Explainable AI: Visualizing Deep Learning Based Pneumonia and Other Lung Diseases Detection Using Chest X-Ray Scans

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Abstract - Early and accurate detection of lung diseases such as Pneumonia, Tuberculosis, COVID-19, and Lung Cancer is crucial for timely medical intervention. This project presents an intelligent, explainable deep-learning–based web application that analyzes chest X-ray images and provides disease classification along with visual explanations to improve trust and interpretability. A Convolutional Neural Network (ResNet-based model) is trained to classify lung conditions, and the system integrates Explainable AI (XAI) techniques—Grad-CAM and LIME—to highlight the specific regions in the X-ray that influence the prediction. These visual explanations help doctors and users understand why the model makes a particular decision.

***Key Words*:** Explainable AI, Deep Learning, Lung Disease Detection, Chest X-Ray, Grad-CAM, LIME

1.INTRODUCTION

COVID-19, and Lung Cancer continue to be major global health challenges, affecting millions of people every year. Early detection plays a crucial role in improving patient survival rates and reducing the burden on healthcare systems. Traditionally, diagnosis is performed manually by radiologists who analyze chest X-ray images—a process that can be time-consuming, subjective, and prone to human error, especially in areas with limited medical expertise. With advances in artificial intelligence and deep learning, automated medical image analysis has emerged as a powerful tool to assist healthcare professionals in making faster and more accurate diagnostic decisions. This project aims to develop an intelligent, explainable, deep-learning–based web application capable of detecting major lung diseases from chest X-ray images. A Convolutional Neural Network (ResNet-based model) is employed to classify X-ray images into categories such as Normal, Pneumonia, Tuberculosis, COVID-19, and Lung Cancer. Unlike traditional AI models that behave like "black boxes," this system integrates Explainable AI techniques Grad-CAM and LIME to show visual evidence of how the model arrives at each prediction. By highlighting the most important regions of the lung in the X-ray, the systemprovides transparency and builds trust among doctors and users.The project incorporates additional features such as image preprocessing, confidence scoring, disease descriptions, and a database of emergency medical specialists. A Gemini-powered chatbot is also integrated to answer user queries and offer health-related support. Overall, this project demonstrates how AI, combined with explainability and user-centered design, can assist in early diagnosis, support medical professionals, and enhance the reliability of AI-based healthcare solutions.

2. . PROPOSED METHODOLOGY

The proposed methodology begins with the systematic collection and preparation of chest X-ray images, which form the foundation of the entire system. Since medical images often come from multiple sources with varying formats and resolutions, preprocessing is performed to standardize the dataset. This includes resizing all images to a fixed size, normalizing pixel values, and converting images into grayscale for uniform analysis. Additional enhancement techniques such as edge detection and thresholding are applied to highlight structural features of the lungs. To improve the robustness of the model and prevent overfitting, data augmentation techniques—such as rotation, flipping, zooming, and shifting—are used to artificially expand the dataset and expose the model to diverse visual variations. The core of the system involves developing a deep-learning model capable of accurately identifying lung diseases from X-ray images. A Convolutional Neural Network based on the ResNet architecture is implemented due to its ability to extract deep hierarchical features efficiently. The model is trained to classify images into five categories: Normal, Pneumonia, Tuberculosis, COVID-19, and Lung Cancer. During training, convolutional layers learn to detect patterns such as opacities, nodules, and abnormal textures that correspond to different diseases.

Once trained, the model predicts the most probable disease for any input image and generates a confidence score that quantifies the reliability of the prediction. To address the critical need for transparency in AI-driven medical systems, the methodology incorporates Explainable Artificial Intelligence (XAI) techniques. Two widely used methods—Grad-CAM and LIME— are integrated to generate visual explanations for each prediction. Grad-CAM produces heatmaps that highlight the most influential regions of the X-ray image, showing doctors exactly where the model is focusing. LIME provides a complementary explanation by dividing the image into superpixels and identifying the regions that positively contribute to the classification. These explanations help radiologists understand the rationale behind the model's decisions, increase trust, and support clinical validation. The final stage of the methodology focuses on system integration and deployment using a Flask-based web application. The web interface allows users to upload chest X-ray images and instantly view preprocessing outputs, predicted disease categories, confidence levels, and visual explanations generated by the XAI methods. To support real-world medical use, the system includes an SQLite database.

3.IMPLIMENTATION

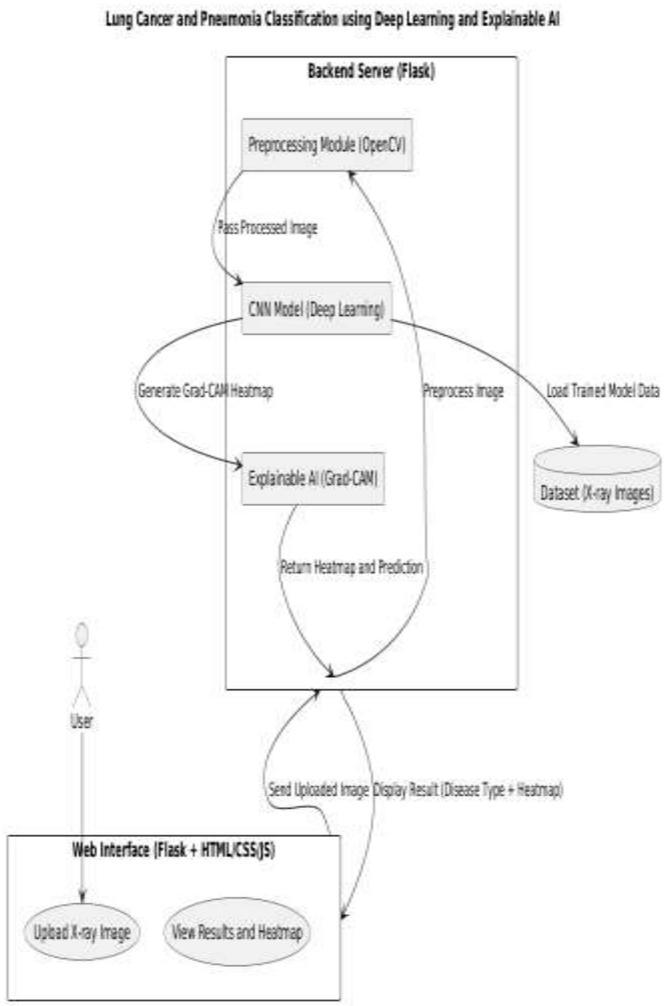


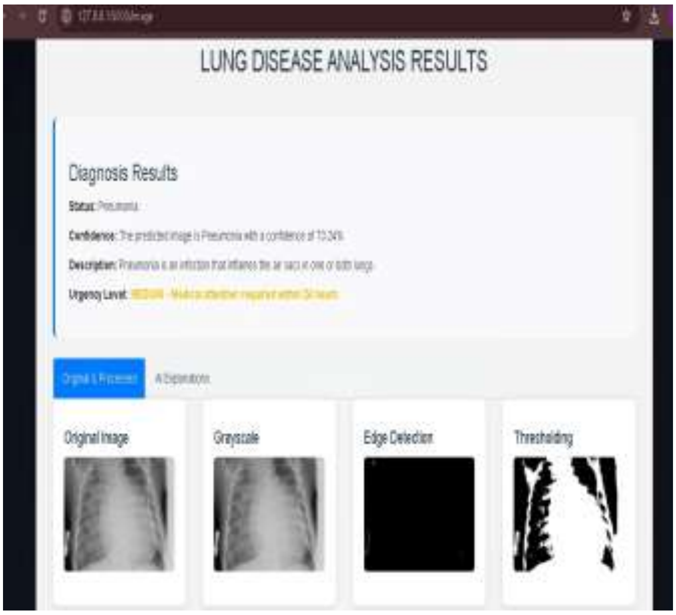
Fig : System Architecture

The implementation of the Lung Disease Detection System is carried out using a Flask-based web application that integrates deep learning, medical image processing, explainable AI, and chatbot technologies. When a user uploads a chest X-ray image, the system performs several preprocessing operations such as resizing, grayscale conversion, edge detection, and thresholding using OpenCV. These steps enhance important features and prepare the image for accurate model prediction.User authentication and registration functionalities are also implemented using SQLite, ensuring secure login and personalized access to the platform.A pre-trained ResNet-based convolutional neural network model is used for disease classification. The uploaded X-ray image is normalized and fed into the model, which predicts diseases such as Pneumonia, Tuberculosis, COVID-19, Cancer, or Normal. Theprediction output includes the disease class along with a confidence score. Along with the prediction, the system displays different processed views of the X-

ray(grayscale, edge-detected, and threshold images) to give users better visual understanding of the input. results for each new input without manual cleanup. Overall, the implementation integrates AI-based diagnosis, interpretability tools, medical assistance, and database-driven doctor recommendations into a unified, user-friendly platform suitable for real-world To make the deep learning predictions interpretable, the system integrates two powerful Explainable AI
techniques: Grad-CAM and LIME. Grad-CAM
highlights the lung regions that influence the model's decision, producing a heatmap superimposed on the X-ray image. LIME further adds interpretability by identifying important pixel segments that impact classification, making the decision-making process transparent for both doctors and users. Additionally, a doctor recommendation module retrieves available emergency specialists from a SQLite database and
displays their details to users based on the predicted
disease severity. The application also includes a medical chatbot powered by Google's Gemini AI, enabling users to ask health-related questions and receive meaningful responses. This enhances the platform's functionality by providing interactive guidance and medical support.All outputs—including predictions, processed images, explainability visuals, and doctor suggestions—are displayed using HTML templates, creating a user-friendly and complete diagnostic support system that bridges AI-based prediction with interpretability and healthcare assistance.

To enhance user experience, the project incorporates a well-organized frontend built using HTML, CSS, and integrated Flask templates. Each output—such as uploaded images, processed versions, predicted disease labels, confidence scores, and explainability visualizations—is displayed clearly on the results page for better comprehension. The interface is optimized for easy navigation, allowing users to move between the login page, image analysis module, graph visualization page, and medical chatbot effortlessly. The use of separate static folders for storing generated outputs (GradCAM, LIME, gray scale images, and edge maps) allows the system to dynamically update healthcare applications.

4.RESULTS AND DISCUSSION



1.Diagnosis Results Section
The top part of the second screenshot shows the disease prediction summary generated by the deep learning model. This includes:
Status: Predicted lung condition (here: Pneumonia).
Confidence: Percentage of certainty (73.24%).
Description: Brief explanation of what the disease means.
Urgency Level: Color-coded medical alert indicating how quickly the patient needs to consult a doctor.

2. Original & Processed Images
Below the diagnosis, the interface shows four processed versions of the uploaded X-ray:a. Original Image

This is the untouched chest X-ray uploaded by the user.
b. Grayscale Image
The X-ray is converted to grayscale to enhance contrast and simplify feature extraction.
c. Edge Detection (Canny)
This black-and-white output highlights the edges of the lung structure, helping identify shapes and boundaries useful for medical analysis.
d. Thresholding
This image shows a binary (black-white) version where the lung regions are segmented based on pixel intensity.
It helps visualize abnormal patterns clearly.
These processed images demonstrate how the system analyzes the input before making a prediction.

3. AI Explainability – GradCAM & LIME
The first screenshot shows the AI Explanations tab, containing two advanced explainability outputs:
a. GradCAM Heatmap
The left image overlays a heatmap on the X-ray.
Red/Yellow areas = regions that most influenced the AI's prediction.
Blue/Green areas = less important regions.
This helps users understand where the model detected signs of pneumonia.
b. LIME Explanation
The right image shows bright yellow/green regions, representing pixel segments that contributed positively to the prediction.
LIME breaks the image into interpretable segments and highlights the areas that the AI considered important.
Together, GradCAM and LIME make the model's predictions transparent and medically interpretable.

5. CONCLUSION

This project successfully demonstrates the development of an explainable deep-learning–based system for the detection of lung diseases using chest X-ray images. By integrating a ResNet-based Convolutional Neural Network with Explainable AI techniques such as Grad-CAM and LIME, the system not only provides accurate disease predictions but also offers transparent visual explanations that improve trust and understanding among medical professionals and users. The model's ability to classify conditions such as Pneumonia, Tuberculosis, COVID- 19, and Lung Cancer highlights its potential usefulness in early diagnosis and timely treatment, especially in areas where access to specialized radiologists is limited. The deployment of the system as a user-friendly Flask web application further enhances its practical value, allowing users to upload images, view preprocessing steps, analyze prediction outputs, and receive clear interpretivevisualizations. Additional features such as an emergency doctor database and a Gemini-powered AI chatbot make the system more interactive, informative, and supportive for health-related decision-making. The results obtained from testing and validation confirm that the system is efficient, reliable, and capable of assisting in real-world medical workflows. Overall, the project demonstrates how AI, when combined with explainability and accessibility, can significantly improve the accuracy, speed, and transparency of medical image analysis. It provides a strong foundation for future enhancements, such as expanding the dataset, integrating more advanced deep-learning architectures, or extending the system to other medical imaging domains. This work emphasizes the growing importance of explainable AI in healthcare and showcases its potential to support doctors, empower patients, and contribute to better clinical outcomes.

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