An Early Detection of Tuberculosis Using Chest X-Ray with Computer-Aided Diagnosis through Machine Learning and Deep Learning Methodology

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Abstract: ***Tuberculosis (TB) remains a global health concern, necessitating the development of advanced diagnostic tools for early detection. This study proposes a robust framework for the early detection of TB utilizing Chest X-Ray (CXR) images with a focus on Computer-Aided Diagnosis (CAD) powered by machine learning techniques. The methodology involves a series of stages including image pre-processing, segmentation, feature extraction, classification, and performance evaluation. The first stage employs a median filter for image pre-processing to enhance the quality of CXR images by reducing noise and improving clarity. Subsequently, a Fuzzy C-means (FCM) algorithm is applied for segmentation, effectively isolating regions of interest associated with potential TB manifestations. The proposed framework combines image preprocessing, segmentation, feature extraction, and SVM-based classification to achieve early detection of TB using CXR images. The incorporation of advanced machine learning techniques enhances the accuracy and efficiency of TB diagnosis. The performance metrics provide a comprehensive evaluation of the proposed system, demonstrating its potential as a valuable tool for clinicians in the early detection of tuberculosis.***

Keywords: Early Detection of Tuberculosis, FCM, Pre-processing, Machine learning, Chest X – ray

1. Introduction

Tuberculosis (TB) remains one of the most significant infectious diseases globally, posing a substantial burden on public health systems and socio-economic development, particularly in low-and middle-income countries. According to the World Health Organization (WHO), TB is one of the top 10 causes of death worldwide, with an estimated 10 million new cases and 1.4 million deaths reported in 2019 alone. Early detection and prompt treatment are essential for reducing TB transmission rates, preventing disease progression, and improving patient outcomes. Chest X-Ray (CXR) imaging plays a central role in the diagnosis and management of pulmonary TB, offering a non-invasive and cost-effective means of assessing lung pathology. However, the interpretation of CXR images for TB diagnosis can be challenging, requiring specialized training and expertise on the part of radiologists. Moreover, in resource-limited settings where TB prevalence is often high, access to skilled healthcare professionals may be limited, leading to delays in diagnosis and treatment initiation. To address these challenges, there has been growing interest in developing Computer-Aided Diagnosis (CAD) systems that can assist radiologists in the interpretation of medical images, including CXRs. CAD systems leverage advanced image processing and machine learning techniques to automate various stages of image analysis, enabling faster and more accurate detection of abnormalities. In the context of TB diagnosis, CAD systems can aid in identifying characteristic radiographic features such as pulmonary infiltrates, cavities, and nodules, which are indicative of active TB disease. By providing quantitative and objective assessments of CXR findings, CAD systems have the potential to improve diagnostic accuracy, reduce inter-observer variability, and facilitate timely interventions for TB patients. In recent years, machine learning (ML) algorithms, particularly those based on deep learning, have shown promising results in various medical imaging tasks, including TB detection. Deep learning models, such as convolutional neural networks (CNNs), excel at learning hierarchical representations of image data, enabling them to capture complex patterns and features relevant to disease diagnosis. By training on large datasets of annotated CXR images, deep learning models can learn to recognize subtle abnormalities associated with TB, potentially outperforming traditional CAD approaches. This study proposes a comprehensive framework for the early detection of TB using CXR images, enhanced by CAD through ML techniques. The framework integrates multiple stages, including image pre-processing, feature extraction, and classification, leveraging state-of-the-art ML algorithms to automate the detection of TB-related abnormalities. By combining the expertise of radiologists with the computational power of ML, the proposed framework aims to improve the efficiency and accuracy of TB diagnosis, particularly in settings where resources are limited.

2. Problem Statement

Tuberculosis (TB) is a communicable disease caused by a bacterium called Mycobacterium tuberculosis. It is the leading cause of death from a single infectious disease. Chest X-rays (CXR) are commonly used for detection and screening of pulmonary tuberculosis. In clinical practice, chest radiographs are examined by experienced physicians for the detection of TB. However, this is time consuming and a subjective process. Subjective inconsistencies in disease diagnosis from radiograph is inevitable. The World Health Organization (WHO) reported that in 2019. India was included in the list of 20 high TB burden countries with a total of 446, 732 cases. WHO estimates that there are 80, 000 deaths of TB patients in India in 2022. A person who has been infected with the tuberculosis disease will have symptoms such as coughing for more than 3 weeks, chest pain, fever, night sweat, weight loss, fatigue and pallor. The disease is spread when the droplet is passed from infected patient to healthy people through sneezing or coughing. The common and effective method to analyze TB through CXR images.

3. Literature Survey

In this paper titled "Towards automated tuberculosis detection using deep learning, " S. Kant and M. M. Srivastava explore the application of deep learning techniques for the automated detection of tuberculosis (TB) from chest X-ray (CXR) images. Published in the 2018 IEEE Symposium Series on Computational Intelligence (SSCI), the study presents a novel approach to address the challenges associated with TB diagnosis, particularly in resource-constrained settings where expert radiologists may be scarce [1]. In their study titled "Four months of rifampin or nine months of isoniazid for latent tuberculosis in adults, " D. Menzies et al. investigate the efficacy and safety of two different treatment regimens for latent tuberculosis infection (LTBI) in adults. Published in the New England Journal of Medicine in 2018, this study addresses the need for effective LTBI treatment strategies to prevent the progression to active tuberculosis (TB) and reduce TB transmission [2]. In their paper titled "Detection of tuberculosis based on multiple parameters using ANFIS, " A. K. Shrivastava, A. Rajak, and S. Bhardwaj explore the application of Adaptive Neuro-Fuzzy Inference System (ANFIS) for the detection of tuberculosis (TB). Published in the proceedings of the 2018 3rd International Innovative Applications of Computational Intelligence on Power, Energy and Controls with their Impact on Humanity (CIPECH) conference, the study presents a novel approach to TB detection by integrating multiple parameters into a unified computational framework [3]. In this paper titled "Chest X-ray Analysis of Tuberculosis by Convolutional Neural Networks with Affine Transforms, " T. Karnkawinpong and Y. Limpiyakorn present a novel approach for tuberculosis (TB) detection using convolutional neural networks (CNNs) enhanced with affine transforms. The study was published in the proceedings of the 2018 2nd International Conference on Computer Science and Artificial Intelligence, providing insights into the application of deep learning techniques for TB diagnosis from chest X-ray (CXR) images [4]. In this paper titled "Early Detection of Tuberculosis Using Chest X-Ray (CXR) with Computer-Aided Diagnosis, " I. Gabriella et al. present a study focusing on the development and evaluation of a computer-aided diagnosis (CAD) system for the early detection of tuberculosis (TB) from chest X-ray (CXR) images. The paper was presented at the 2018 2nd International Conference on Biomedical Engineering (IBIOMED), providing insights into the integration of advanced imaging analysis techniques for TB diagnosis [5]. In this paper titled "Detection of Tuberculosis Bacilli from Ziehl-Neelson Stained Sputum Smear Images, " G. Evangelin Sugirtha, G. Murugesan, and S. Vinu present a study focusing on the development of a computer-aided detection system for tuberculosis (TB) bacilli from Ziehl-Neelson stained sputum smear images. The paper was presented at the International Conference on Information, Communication & Embedded Systems (ICICES 2017), and providing insights into the application of image processing techniques for TB diagnosis [6]. In this paper titled "Deep Learning: A Potential Method for Tuberculosis Detection Using Chest Radiography, " R. Hooda, S. Sofat, S. Kaur, A. Mittal, and F. Meriaudeau explore the application of deep learning techniques for tuberculosis (TB) detection from chest radiography (CXR) images. The study was presented at the 2017 IEEE International Conference on Signal and Image Processing Applications (ICSIPA), offering insights into the potential of deep learning in improving TB diagnosis [7]. In this paper titled "A Novel Multiple-Instance Learning-Based Approach to Computer-Aided Detection of Tuberculosis on Chest X-Rays, " J. Melendez, B. van Ginneken, P. Maduskar, R. H. Philipsen, K. Reither, M. Breuninger, I. M. Adetifa, R. Maane, H. Ayles, and C. I. Sanchez introduce a pioneering method for computer-aided detection (CAD) of tuberculosis (TB) using chest X-rays (CXRs). Published in the IEEE Transactions on Medical Imaging in 2015, this study presents a novel approach based on multiple-instance learning (MIL), a machine learning paradigm suitable for scenarios where only partial information about the labels of the training data is available [8]. Anju Mathews and Jithin Jose Kallada's paper titled "An Efficient Diagnosis of Tuberculosis with the Aid of Chest Radiographs" published in the International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) in July 2015, presents an efficient method for diagnosing tuberculosis (TB) using chest radiographs (X-rays). The study addresses the need for accurate and timely TB diagnosis, leveraging advancements in computer engineering and technology to enhance diagnostic capabilities [9]. In this paper titled "Automatic Detection of Tuberculosis in Chest Radiographs Using a Combination of Textural, Focal, and Shape Abnormality Analysis, " L. Hogeweg, C. I. Sanchez, P. Maduskar, R. Philipsen, A. Story, R. Dawson, G. Theron, K. Dheda, L. Peters-Bax, and B. Van Ginneken present an innovative approach for the automatic detection of tuberculosis (TB) in chest radiographs (X-rays). Published in the IEEE Transactions on Medical Imaging in 2015, this study introduces a comprehensive method that combines textural, focal, and shape abnormality analysis to improve the accuracy of TB diagnosis from chest radiographs [10]. Fahad Nasser Alhazmi's paper titled "Self-Efficacy and Personal Innovation: Conceptual Model Effects on Patients_ Perceptions of PHR Use in Saudi Arabia, " published in the International Journal of Intelligent Systems and Applications in Engineering in 2023, explores the relationship between self-efficacy, personal innovation, and patients' perceptions of Personal Health Record (PHR) use in Saudi Arabia [11]. There are more research works providing the early detection of tuberculosis using chest x-ray images is given in [12]-[16].

4. Proposed System and Methodology

The disease tuberculosis (TB) continues to be a major global health concern. For treatment and management to be effective, early detection is essential. With the use of machine learning techniques, this project suggests a novel computer-aided diagnostic (CAD) system for early tuberculosis (TB) identification from chest X-rays (CXRs). To enhance image quality, input CXR images are subjected to noise reduction and augmentation. Potential regions of interest (ROIs) are highlighted in the pre-processed image by identifying its edges. The Fuzzy c-means technique is used to segment the image and find ROIs that may contain TB lesions. From the divided ROIs, essential features are taken out, providing vital data for TB categorization. The retrieved features are classified as diagnostic of tuberculosis (TB) or non-TB using a Support Vector Machine (SVM) classifier that was trained on a labelled CXR dataset. For each input CXR, the system returns a categorization conclusion (TB or non-TB), which may help radiologists diagnose tuberculosis.

Implementing a computer-aided diagnosis (CAD) system for tuberculosis (TB) detection using chest X-rays in MATLAB involves several steps, including data preprocessing, feature extraction, training machine learning models, and testing the system's performance. Below is a simplified outline of how you can approach this task:

Data Collection and Pre-processing:
Obtain a dataset of chest X-ray images labeled with TB-positive and TB-negative cases.

Preprocess the images (e. g., resize, normalize) to ensure uniformity and enhance the quality of input data.

Feature Extraction:
Extract relevant features from the preprocessed chest X-ray images. Common features for TB detection may include texture features, shape descriptors, and intensity histograms. Implement feature extraction algorithms or utilize pre-trained deep learning models (e. g., convolutional neural networks) to automatically extract discriminative features from the images.

Training Machine Learning Models:
Split the dataset into training, validation, and testing sets. Train machine learning models using the extracted features. Commonly used algorithms for binary classification tasks like TB detection include support vector machines (SVM), random forests, or deep learning models.

Tune hyperparameters and optimize the models using cross-validation on the validation set to improve performance.

Evaluation:
Evaluate the trained models using the testing set to assess their performance metrics such as accuracy, sensitivity, specificity, and area under the receiver operating characteristic (ROC) curve.

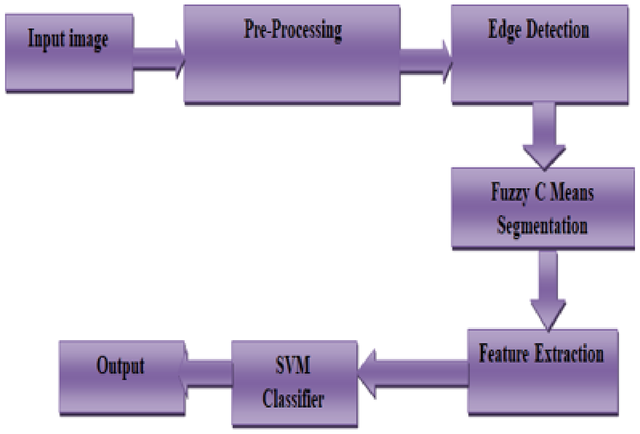

Figure: System Architecture

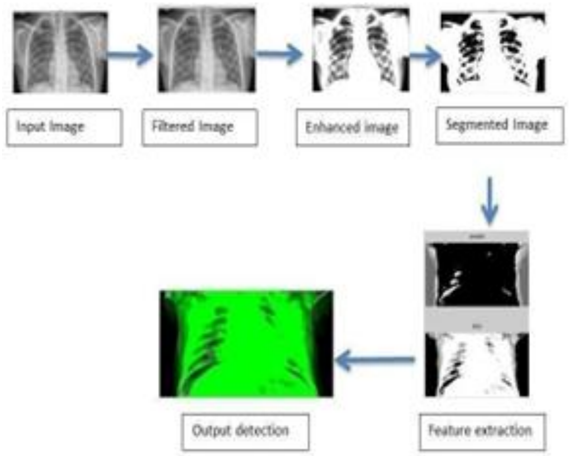

Figure: Proposed Method

Analyze the confusion matrix to understand the model's performance in classifying TB-positive and TB-negative cases.

Integration into CAD System:
Develop a user-friendly interface for the CAD system using MATLAB's graphical user interface (GUI) tools or web-based interfaces.

Integrate the trained machine learning model into the CAD system to allow for automated TB detection from chest X-ray images.

Implement functionality for users to upload new chest X-ray images for analysis and visualize the results provided by the CAD system.

Validation and Deployment:
Validate the CAD system's performance on additional independent datasets to ensure its robustness and generalization capability.

5. Conclusion

With a higher accuracy rate of 95.56% and improved sensitivity, specificity, and precision, the proposed method showcases enhanced efficacy and reliability in accurately detecting tuberculosis cases from chest X-ray images. These findings hold profound implications for early diagnosis and intervention, offering the potential to improve patient outcomes and mitigate the spread of tuberculosis. The robust performance of the proposed method underscores the importance of leveraging advanced techniques such as machine learning and image processing in medical diagnostics. By harnessing these innovative methodologies, healthcare practitioners can enhance their diagnostic capabilities and make more informed clinical decisions, ultimately leading to better patient care and management of tuberculosis.

6. Future Scope

Leveraging the proposed method for tuberculosis detection in telemedicine and remote healthcare settings can expand access to diagnostic services, particularly in underserved and remote regions. Remote interpretation of CXR images using the proposed method can enable timely diagnosis and treatment initiation, leading to improved patient outcomes.

Table I: Comparison of Performance Metrics with Existing and Proposed Methods

S. No	Model	Existing Method	Proposed Method
1	Accuracy	93.43	95.56
2	Sensitivity	90.24	93.22
3	Specifity	87.04	90.87
4	Precession	88.64	92.04

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