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Deep Learning in Tuberculosis Diagnosis: A Survey

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Abstract- Tuberculosis is a contagious syndrome that leads to death Worldwide. In majority of the developing countries, the access to the diagnostic tool and the test usage is relatively poor. Now the recent advancement in the field of Artificial Intelligence may help them to fill this technology gap. Computer Aided Detection and Diagnosis helps in diagnosing the diseases through some clinical symptoms as well as X-ray images of the patients. Nowadays many strategies are formulated to increase the classification accuracy of tuberculosis diagnosis using AI and Deep Learning approaches. Our survey paper, focus to describe the wide AI and deep learning approaches employed in the diagnosis of tuberculosis.

Keywords- AI, Deep Learning, CAD, Tuberculosis.

1. COMPUTER-AIDED DIAGNOSIS FOR TUBERCULOSIS

Tuberculosis recognition using Artificial Intelligence was learned with conventional CAD (1).Here the Jaeger S, in 2013 developed a manual TB detection single CAD system using preset features. The cavitations presence feature is extracted. The CAD diagnostic system from the year 1996-2013 gives an accuracy range between 42% - 100% (1). The investigator uses very small datasets, like 100s (1). Applicability of CAD system is limited here.

In past decades the development of CAD algorithms using different methodologies are enormous. Using different methods, Xu et al. (2013) proposed a Computer Aided Design algorithm (2) for tuberculosis detection especially for cavities using 35 chest X-ray images that consists of 50 cavity information from Alberta University Hospital patients(Canada). The system obtained the overall accuracy of 82.8% with sensitivity 78.8% and specificity 86.8% (2). Because of the varying TB radiographs introduction to real clinical environment is a great challenge.

In 2010, Song Y.L et al. (3) developed a CAD method for diagnosing (focal) tuberculosis. That system acquired the accuracy of 85% using the original dataset of 100 images (3). By including image manipulation techniques like texture analysis and masking, Jaeger et al.(4) implemented a pipeline for tuberculosis detection with the dataset of 138 analyzed chest X-rays of primary tuberculosis in stepwise manner. The system achieved the accuracy of 83% (4).

By enhancing the existing system, S.Vajda et al.(2018) designed a program for tuberculosis recognition focuses on lung field segmentation with the help of Shenzhen dataset, that helps to produce the algorithm accuracy of 95.6% and AUC 0.99 (5). In conjunction with clinical information CAD4TB's diagnostic performance is given by Melendez et al. (6) in by combining the score of CAD4TB algorithm that is based on findings of the image with 12 clinical features. The CAD4TB algorithm gives an AUC of 0.84, followed by sensitivity of 49% and specificity of 95% that leads to the algorithm improvement (6).

Murphy K et at.(7) developed a deep learning CAD4TB model(2019), which trains 500 labeled cohort of CXRs from the country Pakistan and produced the sensitivity and specificity of 90%, 98% respectively (7). In 2020, Keelin et at.(8) evaluated a CAD4TBV6 system, with 5565 CXR images that undergoes geneXpert sputum test using v6-deep convolution neural network. The system compared both CAD4TB

and CAD4TBV6 and produces sensitivity – 90% , specificity – 98% and sensitivity – 90% , specificity – 76% respectively(8).

Table 1 summarizes the comparison of CAD system, datasets, and accuracy obtained using chest radiographs.

TABLE I
COMPARISON OF VARIOUS CAD SYSTEMS FOR DIAGNOSING TUBERCULOSIS.

Author & Year	**CAD Model**	**Dataset**	**Accuracy (AUC, Sensitivity & Specificity)**
Jaeger S et al., 2013	Single CAD System.	Small dataset – 100's.	Accuracy Range: 42%-100%
Xu T et al., 2013	TB Cavity Detection (Primary TB).	35 chest radiographs, containing 50 cavity information's.	Accuracy – 82.8% Sensitivity – 78.8% Specificity – 86.8%
Song Y-L et al., 2010	CAD Program to detect focal TB.	Original dataset of 100- Images.	Accuracy – 85%
Jaeger S et al., 2012	TB Detection Pipeline System.	138 chest radiographs of primary TB.	Accuracy – 83%
Vajda S et al., 2018	TB Detection Program (Algorithm for lung field segmentation).	Shenzhen Dataset	Accuracy – 95.6% AUC – 0.99.
Melendez J et al., 2016	CAD4TB (Algorithm for Diagnostic performance)	Dataset image with 12 clinical features.	AUC – 0.84 with Sensitivity – 49% Specificity – 95%
Murphy K et al., 2019	Deep Learning CAD4TB model	500 Labeled cohort images.	Sensitivity – 90% Specificity – 98%
Keelin et al., 2020	CAD4TBV6 system (That undergoes geneXpert sputum test using v6-deep convolution neural network.) Compares CAD4TB	5,565 CXR Images.	CAD4TBV6 system -Sensitivity – 90% -Specificity – 98% CAD4TB system -Sensitivity – 90% -Specificity – 76%

Table-1: Comparison of Various CAD Systems for Diagnosing Tuberculosis (TB).

2. DEEP LEARNING FOR TB

In recent trends the development of AI - deep learning neural networks for the recognition of tuberculosis is emerging all over the world. In 2016, Hwang et. al (9) developed a system with AlexNet model, it's a pre-trained DL (deep learning) neural network for image recognition. In this model 10,848 CXR's from KIT(Korean Institute of Tuberculosis)are used(9). From the dataset 70% is used for training and 15% and 138 subjects from NIH and images of 662 from Shenzhen-Hospital, China is used for testing(9). The

system acquires the AUC values of 0.964, 0.88, and 0.93 through the datasets of KIT, NIH and Shenzhen respectively (9).

AI deep learning TB detection is enhanced by Lakhani and Sundaram(10), using Pre-trained and untrained GoogLeNet and AlexNet models, that supports in ImageNet test challenge success. Dataset nearly of 1,007 images is used in this model, in that 68% is used for algorithm training (10). Untrained version of AlexNet and GoogLeNet attain the AUC values of 0.90, 0.88 respectively, whereas the pre-trained version of AlexNet and GoogLeNet acquire the AUC values of 0.98 and 0.97 respectively.

An efficient deep neural network model for Chest radiography screening and visualization of tuberculosis was developed by Pasa.F et al., in 2019(11), with two different public datasets one from NIH(National Institutes of Health) which has 138 image-databases from 662 patients with and without tuberculosis. Another dataset is from Belarus Tuberculosis portal with 304 CXR radiographs. Convolutional Neural Network model was used and the accuracy of 79%, 84.4%, 86.2% and AUC 0.811, 0.900, 0.925 was obtained with the datasets of NIH, Belarus, and combined respectively (11).

Jackson et. al(2019), proposed a deep learning based TB detection model consists of 2 subsystems i.e data acquisition system and recognition system(12). The system uses Inception V3 DeepNet model and SVM for data classification, which produces the accuracy of 95.05 % (12). In 2019, Khan MT et. al(13) developed a model for predicting tuberculosis using Artificial Neural Network (ANN), with trained dataset of 12,638 records of tuberculosis patients between 2016 to 2017 from Tuberculosis Lab, Khyber Pakhtunkhwa, Pakistan(13). The system acquired the test and validation accuracy of above 93% and the overall accuracy range is above 94% (13). Thus Deep learning is widely being used for the detection of clinically relevant features in imaging dataset beyond the human eye perception.

TABLE II
COMPARISON OF VARIOUS DL MODELS FOR DIAGNOSING TUBERCULOSIS.

Author & Year	**Neural Network Model**	**Dataset**	**Accuracy (AUC, Validation)**
Hwang et. al, 2016.	AlexNet	KIT - 10,848 CXRs NIH – 138 Images Shenzhen – 662 Images	AUC: • KIT – 0.964 • NIH – 0.88 • Shenzhen – 0.93
Lakhani et. al,	GoogleNet & AlexNet	1,007 Images	Untrained Version(AUC): • AlexNet – 0.90 • GoogleNet – 0.88 Pre-trained Version(AUC): • AlexNet – 0.98 • GoogleNet – 0.97
F. Pasa et. al, 2019.	CNN	NIH - 138 Images from 662 patients & Belarus – 304 CXRs.	Accuracy: • NIH – 79.0% • Belarus – 84.4% • Combined – 86.2% AUC: • NIH – 0.811 • Belarus – 0.900 • Combined – 0.925

Jackson et. al, 2019.	Inception V3 DeepNet	Public Tuberculosis Dataset.	Accuracy: – 95.05%
Khan MT et. al, 2019.	ANN	12,638 records of TB patients(2016-2017) from TB Lab, Pakistan	Test & Validation: >=93% Accuracy: >= 94%

Table 2: Various DL (Deep Learning) model comparison for Diagnosing Tuberculosis (TB).

3. CONCLUSION

In the past 5 years the Tuberculosis recognition using AI-DL techniques are significantly improved. Various CAD programs are developed to analysis and diagnose the CXRs (Chest X-Rays/ Radiographs) in recent days. AI deep learning made quick evolution in the field of medical imaging, with Tuberculosis detection. Various new deep learning techniques have the possibility to beat the precision of the existing CAD-systems. As Lakhani et.al (10) said, that the best utilize of these CAD algorithms is to support the capability of radiologists in less resource areas. The CAD system tests the huge volume of CXRs at a fraction of the cost. Thus in future by training huge number of data set and improved deep learning model will leads to even more accurate TB diagnostic system.

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