**Accelerating the Eradication of Tuberculosis Using AI-Powered Diagnostic Tools**

**(UN SDG [**GOOD HEALTH AND WELLBEING**]3.3)**

Author: Mwangi Wambugu

Date: July 2025

Executive Summary

Target 3.3 of the United Nations Sustainable Development Goal 3 (Good Health and Wellbeing) aims to end the epidemics of AIDS, tuberculosis (TB), malaria, and neglected tropical diseases by 2030. Tuberculosis remains one of the deadliest infectious diseases worldwide, disproportionately affecting low- and middle-income countries. This report outlines a novel AI-powered solution that leverages fine-tuned multimodal models, specifically GEMMA 3N for Visual Question Answering (VQA), and a traditional machine learning model trained using Scikit-learn, to support the early and accurate detection of TB from chest x-rays.

1. Introduction

Tuberculosis, caused by *Mycobacterium tuberculosis*, is a curable and preventable disease. However, it still claims over 1.3 million lives annually, with millions more suffering prolonged illness. TB primarily affects the lungs and spreads through airborne particles. According to the World Health Organization (WHO), in 2022 alone:

10.6 million people fell ill with TB

1.3 million died

86% of new TB cases occurred in 30 high-burden countries

Africa accounted for 25% of TB cases globally

Efforts to eradicate TB have been hindered by late diagnosis, lack of qualified radiologists, and limited access to health services. Innovations in artificial intelligence can revolutionize early TB diagnosis by making screening more scalable and cost-effective.

2. Problem Statement

In regions with high TB prevalence, there are severe shortages of trained medical personnel, particularly radiologists capable of reading x-rays. Misdiagnosis or delayed diagnosis leads to higher transmission rates, increased mortality, and prolonged recovery. Traditional diagnostic methods like sputum microscopy or GeneXpert require specialized labs, time, and resources, making them impractical for rural and underserved communities.

3. Objectives

Develop an AI-based system to detect tuberculosis from chest x-rays.

Improve early diagnosis and accessibility using mobile and web platforms.

Compare performance between multimodal LLMs (GEMMA 3N) and classical ML models.

Support public health initiatives with scalable, accurate, and cost-effective diagnostics.

4. Methodology

4.1 Dataset

We used a curated dataset of chest x-ray images labeled as either "Normal" or "Tuberculosis" from a reputable public TB radiography database. The data was preprocessed to standardize resolution, normalize pixel values, and split into training, validation, and testing sets.

4.2 GEMMA 3N for Visual Question Answering (VQA)

Fine-tuned the open-weight Med-GEMMA 3N model using LoRA on multimodal prompts.

Input: X-ray image + instruction prompt: "You are an expert radiologist. Describe what you see."

Output: A natural language diagnostic response.

Training framework: Unsloth, integrated with Hugging Face.

Hosted model: [MwangiWambugu/tb\_xray\_model](https://huggingface.co/MwangiWambugu/tb_xray_model)

4.3 Scikit-learn Model

Features: Extracted from x-ray images using Histogram of Oriented Gradients (HOG) and PCA.

Model: Random Forest Classifier.

Accuracy: 95% on held-out test set.

Advantage: Lightweight model suitable for embedded or offline devices.

4.4 Evaluation Metrics

Precision, Recall, F1-Score for classification

BLEU Score and ROUGE for VQA output evaluation

5. Results and Findings

| Model Type | Accuracy | Recall (TB) | F1-Score | Deployment Suitability |
| --- | --- | --- | --- | --- |
| GEMMA 3N VQA | N/A (textual output) | High (Qualitative) | N/A | Web, Diagnostic Bots |
| Scikit-learn RF | 95% | 95% | 95% | Offline/Edge devices |
|  |  |  |  |  |

Sample GEMMA 3N output:  
Prompt: "What do you see in this x-ray image?"  
Response: "The chest x-ray reveals diffuse infiltrates in the upper lobes, consistent with pulmonary tuberculosis."

6. Why Early Diagnosis Matters

Prevent Transmission: A single person with active TB can infect 10-15 others annually.

Improve Survival: Early treatment reduces mortality by over 50%.

Save Costs: Preventing advanced TB reduces treatment complexity and hospitalization.

7. Causes of TB

Poor living conditions and ventilation

Weakened immune systems (e.g., HIV/AIDS)

Malnutrition

Smoking and substance abuse

8. Preventative Measures

BCG Vaccination

Early screening and contact tracing

Public education and awareness campaigns

Masking and improved ventilation

9. Why Our Solution Is Different

Multimodal Diagnosis: Unlike traditional classifiers, GEMMA 3N provides human-readable, interpretable feedback.

Accessibility: Can be deployed via mobile app, web portal, or rural health kiosks.

Speed: X-ray image to diagnosis in under 10 seconds.

Cost-effective: No need