Deep Learning and Chest X-ray Image-Based Tuberculosis Detection

Ajay Kumar S.[1], Ananth Kumar S.[2], Karthik D. A.[3], Harshal M.[4] and Prof. Keerthi K. S.[5]
Student, BE, Department of CSE, Atria Institute of Technology, Bangalore, India [1-4]
Professor, Department of CSE, Atria Institute of Technology, Bangalore, India [5]

Abstract— **This review of the literature explores the deep learning methodologies for the interpretation of thorax x-ray images with the aim of tuberculosis (TB) detection. As tuberculosis continues to remain a major worldwide health concern, sophisticated diagnostic methods are essential for enabling early and precise identification. By utilizing deep learning's skills for image processing, scientists have looked at creative ways to improve tuberculosis detection by automatically interpreting images from thorax x-rays. This literature survey provides a summary of the latest research, methods used, and challenges faced in the relationship between medical imaging and TB detection techniques. The synthesis of the body of literature aims to draw focus on the successes, identify gaps in our understanding, and pave the way for future discoveries in this crucial field.**

Keywords—**convolutional neural networks, tuberculosis, deep learning, Classification, Image Segmentation, image processing, and chest x-ray.**

I. INTRODUCTION

Applying AI to precisely and early diagnose diseases has gained a lot of attention due to recent advancements in DL and medical imaging techniques. As a persistent global health concern, tuberculosis (TB) requires novel strategies for prompt diagnosis and treatment. The current literature review explores the changing field of tuberculosis (TB) detection, with particular focus on the use of DL methods and chest X-ray pictures. When paired with artificial intelligence, medical imaging can significantly increase the success rate of public health initiatives, expedite the detection of TB patients, and enhance diagnostic precision. This survey examines existing practices, and prospective future approaches regarding DL and other methods in conjunction with thorax x-rays to diagnose TB.

II. METHODOLOGIES

Exploring how artificial intelligence and ML techniques may be utilized to detect TB. Numerous studies are investigating various methods for using AI and ML in TB detection. Here are a couple of more prevalent approaches to identifying tuberculosis:

A. Convolutional Neural Networks (CNNs):

CNNs are often employed in image-based tuberculosis detection from chest X-rays. They can automatically identify whether a picture is TB-positive or negative according to its qualities.

B. Deep Learning Models:

Through the usage of ML techniques, deep learning teaches computers how humans naturally learn by doing. A crucial component of autonomous vehicles is DL, which allows them to discern between a lamppost and a pedestrian or to detect stop signs. Inconsumer electronics like phones, tablets, TVs, and hands-free speakers, it is the secret to voice control. DL has garnered a great deal of attention lately, and rightfully so. It is producing results that hadn't been possible before. To train models, multiple layer neural network topologies with a significant amount of labeled data are utilized.

C. ResNet-50:

ResNet-50 is a 50-layer neural network developed by Microsoft Research in 2015 in order to recognize images. Its innovation lies in using "shortcuts" between layers, allowing more efficient learning and solving the issue of information loss in very deep networks. These shortcuts, known as residual connections, help prevent the "vanishing gradient problem" while improving the model's ability to deeply understand images, making ita widely used and powerful tool in image classification tasks.

D. Ensemble Learning:

ML method that combines the predictions made by several other models to offer a prediction that is more reliable and more precise than any individual models could generate alone. The theory underlying ensemble learning is that several models' predictions can counter balance one another and produce a prediction that is more accurate overall.

E. Support Vector Machines (SVM):

SVMs are used for TB detection, particularly in scenarios with structured data or when dealing with high-dimensional data.

F. Reinforcement Learning (RL):

To optimize treatment regimens or resource allocation, RL techniques can be employed in lieu of direct detection in tuberculosis management.

III. LITERATURE SURVEY

We reviewed the current surveys available on tuberculosis detection by Abdul Sattar *et al*. [1] suggested ResNet50 neural network architecture in the paper can be applied to determine tuberculosis patterns in chest X-ray pictures. In both the validation and test sets, this technique obtains an exceptional overall classification accuracy of more than 99.5 percent. For classification, the SVM algorithm produces the greatest outcomes.

Nizar Banu P. K. *et al*. [2] give a method for identifying lung tuberculosis in X-ray pictures. The research uses pre-processing methods, including Gaussian and median filters to remove noise, with an emphasis on lowering diagnostic waiting times and providing second views for patients. Watershed and gray level segmentation are two segmentation methods that concentrate on the pulmonary area and extract statistical data derived from the region of interest. Classification methods like the KNN classifier show promise with an 80% accuracy rate.

Arief Purnama Muharram *et al*. [3] The procedure entails pre-processing images, finding anomalies, and producing reports. The input photographs are divided into thirds and resized during the picture pre-processing step. DL techniques are used to discover anomalies. For every anomaly discovered, the report creation process chooses the relevant pre-written statement.

Jimmy Lay *et al*. [4] The proposed multimodal ensemble model, which incorporates patient demographics and images, is very accurate in diagnosing pulmonary tuberculosis. Both the unimodal model and the prior cutting-edge multimodal model are outperformed by the new model. EfficientNet is applied in the method for image classification, whereas XGBoost is applied for the categorization of demographic factors. The effectiveness of the suggested methodology is confirmed by tests carried out using a dataset from Indonesia's Murni Teguh Memorial Hospital.

Vasundhara Acharya *et al*. [5] A normalization-free network was employed in a DL model to identify and categorize tuberculosis (TB) in chest X-rays. High AUC, sensitivity, specificity, and accuracy were attained by the model for both binary and multiclass TB classifications. The chest X-ray regions that are suggestive of tuberculosis were visualized using the Score-CAM technique.

Daniel Capellan-Martin *et al.* [6] A lightweight deep CNN called LightTBNet is intended to identify tuberculosis in chest X-ray pictures. It requires less processing power and fewer parameters to attain accuracy equivalent to other state-of-the-art systems.

Sergio Fabián *et al*. [7] A method that is non-invasive for detecting and tracking pulmonary tuberculosis (TB) is EBC analysis. Certain lipids, lipoarabinomannan lipoglycan, and proteins linked to Mycobacterium tuberculosis (Mtb) are located in the EBC. samples from TB patients. The capacity to differentiate TB cases from controls is made possible by these indications. The EBC-based method demonstrated promise in tracking treatment outcomes and accelerating tuberculosis clinical diagnosis. Compared to conventional sputum testing, EBC analysis is noninvasive, quicker, and less expensive.

Vasundhara Acharya *et al*. [8], The findings that stood out in the research are the outcomes generated by the AI Neural-Network model when working with datasets. The study also showed how well SVM using GoogLenet, ResNet, and VggNet features work together in ensemble models when atlas-based lung segmentation is used. The survey also acknowledged the application of ML to diagnose tuberculosis from CT scans, mentioned the objective of developing the best learning models for COVID-19 identification, and mentioned the varied sensitivity of Mycobacteria detection.

Vo Trong Quang Huy *et al*. [8], The CBAMWDnet model blends the greatest attributes of Wide Dense Net (WDnet) and the Module for Convolutional Block Attention (CBAM) to diagnose TB in x-ray pictures. It shows outstanding results with regards to accuracy, generalization across datasets, and training efficiency. Combined with improved classification performance and the acquisition of contextual and spatial information, this approach greatly enhances ML for tuberculosis identification in medical picture analysis.

Shota Ichikawa *et al*. [9] showcase a programme that utilises ML software for precise CXR-image evaluation. This software excels at recognizing lung field defects and obstacle shadows. By combining algorithms for semantic segmentation and semantic classification, the MATLAB software quickly and accurately determines whether to retake chest X-ray pictures. Abobaker Mohammed Qasem F. *et al*. [10], The HDLA provides an improved method for classifying lung diseases. By combining powerful CNNs, machine learning classifiers, and pre-processing techniques, the HDLA significantly outperforms state-of-the-art methods with regards to overall accuracy,gaining 3.1%, and computational

complexity, saving16.91%. The pre-processing steps of the algorithm's methodology include contrast adjustment, Wiener filtering, and histogram equalization. The pre-trained ResNet50 model is utilized to extract features, andnumerous classifiers are employed for classification.

Zaid Ibni Farooq *et al*. [11] A suggested model that looked like a convolutional network and used genetic algorithms and GANs was able to identify tuberculosis from CXR-pictures with 80% accuracy. Accuracy was significantly enhanced by the Info-GAN and genetic algorithm hyper parameter tweaking. The study, preparing images, testing, and model training were all part of the technique, which was compared to a convolutional network. Research on CNNs for TB screening, computer-aided diagnosis, and DL in lung image analysis were also mentioned.

Christopher S. Ealand *et al*. [12] Although less intrusive than sputum samples, tongue swabs are less sensitive when used to diagnose tuberculosis. Growth supplements have boosted tongue swab sensitivity, but overall diagnostic performance is still below expectations. The tongue swab's performance was evaluated by an extensive analysis that made use of a range of scientific techniques and statistical analysis. The distinction between the outcomes of sputum sample and the tongue swab was brought to light by the McNemar test, which supported this conclusion.

Obaid Alotaibi *et al*. [13] The paper examines the most recent methods for removing common problems such as duplicates, outliers, missing values, and irrelevant data from large data streams. It explores a range of cleaning methods, such as AI, ML, DL, and statistical approaches, and it emphasizes the difficulties and potential paths ahead in this field.The paper highlights the significance of real-time big data stream cleaning because of its enormous volume and variety of formats. It also provides a thorough literature review, identifying common problems with data cleaning and talking about the field's upcoming paths and challenges. The systematic literature review is completed utilising the PRISMA framework, and pertinent research can be found in four databases: IEEE Xplore, ACM Library, Scopus, and ScienceDirect.

Mallikarjuna Chandrappa *et al*. [14] The paper presents a DL model, DLH_COVID, for the categorization of CXR using COVID-19. The model succeeds in 96% accuracy in detecting COVID-19 cases. A web application according to the model is being developed to facilitate rapid COVID-19 diagnosis.

Satoshi Anai *et al*. [16] DL models can predict fatal pneumonia with moderate accuracy using CXR images. Their effectiveness is on par with that of respiratory doctors. Their effectiveness is on par with that of respiratory doctors. These models could assist in the severity assessment of pneumonia patients.

Eman Showkatian *et al*. [17] Utilizing transfer learning, deep CNNs can accurately detect tuberculosis (TB) in chest radiography images. Pre-trained CNN models such as Exception, ResNet50, and VGG16 perform well in TB detection. Image augmentation techniques and transfer of knowledge improves classification accuracy.

Beanbonyka Rim *et al*. [18] In order to increase the precision of computer-aided diagnostic systems for the classification of lung disorders on chest X-ray pictures, the study suggests a deep learning technique utilising transfer learning. The method was trained and evaluated on publicly available benchmark datasets and achieved high performance. The suggested approach might enhance the identification of lung diseases.

James Devasia *et al.* [19] A DL model using transfer of knowledge and EfficientNetB4 architecture was developed to accurately classify tuberculosis abnormalities in chest radiography images. 1,312 chest X-ray pictures from the dataset were used to train the algorithm from 837 patients and evaluated on an external test set. Grad-CAM visualization was used to localize tuberculosis manifestations in the X-ray images.

Mr. P. A. Kamble *et al*. [20] A MATLAB-based technique for image processing to identify tuberculosis (TB) in CXR images is presented. In order to distinguish between normal and aberrant CXRs with TB symptoms, the method entails segmentation, preprocessing, feature extraction, and classification.

The framework has demonstrated promising results in TB detection. Dipali Himmatrao Patil *et al*. [21], This survey examines the progress made in identifying tuberculosis through chest X-ray images. The article offers a model called Scale Attention-Based Densenet with

Extreme Learning Machine (MAD ELM), which achieves an impressive accuracy of 94.2% in detecting tuberculosis. Lindiwe M. Faye et al. [22] A study on M. tuberculosis strains in the rural Eastern Cape Province of South Africa revealed a high prevalence of drug-resistant mutations, genetic diversity, and dominance of the Beijing family. Targeted interventions and continuous surveillance are needed to control drug-resistant tuberculosis.

Salma Sultana *et al*. [23] Classification of lung diseases from chest X-ray pictures using DL models. It's critical to diagnose and recognize lung problems as quickly as feasible. Utilizing a deep CNN is the most popular approach. In contrast to other popular CNN models, the suggested CNN model performs comparably. The suggested CNN model is quite accurate at identifying lung conditions like COVID-19.

Andayan *et al*. [24] suggest use X-ray pictures to determine tuberculosis disease using a computer system. At an average of 96% accuracy, the system uses the technique of a PNN. Feature extraction, pre-processing images, and PNN-based identification are all part of the method. The findings indicate the approach to diagnosing tuberculosis is successful.

The validity of two methods that apply CNN to patient n 11% detection rate in the study. The concordance study between the buccal swab PCR and sputum smear examination shows poor agreement, suggesting that the buccal swab PCR method might not be as successful in diagnosing pulmonary tuberculosis.

Tawsifur Rahman *et al.* [28] implement an innovative approach to tuberculosis detection that makes use of segmentation, visualization, and deep learning methods. The study shows that segmented lung pictures perform better in tuberculosis detection than entire X-ray image-based categorization. With its excellent F1-score, specificity, accuracy, precision, and sensitivity, the recommended approach is a viable toolfor a quicker diagnosis of tuberculosis.

Hyo Min Lee *et al*. [30] The paper "TB Detection Using Thorax X-ray Image Classification by Deep Learning" puts forth a deep learning-based model for TB detection making use of thorax X-ray images. Higher recall, precision, accuracy, and f1-scores are attained by the model in classifying tuberculosis in multiple datasets. It is predicated on the mechanism of attention of the VGG16 and VGG19 models. The application of DL algorithms improves the efficacy of TB detection by reducing the need for expert analysis

chest X-ray images to detect pulmonary tuberculosis is examined by Michael Norval, ZenghuiWang, *et al*. [25]. The study examines various picture pre-processing techniques and suggests a hybrid strategy that combines DCNN and computer-assisted detection (CAD). Using the hybrid technique, the required portion or resolution is taken out of the pictures and sent into the DCNN to enable it to be trained. By removing superfluous features and data, this method seeks to decrease overfitting and increase accuracy.

Hrishikesh Viswanath *et al.* [26] To incorporate human bias into machine learning models, the article suggests a crowdsourcing-based technique. The authors demonstrate that ML models can extract more precise and representative insights from the underlying population by gathering human views on the significance of various features in a dataset. The efficiency of ML models on binary classification problems can be effectively enhanced by using this method.

Mycobacterium TB can be detected using the PCR method on buccal mucosa samples, as examined by Reiska Kumala Bakti *et al*. [27]. Unlike traditional AFB and culture investigation techniques, which failed in identifying the bacteria, PCR demonstrated

and fine-tuning.

Leila Heidari *et al*. [31] The study "Segmentation Performance Comparison Considering Regional Characteristics in Chest X-ray Using Deep Learning" explores the impact of regional characteristics on the efficiency of DL-based rib segmentation in chest X-ray images. Results show lateral ribs outperform medial ribs by 6-7% in segmentation accuracy, emphasizing the need for regional considerations in rib segmentation algorithms.

Siva Kumar *et al*. [33] employ an innovative method for using processed chest X-ray images and various ML techniques to diagnose lung illnesses. Pneumothorax, viral pneumonia, COVID-19 pneumonia, and healthy cases fall under the lung disorders that are reliably classified using the DL method that the authors suggest. The suggested architectural design achieves an overall classification success rate of 99% using a reliable dataset of 4731 chest x-ray images, demonstrating its utility as a means of diagnosis for medical professionals.

S. Zainab Yousuf Zaidi *et al.* [34] Using chest X-ray pictures, a DL system is suggested for the

categorization of respiratory ailments. The system attains an overall classification accuracy of 99% after being trained on a dataset of 4731 chest X-ray pictures. It is demonstrated that the framework is useful for categorizing lung disorders into four groups: viral pneumonia, COVID-19 pneumonia, pneumothorax, and healthy patients.

Raghav Sharma *et al*. [35] A novel DL model is suggested for the detection of TB in chest X-rays. The NIH CXR dataset, which included 112,120 frontal chest X-ray pictures labeled with 14 different symptoms, was employed to provide guidance to the model. The model outperformed previous techniques, attaining more accuracy and F1 scores. Apart from classifying CXR images as either healthy or TB-infected, the model has the capability to further sub classify infected images based on TB-specific features and group CXR images according to the presentations of thoracic diseases. As a tool for diagnosing pneumonia, the model outperformed radiologists' mean F1 score as well.

Madlen Nash *et al*. [36], which helped us understand the performance degree of the qXR DL software. The precision of diagnosing tuberculosis in a medical setting is mediocre focusing in particular on cases confirmed through microbiological testing. Noteworthy accomplishments of the software include an AUC (area under the curve) value of 0.81, a sensitivity rate of 71%, and a specificity rate of 80% for detecting PTB (tuberculosis).

Keelin M *et al*. [37] The accuracy of qXR, a DL program, in diagnosing pulmonary tuberculosis (PTB) in a tertiary care context with a high pretest risk of PTB was assessed. The program showed good accuracy in identifying important anomalies associated to PTB and obtained an AUC of 0.81 for microbiologically verified PTB. The research indicates that in primary care locations without easy access to radiologists, qXR may play a more significant role as a triage diagnostic for PTB.

IV. CONCLUSION

In conclusion, the primary emphasis of this literature review is on using DL methods to analyze chest x-ray pictures so as to detect tuberculosis (TB). As a global health concern, the paper highlights the urgent desire to create improved methods of diagnosis for the precise and prompt recognition of TB. Chest X-ray pictures are analyzed by applying DL methods like ResNet-50 and CNNs to identify if the pictures are positive or negative for tuberculosis. Notable achievements include high TB detection rates utilizing ML algorithms in terms of precision, sensitivity, and specificity. The study highlights how vital it is to advance diagnostic techniques to be able to recognize TB a global health concern, and to offer a prompt and reliable diagnosis

REFERENCES

[1] Abdul Sattar, Abdullah Hamad, Saud A., Tariq S. A., Mohammad A., Gharbi A., Assaye Belay, and Vishal K. Kumar “Detection of TB Disease Through Image Processing Techniques”. Hindawi Mobile Information Systems, article number 74248 Volume 2021.

[2] Nizar Banu, P. K. “Lung TB Detection Using X-Ray Images”. The International Journal for Applied Engineering Research, ISSN 0973-4562, Volume 12, Number 24 (2017),pp.

[3] Arief Purnama Muharram, Hollyana Puteri Haryono, and Ira Puspasari “Automated Chest X-Ray Report Generator Using Multimodal Deep Learning Approach”. Preprint: September 2023.

[4] Jimmy Lay, Tjeng Wawan Cenggoro, and Bens Pardamean, “Detection of pulmonary TB using chest X-ray images using multimodal ensemble method”. Article in Communications in Mathematical Biology and Neuroscience, December 2022

[5] Vasundhara Acharya, Gaurav Dhiman, Krishna Prakasha, Pranshu Bahadur, Ankit Choraria, Sushobhita M., Sowjanya J., SrikanthPrabhu, Krishnaraj Chadaga, Wattana Viriyasitavat, and Sandeep Kautish “AI-Assisted Tuberculosis Detection and Classification from Chest X-Rays Using DL Normalization-Free Network Model". Hindawi, Computational Intelligence and Neuroscience,Volume 2022, Article ID 2399428

[6] Daniel Capellan-Martin, Juan J. Gomez-Valverde, David Bermejo-Pelaez, and MaJ. Ledesma-Carbayo. “A lightweight, rapid, and effective deep convolutional system for chest X-ray tuberculosis detection”. 5 September 2023

[7] Sergio Fabián Mosquera-Restrepo, Sophie Zuberogoïtia, Lucie Gouxette, Emilie Layre, Martine Gilleron, Alexandre Stella, David Rengel, Odile Burlet-Schiltz, Ana Cecilia Caro, and Luis F. Garcia, César Segura, Carlos Alberto Peláez Jaramillo, Mauricio Rojas, and Jérôme Nigou “A Mycobacterium tuberculosis fingerprint in human breath allows tuberculosis detection”. Article 14, December 2022.

[8] Vo Trong Quang Huy and Chih-Min Lin “An Improved Densenet Deep Neural Network Framework for TB Detection Using Chest X-Ray Images”. IEEE 109-2811-E-155-504-MY3

[9] Shota Ichikawa and Hiroyuki Sugimori “Development of a Chest X-ray Image Evaluation Software Using Advanced Deep Learning Techniques”. Article in Applied Sciences, May

[10] Abobaker Mohammed Qasem Farhan and Shangming Yang “Automatic diagnosis of lung diseases using chest X-ray images with a hybrid DL algorithm”. Multimedia Tools and Applications (2023) 22 March 2023.

[11] Zaid Ibni Farooq and Dr. Sweta Srivastava, “Detection of Tuberculosis by Image Processing, GAN's International Journal for Research in Engineering and Science (IJRES), ISSNolinene: 2online64, ISSN (print): 23print56

[12] Christopher S. Ealand, Astika Sewcharran, Julian S.Peters, Bhavna G. Gordhan, Mireille Kamariza, Carolyn R. Bertozzi, Ziyaad Waja, Neil A. Martinson and Bavesh D.Kana. “The performance of tongue swabs to identify pulmonary TB”. Frontiers in Cellular and Infection Microbiology 06 September 2023.

[13] Obaid Alotaibi, Eric Pardede and Sarath Tomy. “Cleaning Big Data Streams: A Systematic Literature Review”. Technologies 2023, 11, 101 26 July 2023.

[14] Mallikarjuna Chandrappa, Gunther Correia Bacellar, Rajlakshman Kulkarni, and Soumava Dey. “COVID-19 Chest X-Ray Image Classification Using DL”. medRxiv preprint July 19, 2021.

[15] Khairul Munadi, Kahlil M., Novi M., and Biswajeet Pradhan. “Image Enhancement for TB Detection with Deep Learning". IEEE Access December 15, 2020.

[16] Satoshi Anai, Junko Hisasue, Yoichi Takaki and Naohiko Hara. “Deep Learning Models to Predict Fatal Pneumonia Using Chest X-Ray Images”. Article ID 8026580, Volume 2022, Hindawi Canadian Respiratory JournalMotorola Semiconductor Data Manual, Motorola SemiconductorProducts Inc.Phoenix,AZ, 1989.

[17] Eman Showkatian, Mohammad Salehi, Hamed Ghaffari, Reza Reiazi. “Deep learning-based automatic detection of TB disease in chest X-ray images”. Article in Polish Journal of Radiology March 2022.

[18] Beanbonyka Rim, Seongjun Choi, Ahyoung Lee, Se Dong Min. “Deep Learning in Multi-Class Lung Diseases’ Classification on Chest X-ray Images”. Article in Diagnostics, April 2022.

[19] James Devasia, Hridayananda Goswami, Subitha Lakshminarayanan, Manju Rajaram, & SubathraAdithan. “Deep learning classification of active tuberculosis lung zones wise manifestations using chest X-rays: a multi label approach”. Scientific Reports | (2023) 13:887

[20] Mr. P. A. Kamble, Mr. V. V. Anagire, Mr. S. N. Chamtagoudar. "Detection of CXR tuberculosis with MATLAB Image Processing ". International Research Journal for Engineering and Technology e-ISSN: 2395 -0056 Volume: 03 Issue: 06 | June-2016.

[21] Dipali Himmatrao Patil. “Tuberculosis Disease Detection through CXR Images based on Deep Neural-Network Approach”. Research in International Journal on Recent and Innovation Trends in Computing and Communication September 2023.

[22] Lindiwe M. Faye, Mojisola C. Hosu, Selien Oostvogels, Anzaan Dippenaar, Robin M. Warren, Ncomeka Sineke, Sandeep Vasaikar and Teke Apalata. “The Detection of Mutations and Genotyping of Drug-Resistant Mycobacterium TB Strains Isolated from Patients in the Rural Eastern Cape Province”. Infect. Dis. Rep. 2023, 15, 403–416 10 July 2023.

[23] Salma Sultana, Anik Pramanik, Md. Sadekur Rahman. “Lung Disease Classification via DL Models Based on Chest X-ray Images”. Conference Paper December 2022.

[24] U Andayani, R F Rahmat, Nani Sylviana Pasi, B Siregar, M F Syahputra, M A Muchtar. “Identification of the TB Disease using X-Ray Images Using PNN”. The Journal of Physics, Conference Series 1235 (2019) 012056: Proceedings of the Third International Symposium on Computing & Applied Informatics 2018 IOP Conf.

[25] Michael Norval, Zenghui Wang, Yanxia Sun. “Pulmonary TB Detection Through Deep Learning Convolutional Neural Networks". Conference Paper December 2019

[26] Hrishikesh Viswanath, Andrey Shor, Yoshimasa Kitaguchi. “Quantifying Human Bias and Knowledge to guide ML models during Training”. arXiv:2211.10796v1 19 Nov 2022.

[27] Reiska Kumala Bakti, Bagus Soebadi, Diah Savitri Ernawati, Ni Made Mertaniasih. “The role of Mycobacterium Tuberculosis detection on oral mucosa in diagnosis of pulmonary TB”. Indonesian Journal of Dental Medicine Volume 6 Issue 1 2023

[28] Tawsifur Rahman, Amith Khandakar, Muhammad Abdul Kadir, Khandakar Reajul Islam. “Reliable TB Detection using Chest X-ray with DL, Segmentation and Visualization”. Preprint July 2020.

[29] Sana Sahar Guia, Abdelkader Laouid, Mostefa Kara, Mohammad Hammoudeh. “TB Detection Using Chest X-Ray Image Classification by DL”. The 10th International Conference, December 2022, Uzbekistan.

[30] Hyo Min Lee, Young Jae Kim and Kwang Gi Kim. “Segmentation Performance Comparison Considering Regional Characteristics in chest x-ray Using DL”. Sensors 2022, 22, 3143 20 April 2022.

[31] Leila Heidari, Gholamreza Rafiei Dehbidi, Ali Farhadi, Golnar Sami Kashkooli, Farzaneh Zarghampoor, Sepide Namdari, Noorossadat Seyyedi, Saeid Amirzadh Fard, Abbas Behzad- Behbahani. “Simultaneous detection and differentiation of Mycobacterium tuberculosis and nontuberculous mycobacteria coexisting in patients with pulmonary tuberculosis by single- tube multiplex PCR". Iranlan Journal of Microbiology Volume 15 Number 3 (June 2023) 401- 407.

[32] Payal Gidwani, Urmi Gori, Aayush Dedhia, Prof. Nasim Banu Shah. “Tuberculosis Detection Using CNN”. Jan 2021.

[33] Siva Kumar. “A Deep Learning (DL) Framework tocategorize lung diseases via Chest X-Ray Images”. Chapter July 2022.

[34] S. Zainab Yousuf Zaidi, M. Usman Akram, Amina Jameel and Norah Saleh Alghamdi. “A DL method for the classification of TB from the NIHCXR dataset”. IET Image Process. 16, 787–796 (2022).

[35] Raghav Sharma, Preeti Gupta, and Harvinder Kaur. “A Deep Learning Method to Diagnose TB from Chest X-Rays: A Survey”. International Conference on Emerging Technologies: AI, IoT, and CPS for Science & Technology Applications, September 06–07, 2021, NITTTR Chandigarh, India.

[36] Madlen Nash, Rajagopal Kadavigere, Jasbon Andrade, CynthiaAmrutha Sukumar, KiranChawla, Vishnu Prasad Shenoy, Tripti P., Sophie H., Madhukar Pai & Kavitha Saravu. “Deep learning, computer-aided radiography reading for tuberculosis: a diagnostic accuracy study from a tertiary hospital in India”. Scientific Reports (2020) 10:210.

[37] Keelin M., Shifa S. H., Syed Md. Asad Z., Saira Khowaja., Aamir Khan., Jaime Melendez., Ernst T. Scholten, Farhan A., Steven S., Maurits V., Rick H. H. M. Philipsen., Annet M., & Bram van Ginneken. “Computer aided detection of TB on chest radiographs: An evaluation of CAD4TB v6 system”. Scientific Reports | (2020) 10:5492.

[38] Abdullahi Umar Ibrahim, Ayse Gunnay Kibarer, and Fadi Al-Turjman. “Computer-aided Detection of Tuberculosis from Microbiological and Radiographic Images" January 4th 2023.