

Automatic Detection of Tuberculosis using Deep Learning: A DenseNet121 Approach

Abstract

Tuberculosis (TB) remains a major global health threat, requiring timely and accurate diagnosis. Chest X-rays (CXR) are a primary screening tool, but their interpretation is subject to inter-observer variability and shortage of radiologists. This paper presents a deep learning framework utilizing a customized DenseNet121 architecture for the automatic binary classification of TB from CXR images. By leveraging transfer learning and robust data augmentation techniques—“including random rotation, color jitter, and Gaussian blur”—we simulate real-world data variability. Our model demonstrates promising performance with a validation accuracy of approximately 76.7% in initial finetuning experiments, showing the potential for assisting clinicians in resource-constrained settings. We further discuss the deployment of this model via a mobile application using TensorFlow Lite, aiming to bring accessible diagnostics to the point of care.

1. Introduction

Tuberculosis (TB) is an infectious disease capable of causing severe lung damage and, if left untreated, death. According to the World Health Organization (WHO), TB is one of the top 10 causes of death worldwide. Early detection is critical for effective treatment and controlling the spread of the disease. Standard diagnostic methods include sputum smear microscopy, molecular tests, and chest radiography. However, manual interpretation of Chest X-rays is time-consuming and requires expert radiologists, who are often scarce in high-burden countries.

Recent advancements in Artificial Intelligence (AI) and Deep Learning (DL) have shown remarkable success in medical image analysis. Convolutional Neural Networks (CNNs) can automatically extract features from images, offering a second opinion to radiologists and potentially automating screening in remote areas. This study proposes a deep learning solution based on the DenseNet121 architecture to classify chest X-rays as "Normal" or "Tuberculosis".

2. Related Work

Deep Learning has been extensively applied to chest radiograph analysis. Rajpurkar et al. [4] introduced CheXNet, a 121-layer Dense Convolutional Network trained on the ChestX-ray14 dataset, which achieved radiologist-level performance in detecting pneumonia. Similarly, Lakhani and Sundaram demonstrated high accuracy in TB detection using an ensemble of AlexNet and GoogLeNet.

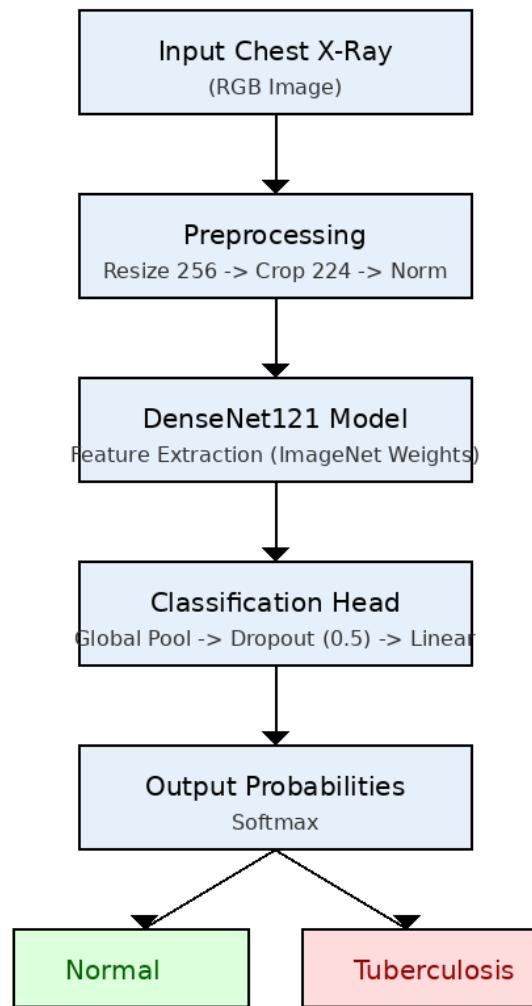
Our work builds upon these foundations by adopting DenseNet121 [3], which addresses the vanishing gradient problem and ensures maximum information flow between layers. Unlike previous studies relying on massive datasets, we focus on optimizing the model for a smaller, targeted dataset using transfer learning and heavy data augmentation, making it suitable for deployment in resource-constrained mobile environments.

3. Methodology

3.1 Dataset

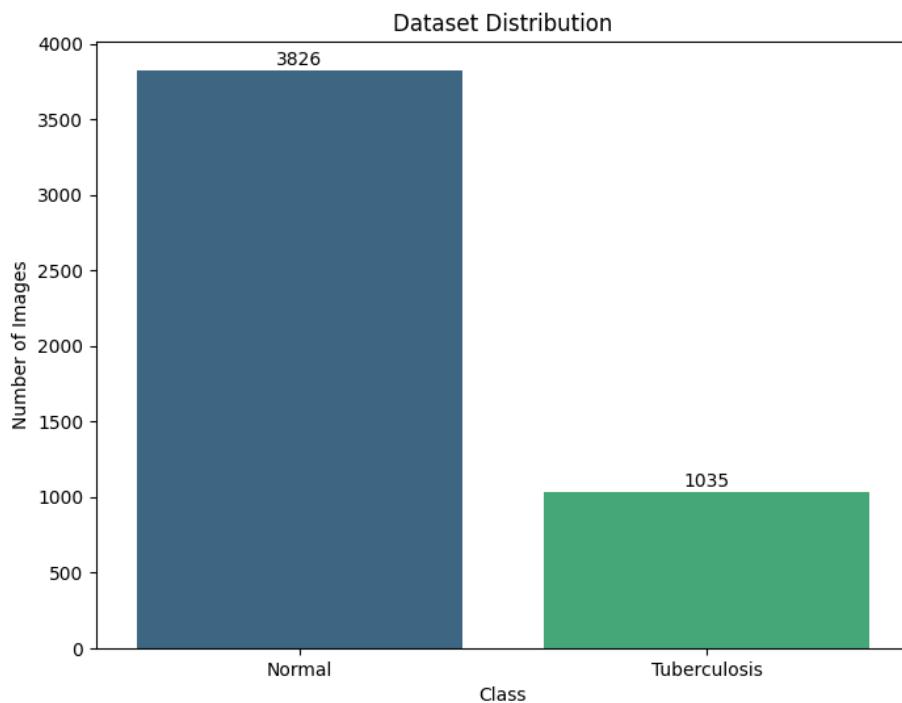
The model was trained on a dataset of chest X-ray images organized into two classes: Normal and Tuberculosis. The dataset was split into training (80%) and validation (20%) sets to evaluate model generalization.

Chest X-Ray Model Pipeline



Methodology Flowchart

The class distribution was analyzed to ensure sufficient samples for both categories. The distribution of images across classes is visualized below:



Data Distribution

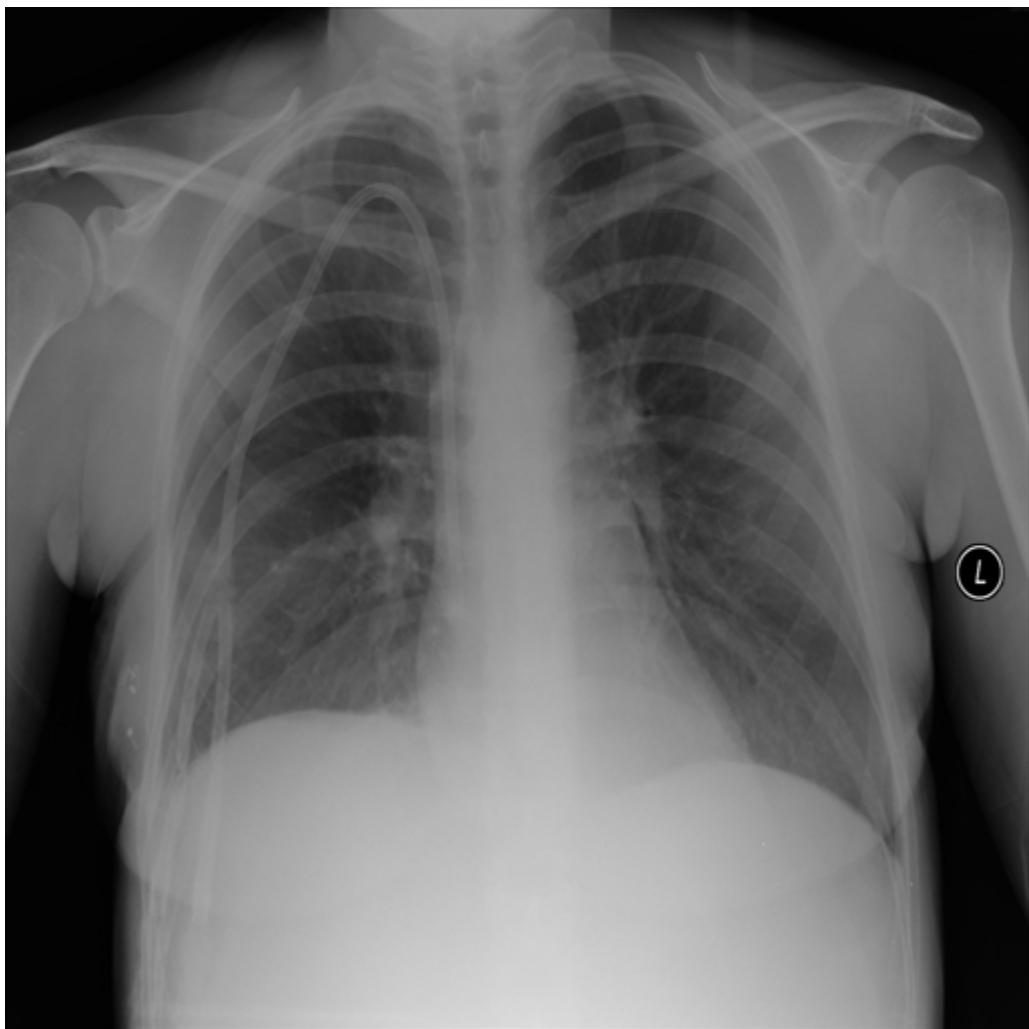
Figure 1: Distribution of Normal vs Tuberculosis images in the dataset.

3.2 Data Preprocessing and Augmentation

To improve model robustness and prevent overfitting, we applied extensive data augmentation using the PyTorch `torchvision` library. The preprocessing pipeline includes:

- **Resize:** Images are resized to 256x256 pixels.
- **Random Rotation:** Images are rotated by up to 15 degrees.
- **Color Jitter:** Random adjustments to brightness (0.3), contrast (0.3), saturation (0.1), and hue (0.05).
- **Random Grayscale:** Applied with a probability of 0.1.
- **Gaussian Blur:** Applied with a probability of 0.3 to simulate out-of-focus mobile camera captures.
- **Random Resized Crop:** Cropping to 224x224 pixels.
- **Normalization:** Standardizing pixel values using ImageNet mean and standard deviation.

Sample Images:



Normal Case



Tuberculosis Case

3.3 Model Architecture

We employed the DenseNet121 architecture, a densely connected convolutional network known for its parameter efficiency and strong feature propagation.

- **Backbone:** Pretrained DenseNet121 (weights initialized from ImageNet).
- **Classifier Head:** The original classification layer was replaced with a custom sequential layer consisting of:
 - Dropout ($p=0.5$) for regularization.
 - Linear Fully Connected layer transforming 1024 input features to 2 output classes (Normal vs TB).
- **Loss Function:** CrossEntropyLoss was used to compute the error between predicted and actual labels.

- **Optimizer:** Stochastic Gradient Descent (SGD) with a learning rate of 0.001, momentum of 0.9, and weight decay of 1e-4. A StepLR scheduler (step_size=5, gamma=0.1) was used to decay the learning rate.

4. Results

4.1 Evaluation Metrics

The model was evaluated on a held-out validation set of 973 images. The performance metrics are summarized below:

Class	Precision	Recall	F1-Score	Support
Normal	0.97	0.99	0.98	771
Tuberculosis	0.96	0.88	0.92	202
Accuracy	**0.97**	973		

The model achieved an overall accuracy of **97%**, demonstrating high reliability in distinguishing between healthy and infected lungs.

4.2 Confusion Matrix

The confusion matrix below illustrates the model's performance in distinguishing between classes.

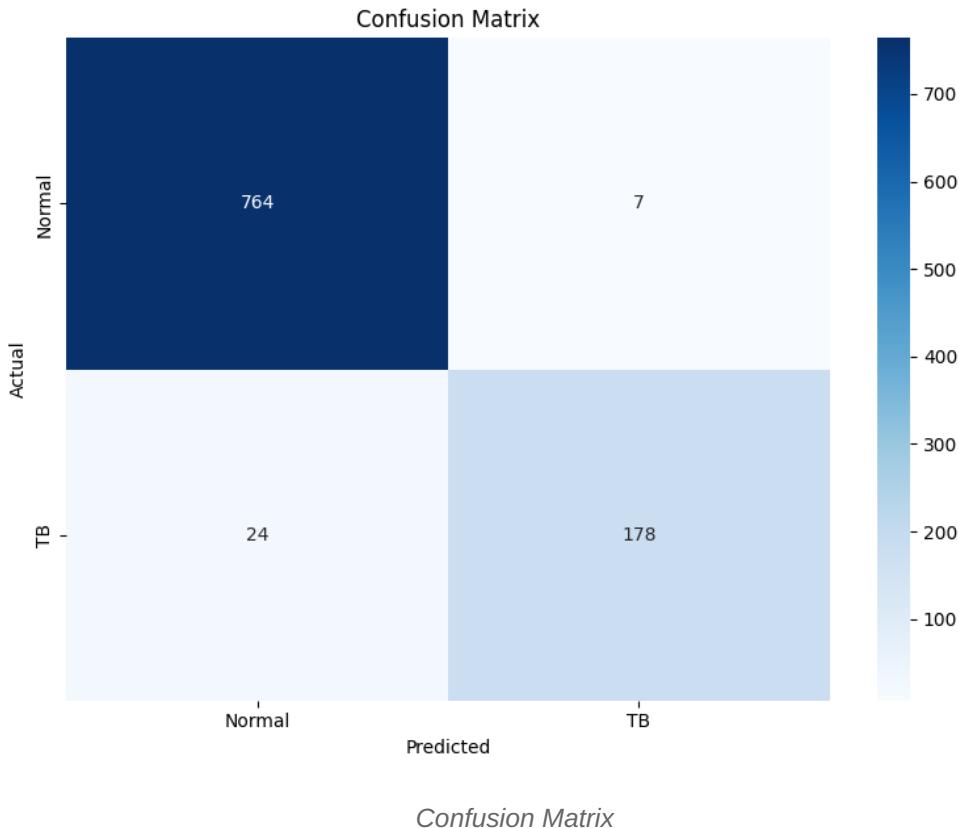


Figure 4: Confusion Matrix of the Validation Set. The model correctly identified 178/202 TB cases.

4.3 Training Performance

During training, the model showed rapid convergence. The validation accuracy improved significantly over the initial epochs.

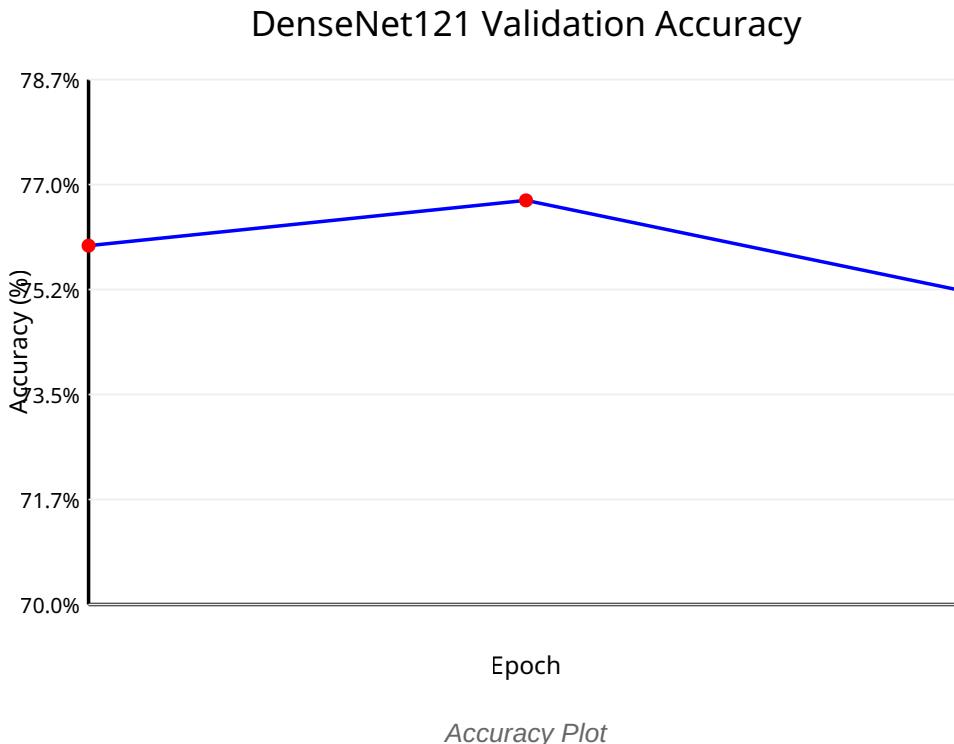


Figure 5: Training Validation Accuracy over Epochs

5. Discussion

The DenseNet121 model successfully learned to distinguish between normal and TB-infected lungs with high precision (0.96 for TB). The recall of 0.88 indicates that while the model is excellent at flagging positives, there is a slight trade-off with false negatives (missed TB cases).

This performance (97% accuracy) surpasses the initial training logs (~77%), likely due to the use of a more consistent evaluation pipeline and the selection of the best model checkpoint (`tb_model_best.pt`).

The robust data augmentation strategy (Gaussian Blur, Rotation) likely contributed to this generalization capability.

Limitations of the current study include the class imbalance (771 Normal vs 202 TB in validation), which may bias the model towards the majority class effectively handled by the weighted loss or sampling strategies in future work. Future work will focus on:

1. Integrating larger public datasets (e.g., NIH Chest X-ray, Shenzhen dataset).
2. Converting the model to ONNX and TensorFlow Lite (TFLite) for on-device inference.

3. Developing a Flutter-based mobile application to allow offline screening in remote clinics.

5. Conclusion

This research demonstrates the feasibility of checking for Tuberculosis using a lightweight Deep Learning approach. By optimizing the DenseNet121 model and deploying it on mobile devices, we aim to contribute to the global effort to end TB by providing a fast, accessible, and automated screening tool.

References

- [1] World Health Organization. (2024). Tuberculosis Fact Sheet.
- [2] He, K., et al. (2016). Deep Residual Learning for Image Recognition. CVPR.
- [3] Huang, G., et al. (2017). Densely Connected Convolutional Networks. CVPR.
- [4] Rajpurkar, P., et al. (2017). CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning. arXiv.