANN has one hidden layer and it was trained with the resilient back propagation algorithm. They included neural model which has sensitivity of 100% and specificity of 99.3%.They used chest X-Ray for detection of TB.

The developed ANN has high accuracy and it can be used as a tool to optimize use of IR in hospitals. [23]To predict TB an approach based on Artificial Neural Network was developed. The ANN took the TB patient's information such as gender, age, HIV status, previous TB history, sample type and sign. Based on these data the ANN predict the Mycobacterium tuberculosis is positive or negative. The accuracy of this method is >94%. [24] Here they used patient's MMR (Measles, Mumps, Rubella) which is extracted and converted into usable format (gray scale values) are given to neural net for training. It is based on back propagation theorem. By using ANN in AI the diagnostic process is non-invasive and gives fast results [25].

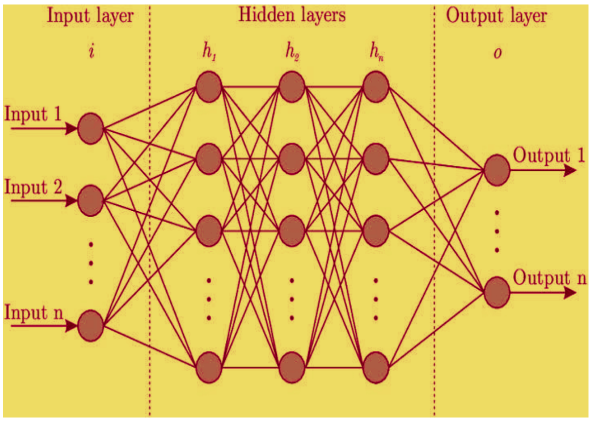

Fig.3 Basic structure of artificial neural network

The most important problem of ANN is the unexplained behavior of the network. This reduces the trust in the network. The network structure is achieved only by the trial and error and experience. The network timing is unknown and it does not give the favorable outcome.

2. Convolutional Neural Network

Convolutional neural network are designed to recognize patterns directly from pixel images. CNN have a basic four types of layers: convolutional, activation, pooling and fully connected layers [26].

Deep learning has brought more clear description and advanced problem solving techniques. The architecture of deep learning is nothing but a stack of multilayer modules which are simple of the subject in learning [27].

In the study of CNN, Adam optimizer was used to minimize the cross entropy. The method was implemented using Theano framework. Later, a convolutional neural network was built named as tuberculosis AI (TB-AI) to recognize the TB bacillus. They used a training set with 45 samples, which had 30 positive cases and 15 negative cases after training the neural network input of about 201 samples were used as test set. The TB-AI achieved 97.94% sensitivity and 83.65% specificity.

In [28] a large scale TB database has been used for automated TB screening. For categorizing, deep convolution neural network was used. By introducing different angled chest x-ray, database can be introduced for non-identifiable chest abnormalities. It generated 4096 dimensional vector. Then, machine learning and mobile computing technique combined for TB diagnosis which used deep convolutional neural network for automated TB screening. The annotation software could help to highlight the TB manifestation which is useful for machine learning algorithm.[29]

Deep learning with DCNNs accurately classify TB at chest radiography. They used Two different DCNNs, AlexNet and GoogLeNet to classify the images as TB infected or as healthy. Augmenting the dataset increased the accuracy. This method has the sensitivity of 97.3% and specificity 100%. According to this method Deep learning with DCNNs can accurately classify TB[30].

In [31] an ensemble deep learning for TB detection using x-ray and carry edge detected image was discussed which produced an accuracy of about 89.77% [31].

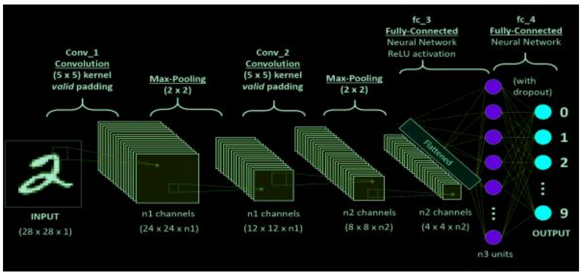

Fig.4 Basic structure of convolutional neural network

Later, some advances in artificial intelligence based on image recognition was developed. It used deep learning methods to develop computer program that analyses chest x-ray to detect pulmonary tuberculosis [32].

In [33] convolution neural network and deep learning for the TB image classification were applied. It also used transfer learning since the data set is small and imbalanced. This method gave an accuracy of about 98% [33].

CNN methods increase the performance of image classification in small data sets using data augmentation [34] [35] [36] and transfer learning, which achieved 92% accuracy [37].

3. Fuzzy Logic

The fuzzy logic shows the way of decision making in humans that involves all possibility between digital value YES and NO. They can be implemented in hardware, software or a combination of both. Fuzzy logic is a type of AI tools used for valuable result. It may not give reasoning, but acceptable reasoning.

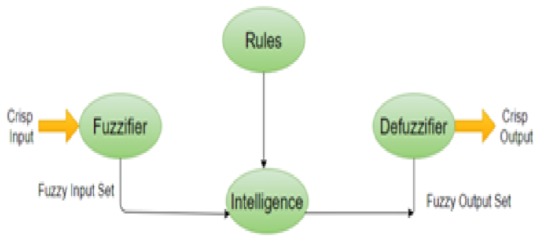

Fig.5 Fuzzy Logic

Fuzzifier - This indicate transforming the TB input into fuzzy forms that are combined with fuzzy sets.
Rules - The parts are antecedents and THEN parts are consequent in the IF-THE fuzzy rules. This is decided with expert who analyzes the TB diagnosis.
Intelligence -This shows analyzing the output after the fuzzy rules has been applied to the input variables.
Defuzzifier -This involves converting the fuzzified output into values that can be read and interpreted by medical expert [38].In [39] work on diagnosis of TB using fuzzy diagnosability has been discussed in detail. They have formalized the construction of diagnose that are used to perform fuzzy diagnosis. It provides the set of techniques to deal with problems of fuzziness, imprecates and precise result. It has focused only on FIS, but with ANFIS also diagnosis can be done.

They are mentioned this as a future subsequent work. In [40] ANFIS has been used to implement intelligent diagnostic system for TB, by using 270 data for training and checking. It obtained an error 0.14177 and 0.4313 during the training and checking. It shows the training and testing performance were 99.58223 and 99.58197 respectively. It concludes by showing ANFIS has shorter learning duration and obtained excellent result.

Later, in [41] a discussion about neuro - fuzzy system for TB was done. Rule based fuzzy system contains symptoms as input variables in certain specified ranges or referrals to doctor as output. The proposed algorithm has neural network and decision making ability of rules based system. This has several applications such as noisy recognitions, noisy images filtering, medical sciences, intelligent agent, and performance analysis of dynamical system. As on the survey research, the fuzzy logic algorithm provides less accuracy in detection tuberculosis. Setting exact fuzzy rules is difficult so it is not widely used.

4. Genetic Algorithm

A genetic algorithm is a search algorithm that is inspired by Charles Darwin's theory of natural evolution. The process of natural selection starts with the selection of fittest individuals from a population. They simulate "survival of the fittest" among individual of consecutive generation for solving a problem. There are five phases in Genetic algorithm: (a) Initial population, (b) Fitness function, (c) Selection, (d) Crossover, (e) Mutation. [42] Genetic algorithm is a method of problem-solving. It is used to produce high quality solution for problems [43].

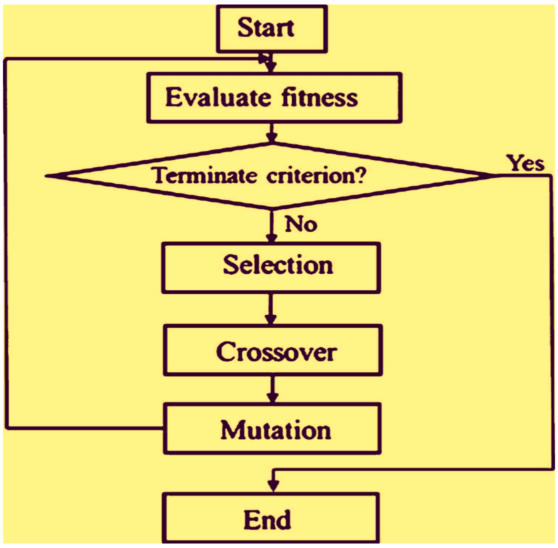

Fig.6 Flow chart of Genetic Algorithm

Hybrid system for diagnosis chest diseases using neural network and Genetic Algorithm were used[44]. Genetic- Neuro-Fuzzy Inferential method for diagnosis of tuberculosis was introduced which showed enhancement in accuracy level of diagnosis [45]. Genetic algorithm Neural network was used for the automated detection of mycobacterium tuberculosis. Ziel-Neelson stained tissue slide images were used for diagnosis.

To separate the tubercle bacilli from the background they used k-means clustering method. Genetic algorithm (GA) is applied to select significant input features for neural network (NN). GA-NN was used to identify significant input features and it was classified into two classes; 'true TB' and 'possible TB'.

The GA-NN approach was able to produce better classification performance with an accuracy of 89.64%. Adding more features in this method, it was able to reduce its performance in some analysis [46].

To detect tuberculosis, Genetic algorithm and neural network was proposed which used different parameters such as Age, Cough, Chest Pain, Fever, Night Sweats, Chest Pain, Hemoglobin and Weight Loss, Unwillingness for work, Loss of appetite is taken as input parameters. Genetic

Algorithm and Neural Network (GANN) performs better with these parameters as compared to other technique. It is the cost effective technique to detect tuberculosis [47].

Genetic-Neuro-Fuzzy Inferential method was used to provide a decision support platform in producing accurate, timely, and cost effective diagnosis of Tuberculosis. The accuracy was 70% [48]. The result of [49] which used genetic algorithm with two hidden layer classification showed the accuracy of 93.93%. Though a greater accuracy, but genetic algorithm is expensive and time consuming.

5. Neural Network with Multiple Layers

Multiple layer neural network has more than one layer of artificial neurons. Single layer neural network was used before in the evolution of AI. It consists of at least one input layer which sends weighted inputs to a series of hidden layers, and an output layer at the end [50].

5.1 Basic Types of Neural Network

5.1.1 Single layered feed forward neural network

A network in which node of input layer transcends into the output layer but not reverse is known as single layered feed forward neural network.

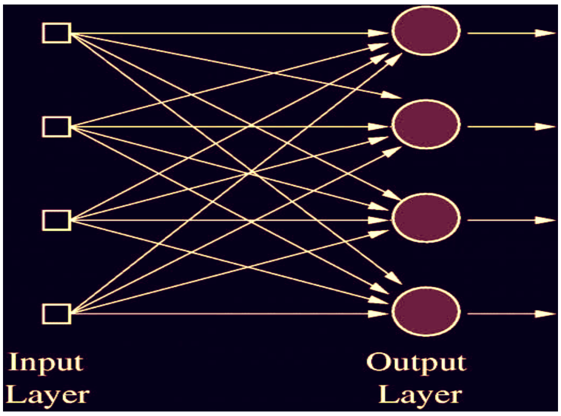

Fig.7 Structure of single layered feed forward neural network

5.1.2 Multilayered feed forward neural network

It consists of more than one hidden layer known as hidden neurons. This hidden neuron works in linking the external input neuron with other neuron in the network. The input from first source of neuron passes the signal to the next.

These signals received as output of second layer then act as input to third layer and continues tills final layer. This final layer consists of total signal output of all the previous neural layers [51].

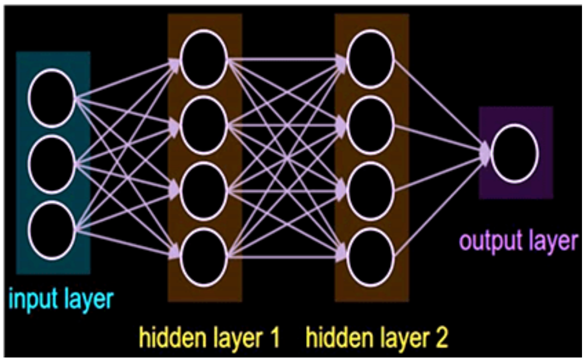

Fig. 8 Structure of multilayered feed forward neural network

The tuberculosis diagnosis was carried out by the multilayer neural network (MLNNs). It has two hidden layers and a genetic algorithm for training, algorithm has been used. The accuracy was 93.93% with back propagation algorithm.

More efficiency was obtained by using Levenburg-Marquardt Training Algorithm but it is different to encode. The result was 94.88% accuracy. Training the multi-layer neural network with genetic algorithm takes too much time. MLNN with genetic algorithm is a successful way to diagnose tuberculosis.

6. Mobile Application to Detect TB

A mobile app was created to detect TB by listening to the sound of the patient's cough. They used artificial intelligence and machine learning to make the cough interpretation.

It is non-invasive and it is easy for the diagnosis of TB. The accuracy of this method was 85% [52]. The IOS mobile app was used to detect TB through chest X-ray by developing an algorithm in artificial intelligence.

The chest X-ray was converted into digital images. Caffe framework with GoogLeNet network were used to create a model for classification of X-ray. The accuracy of this method was 98.39% [53].

III. PROBLEM STATEMENT

The ANN network structure is achieved only by the trial and error and experience. The network timing is unknown and it does not give the favourable outcome. Training of genetic algorithm to detect tuberculosis is better. But genetic algorithm is expensive and time consuming. Fuzzy logic algorithm provides less accuracy and setting exact fuzzy rules is difficult. Even though there are various methods to detect tuberculosis, there are no methods where the patients can see their results by self at their own place. Our aim is to overcome these limitations and to develop a mobile application for the detection of TB stage wise through chest X-ray for both android and IOS. This method of detection will be more useful and viable for doctors and patients especially while applying Telemedicine concepts which is also easy to use and provides the result immediately.

IV. CONCLUSION

In this review research we have discussed various methods of Artificial Intelligence to detect tuberculosis. Many algorithms have been used to increase the accuracy of the result. The detection of TB using Chest X-ray and sputum analysis was done. But there are some limitations present in each method. The Convolutional Neural Network is used for different medical diagnosis. The use of mobile application will be more effective to detect tuberculosis. Our future work is to overcome the existing limitations and to develop an mobile application for both Android and IOS to detect TB and produce the result stage wise which is easy to use and provide higher accuracy.

Table. 1 Comparison of Various Methods used to detect TB

Year	Author	Method	Algorithm	Accuracy(%)
2004	Ramana.K.V	ANN	BP	80%
2009	Erhan Elveren.NejatYumusak	MLNNs	GA	94.88
2010	Er,Temurtas et al	MLNN(1 hidden layer)	BPmW	93.04
		MLNN(2 hidden layer)	LM	95.08
2010	O.Er,F.Temutas	ANN	Genetic-Neuro-Fuzzy	70
2011	E.Elveren and N.Yumusak	ANN	GA(2 hidden layer)	93.93
2011	Elveren&Yumusak	MLNN(2 hidden layer)	GA	94.88
2011	Dongardive et al	Decision tree	Identification tree	94.5
2012	Ansari et al	Neuro-Fuzzy	BP	96
2016	Hwang et al	CNN	Modified AlexNet	90
2016	M.K.Osman&M.Y.Mashor	NN	GA	89.64
2017	Lakhani&Sundaram	CNN	Ensemble	96
2017	Islam et al	CNN	Ensemble	90
2017	Alcantara	CNN	Binary classification	89.6
2017	PayalDande&TurvaSamani	ANN	Fuzzy logic + GA	
2017	Maelon al cantara	CNN	No algorithm	85.68
2018	Roopa H&Asha.T	PCA&KPCA	No algorithm	96.07
2018	Yan Xiong	CNN	No algorithm	97.94
2019	Muhammad Tahir Khan et al	ANN	No algorithm	94
2020	Ray Chang	CNN	Transfer learning	98

REFERENCES

[1]. T. G. Harris, J. S. Meissner, and D. Proops, Delay in diagnosis leading to nosocomial transmission of tuberculosis at a New York City health care facility, *American Journal of Infection Control*, *41(2)*, 2013, 155-160.
[2]. V. S. Daniel, and T. M. Daniel, Old Testament biblical references to tuberculosis, *Clinical Infectious Diseases*, *29(6)*, 1999, 1557-1558.
[3]. H. Herzog, History of tuberculosis, *Respiration*, *65(1)*, 1998, 5-15.
[4]. T. M. Daniel, The history of tuberculosis, *Respiratory Medicine*, *100(11)*, 2006, 1862-1870.
[5]. G. Delogu, M. Sali, and G. Fadda, The biology of mycobacterium tuberculosis infection, *Mediterranean Journal of Hematology and Infectious Diseases*, *5(1)*, 2013, 1-8.

[6]. W. F. Wells, H. L. Ratcliffe, and C. Crumb, On the Mechanics of Droplet Nuclei Infection II. Quantitative Experimental Air-borne Tuberculosis in Rabbits, *American Journal of Hygiene*, *47(1)*, 1948, 11-28.

[7]. R. L. Riley, W. F. Wells, C.C. Mills, W. Nyka, and R. L. McLean, Air Hygiene in Tuberculosis: Quantitative Studies of Infectivity and Control in a Pilot Ward: A Cooperative Study Between the Veterans Administration, The Johns Hopkins University School of Hygiene and Public Health, and the Maryland Tuberculosis Association, *American Review of Tuberculosis and Pulmonary Diseases*, *75(3)*, 1957,420-431.

[8]. E. L. Corbett, R. W. Steketee, F. O. Ter Kuile, A. S. Latif, A. Kamali, and R. J. Hayes, HIV-1/AIDS and the control of other infectious diseases in Africa, *The Lancet*, *359(9324)*, 2020, 2177-2187.

[9]. C. Y. Jeon, and M. B. Murray, Diabetes mellitus increases the risk of active tuberculosis: a systematic review of 13 observational studies, *PLoS Medicine*, *5(7)*, 2008.

[10]. H. H. Lin, M. Ezzati, and M. Murray, Tobacco smoke, indoor air pollution and tuberculosis: a systematic review and meta-analysis, *PLoS Medicine*, *4(1)*, 2007, 173-189.

[11]. K. Lönnroth, B. G. Williams, S. Stadlin, E. Jaramillo, and C. Dye, Alcohol use as a risk factor for tuberculosis–a systematic review, *BMC Public Health*, *8(289)*, 2008, 1-12.

[12]. S. Menon, R. Rossi, L. Nshimyumukiza, A. Wusiman, N. Zdraveska, and M. S. Eldin, Convergence of a diabetes mellitus, protein energy malnutrition, and TB epidemic: the neglected elderly population, *BMC Infectious Diseases*, *16(361)*, 2016, 1-11.

[13]. S. Verver, R. M. Warren, Z. Munch, M. Richardson, G. D. van der Spuy, M. W. Borgdorff, and P. D. van Helden, Proportion of tuberculosis transmission that takes place in households in a high-incidence area, *The Lancet*, *363(9404)*, 2004, 212-214.

[14]. P. Kamolratanakul, N. Hiransuthikul, N. Singhadong, Y. Kasetjaroen, S. Akksilp, and S. Lertmaharit, Cost analysis of different types of tuberculosis patient at tuberculosis centers in Thailand, *Southeast Asian Journal of Tropical Medicine and Public Health*, *33(2)*, 2004, 321-330.

[15]. P. B. Xavier, and B. Peixoto, Emotional distress in Angolan patients with several types of tuberculosis, *African Health Sciences*, *15(2)*, 2015, 378-384.

[16]. G. A. Alemie, and F. Gebreselassie, Common types of tuberculosis and co-infection with HIV at private health institutions in Ethiopia: a cross sectional study. *BMC Public Health*, *14(319)*, 2014, 1-5.

[17]. K. C. Takarinda, C. Sandy, N. Masuka, P. Hazangwe, R. C. Choto, T. Mutasa-Apollo, and N. Siziba, Factors associated with mortality among patients on TB treatment in the Southern Region of Zimbabwe, 2013, *Tuberculosis Research and Treatment*, *2017(6232071)*, *2017*, 1-11.

[18]. Y. J. Ryu, Diagnosis of pulmonary tuberculosis: recent advances and diagnostic algorithms, *Tuberculosis and Respiratory Diseases*, *78(2)*, 2015, 64-71.

[19]. P. J. Hayes, and L. Morgenstern, On John McCarthy's 80th birthday, in honor of his contributions, *AI Magazine*, *28(4)*, 2007, 93-102.

[20]. Y. Xiong, X. Ba, A. Hou, K. Zhang, L. Chen, and T. Li, Automatic detection of mycobacterium tuberculosis using artificial intelligence, *Journal of Thoracic Disease*, *10(3)*, 2018, 1936-1940.

[21]. Q. K. Al-Shayea, Artificial neural networks in medical diagnosis, *International Journal of Computer Science Issues*, *8(2)*, 2018, 150-154.

[22]. P. Dande, and P. Samant, Acquaintance to artificial neural networks and use of artificial intelligence as a diagnostic tool for tuberculosis: a review, *Tuberculosis*, *108*, 2018, 1-9.

[23]. F. Aguiar, J. Pinto, R. Torres, J. Seixas, and F. Mello, Artificial neural network (ANN) for prediction of pulmonary tuberculosis in hospitalized patients, *European Respiratory Society*, *42(57)*, 2013.

[24]. M. T. Khan, A. C. Kaushik, S. I. Malik, S. Ali, and D. Wei, Artificial neural networks for prediction of tuberculosis disease, *Frontiers in Microbiology*, *10(395)*, 2019, 1-9.

[25]. K. V. Ramana, and S. K. Basha, Neural image recognition system with application to tuberculosis detection, *Proc. ITCC 2004 IEEE International Conf. on Information Technology: Coding and Computing*, Las Vegas, Nevada, USA, 2004, 694-698.

[26]. A. Christe, M. Anthimopoulos, S. Christodoulidis, L. Ebner, and S. Mougiakakou, Lung Pattern Classification

for Interstitial Lung Diseases Using a Deep Convolutional Neural Network, *IEEE Transactions of Medical Imaging, 35(5),* 2016, 1207-1216.

[27]. Y. LeCun, Y. Bengio, and G. Hinton, Deep learning, *Nature, 521(7553),* 2015, 436-444.

[28]. Y. Cao, C. Liu, B. Liu, M. J. Brunette, N. Zhang, T. Sun, and W. H. Curioso, Improving tuberculosis diagnostics using deep learning and mobile health technologies among resource-poor and marginalized communities, *IEEE first International conf. on connected health: Applications, Systems and Engineering Technologies (CHASE),* Washington, DC, USA, 2016 , 274-281.

[29]. M. F. Alcantara, Y. Cao, C. Liu, B. Liu, M. Brunette, N. Zhang and C. M. Albarracin, Improving tuberculosis diagnostics using deep learning and mobile health technologies among resource-poor communities in Peru, *Smart Health*, *1*, 2017, 66-76.

[30]. P. Lakhani, and B. Sundaram, Deep learning at chest radiography: automated classification of pulmonary tuberculosis by using convolutional neural networks, *Radiology*, *284(2)*, 2017, 574-582.

[31]. M. H. A.Hijazi, S. K. T. Hwa, A. Bade, R. Yaakob and M. S. Jeffree, Ensemble deep learning for tuberculosis detection using chest X-ray and canny edge detected images, *IAES International Journal of Artificial Intelligence*, *8*(4), 2019, 429-435.

[32]. G. C. Tavaziva, A. Majidulla, A. Nazish, S. K. Abidi, S. Saeed, D. Menzies, and F. Ahmad Khan, Deep Learning-Based AI Software for Chest X-Ray Analysis to Detect Microbiologically-Confirmed Tuberculosis: A Prospective Study of Diagnostic Accuracy, *A19. Tuberculosis Science Highlights, American Thoracic Society,201,* 2020, A1046.

[33]. R. I. Chang, Y. H. Chiu, and J. W. Lin, Two-stage classification of tuberculosis culture diagnosis using convolutional neural network with transfer learning, *The Journal of Supercomputing*, 2020, 1-16.

[34]. J. Ding, B. Chen, H. Liu and M. Huang, Convolutional neural network with data augmentation for SAR target recognition, *IEEE Geoscience and remote sensing letters, 13(3),* 2016, 364-368.

[35]. X. Zhang, X. Zhou, M. Lin and J. Sun, Shufflenet: An extremely efficient convolutional neural network for mobile devices, *Proc. IEEE Conf. on Computer Vision and Pattern Recognition,,* Salt Lake City, Utah, United Sates, 2018, 6848-6856.

[36]. J. Zhou, Z. Li, W. Zhi, B. Liang, D. Moses, and L. Dawes, Using convolutional neural networks and transfer learning for bone age classification, *IEEE International Conf. on Digital Image Computing: Techniques and Applications (DICTA),*Sydney, Australia, 2017, 1-6.

[37]. D. S. Kermany, M. Goldbaum, W. Cai, C. C. Valentim, H. Liang, S. L. Baxter, and J. Dong, Identifying medical diagnoses and treatable diseases by image-based deep learning, *Cell*, *172(5),* 2008, 1122-1131.

[38]. C. C. Lee, Fuzzy logic in control systems: fuzzy logic controller, *IEEE Transactions on Systems, Man and Cybernetics, 20(2),* 1990, 404-418.

[39]. N. Walia, S. K. Tiwari and R. Malhotra, Design and identification of tuberculosis using fuzzy based decision support system, *Advances in Computer Science and Information Technology*, *2(8),* 2015,57-62.

[40]. I. Goni, C. U. Ngene, L. Manga, A.Nata'ala, and S. J. Calvin, Intelligent system for diagnosing tuberculosis using adaptive neuro-fuzzy, *Asian Journal of Research in Computer Science*, *2(1),* 2018,1-9.

[41]. A. Q. Ansari, and N. K. Gupta, Adaptive neurofuzzy system for tuberculosis, *2nd IEEE International Conf. on Parallel, Distributed and Grid Computing,* Himachal Pradesh, India, 2012, 568-573.

[42]. J. Stender, Introduction to genetic algorithms, *IEE Colloquium on Applications of Genetic Algorithms* , 1994, 1-4.

[43]. R. Leardi, Application of genetic algorithm–PLS for feature selection in spectral data sets, *Journal of Chemometrics, 14(5-6),* 2000, 643-655.

[44]. M. R. Daliri, A hybrid automatic system for the diagnosis of lung cancer based on genetic algorithm and fuzzy extreme learning machines, *Journal of Medical Systems, 36(2),* 2012,1001-1005.

[45]. M. O. Omisore, O. W. Samuel and E. J. Atajeromavwo, A Genetic-Neuro-Fuzzy inferential model for diagnosis of tuberculosis, *Applied Computing and Informatics, 13(1),* 2012, 27-37.

[46]. M. K. Osman, F. Ahmad, Z. Saad, M. Y. Mashor, and H. Jaafar, A genetic algorithm-neural network approach for Mycobacterium tuberculosis detection in Ziehl-Neelsen stained tissue slide images, *10th IEEE International Conf. on Intelligent Systems*

Design and Applications, Cairo, Egypt, 2010, 1229-1234.

[47]. Z. Rupali, and A. Jyoti, Pre-prediction of tuberculosis disease using soft computing technique, *International Journal of Advanced Research in Computer and Communication Engineering*, *5(6),* 2016, 56-61.

[48]. O. Er, F. Temurtas and A. C. Tanrıkulu, Tuberculosis disease diagnosis using artificial neural networks, *Journal of Medical Systems*, *34(3),* 2010, 299-302.

[49]. E. Elveren and N. Yumuşak, Tuberculosis disease diagnosis using artificial neural network trained with genetic algorithm, *Journal of Medical Systems*, *35(3),* 2011, 329-332.

[50]. D. Svozil, V. Kvasnicka and J. Pospichal, Introduction to multi-layer feed-forward neural networks, *Chemometrics and Intelligent Laboratory Systems*, *39(1),* 1997, 43-62.

[51]. H. Temurtas, N. Yumusak, and F. Temurtas, A comparative study on diabetes disease diagnosis using neural networks, *Expert Systems with Applications*, *36(4),* 2009, 8610-8615.

[52]. Garima Bora, "App detects TB by listing to the sound of your cough", ET online, December 2019.

[53]. H. Hendrick, W. Zhi-Hao, C. Hsien, C. Pei-Lun, and J. Gwo-Jia, IOS Mobile APP for Tuberculosis Detection Based on Chest X-Ray Image, *2nd International Conference on Applied Information Technology and Innovation (ICAITI),* East Denpasar, Indonesia,2019, 122-125.

Aurtiselvi. K, et. al. “Tuberculosis Detection Using Artificial Intelligence - A Literature Review”. *International Journal of Engineering Research and Applications (IJERA)*, vol.10 (07), 2020, pp 01-09.