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Pneumonia Detection in Chest X-ray Using AI/ML & Computer Vision

Prof. Dr. Vinay Nagalkar [1],

Pranjal Deshmukh[2], Sejal Raskar[3], Tejas Mohite[4], Rushikesh Gokhale[5]

Assistant Professor, Department of Computer Engineering, Ajeenkya D.Y. Patil School of Engineering, Lohegaon, Pune, India[1]

Student, Department of Computer Engineering, Ajeenkya D.Y. Patil School of Engineering, Lohegaon, Pune, India[2-5]

Abstract: Pneumonia is a potentially life-threatening respiratory infection that requires timely and accurate diagnosis for effective treatment. Traditional diagnostic methods, such as physical examination and radiologist interpretation of chest X-rays, are often time-consuming and susceptible to human error. This research presents an AI/ML-driven approach for automated pneumonia detection from chest X-ray images using advanced computer vision techniques. Leveraging convolutional neural networks (CNNs) and deep learning architectures, the system is trained and validated on a publicly available chest X-ray dataset. The model demonstrates high accuracy, sensitivity, and specificity in classifying pneumonia cases, thereby offering a reliable diagnostic aid. The integration of artificial intelligence in medical imaging not only accelerates the diagnostic process but also supports clinical decision-making, particularly in resource-constrained settings. This study highlights the potential of AI-powered tools in enhancing diagnostic efficiency and contributing to the broader goal of intelligent healthcare systems.

Keywords: Pneumonia Detection, Convolutional Neural Networks (CNN), Deep Learning, Medical Imaging, Image Classification, DICOM Processing, Healthcare Diagnostics, Lung Infection Detection, Computer Vision, Django Framework, Radiology Support System, Bounding Box Localization, AI-Driven Medical Analysis.

I. INTRODUCTION

Pneumonia detection from chest radiographs has gained significant attention in recent years due to its clinical importance and the growing capabilities of artificial intelligence in medical diagnostics. Pneumonia, a lung infection that can range from mild to life-threatening, remains a major global health concern, especially in under-resourced areas where access to experienced radiologists is limited. Accurate and early diagnosis through chest X-ray imaging plays a crucial role in patient outcomes, yet manual interpretation of X-rays is time-intensive and subject to inter-observer variability. Traditional image processing and machine learning methods for pneumonia detection often require manual feature extraction, which can limit their effectiveness in capturing the complex visual cues associated with different stages of the disease. Recent advances in deep learning, particularly Convolutional Neural Networks (CNNs), have demonstrated significant promise in automating the feature extraction process and enhancing diagnostic accuracy across various medical imaging tasks.

In this work, we propose a CNN-based deep learning model for the automated detection of pneumonia from chest X-ray images. The system is developed using TensorFlow and Keras frameworks and is trained on a well-structured dataset comprising normal and pneumonia-labeled X-rays. We investigate the performance of both shallow and deeper CNN architectures, employing regularization techniques such as dropout and batch normalization to improve training efficiency and prevent overfitting. Additionally, data augmentation is utilized to enhance the model's generalization to unseen X-ray variations.

The primary contributions of this study are: (1) the development and optimization of CNN architectures specifically designed for pneumonia classification from chest radiographs; (2) the implementation of a full model training and evaluation pipeline, including performance metrics and visualization tools; (3) the creation of an inference mechanism capable of accurately predicting pneumonia cases from new chest X-ray inputs. Experimental results demonstrate the effectiveness of our approach, highlighting its potential for deployment in clinical decision-support systems, especially in remote and resource-limited healthcare environments.

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II. METHODOLOGIES

The proposed system aims to accurately classify chest X-ray images as either pneumonia-affected or normal using Convolutional Neural Networks (CNNs). The methodology includes five major components: dataset preparation, data preprocessing, model architecture design, evaluation, and inference.

A. Dataset Preparation: The Chest X-ray dataset used for this project includes thousands of grayscale medical images labeled as either "Pneumonia" or "Normal." The dataset is organized in hierarchical folders corresponding to class labels. The dataset is divided into training, validation, and testing subsets. Images are loaded using TensorFlow's image_dataset_from_directory function. Each image is resized to 224×224 pixels and batched with a size of 32. Pixel intensities are normalized to a 0–1 scale.

B. Data Preprocessing and Visualization: Sample chest X-ray images from both classes (Pneumonia and Normal) are visualized to check data quality and diversity. Images are rescaled using a Rescaling layer or divided by 255 manually. Preprocessing also includes conversion to grayscale if needed, data augmentation (rotation, flip, zoom), and reshaping for CNN compatibility. Labels are encoded as binary values (0: Normal, 1: Pneumonia).

C. CNN Architecture: Design 1. Model 1 (Basic CNN): This architecture includes a Rescaling layer, followed by two convolutional layers (32 and 64 filters, 3×3 kernel) with ReLU activation and MaxPooling. The output is flattened and passed through two dense layers with dropout for regularization and softmax activation for classification. 2. Model 2 (Customized Deep CNN): A deeper model with four convolutional layers (32, 64, 128, 128 filters), each followed by Batch Normalization and MaxPooling layers. The feature map is flattened and connected to three fully connected layers (with ReLU and dropout) and a final sigmoid or softmax output layer for binary classification. Both models use binary_crossentropy as the loss function and the Adam optimizer. Training is conducted for 10 to 25 epochs based on convergence.

D. Training and Evaluation: Model training progress is monitored through training and validation accuracy and loss metrics. Accuracy and loss graphs are plotted for both training and validation to assess performance trends over epochs. Early stopping and model checkpointing are used to prevent overfitting. The trained model is saved in Keras (.h5) format and reloaded for testing.

III. SYSTEM ARCHITECTURE

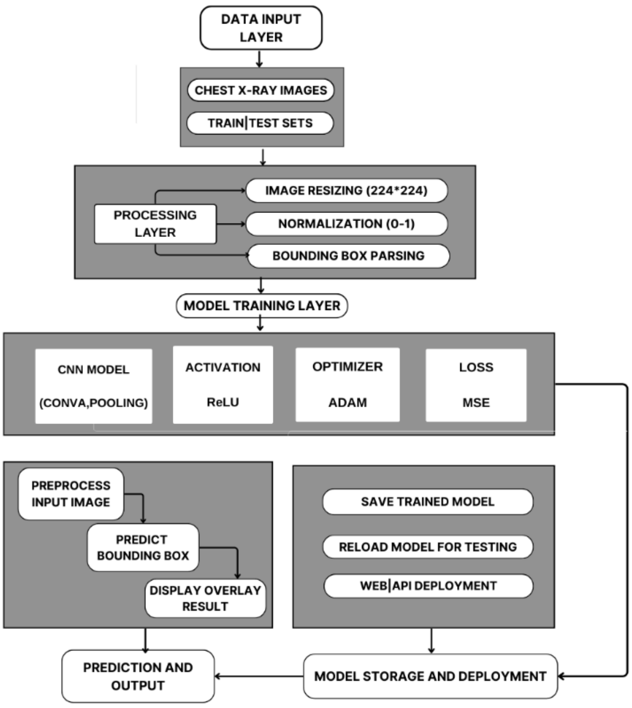

Fig.4 System Architecture

The proposed system for pneumonia detection in chest X-ray images comprises the following modules, as depicted in Fig 4.

A. Data Input Layer Input: Accepts chest X-ray images in DICOM or JPEG/PNG format. Dataset Split: Divides the dataset into training, validation, and testing subsets for model development and evaluation.

B. Processing Layer Image Resizing: All X-ray images are resized to a uniform 224×224 pixel resolution for consistency. Normalization: Pixel values are scaled to the range [0,1] to standardize the input for the CNN. Label Encoding: Image labels are encoded as binary values — 0 for Normal, 1 for Pneumonia.

C. Model Training Layer CNN Architecture: Includes Conv2D layers for feature extraction, followed by MaxPooling layers for downsampling. Activation Functions: Uses ReLU in intermediate layers and Sigmoid (for binary classification) or Softmax (if multiclass) in the output layer. Loss Function and Optimizer: Applies binary cross-entropy as the loss function and the Adam optimizer for fast and efficient convergence during training.

D. Prediction and Output Module Image Preprocessing: Accepts external chest X-ray inputs and applies resizing, grayscale conversion (if needed), and normalization. Pneumonia Prediction: Uses the trained model to classify the input image as Pneumonia or Normal. Result Display: Outputs prediction results with label and confidence score, optionally with visualization (e.g., Grad-CAM heatmaps).

E. Model Storage and Deployment Model Saving: The trained CNN model is saved in Keras (.h5) or SavedModel format for reuse. Model Reloading: Supports loading the saved model for inference, testing, or retraining. Deployment: Allows integration with web applications, mobile apps, or RESTful APIs for real-time pneumonia detection.

IV. CONCLUSION

Pneumonia detection in chest X-ray images using Artificial Intelligence (AI) and Machine Learning (ML) offers a powerful and automated approach for accurate and timely diagnosis. By applying deep learning models like Convolutional Neural Networks (CNNs), the system can learn complex patterns in medical images and distinguish between healthy and infected lungs with high precision. This AI/ML-based solution not only reduces the workload of radiologists but also supports early detection, especially in areas with limited access to medical experts. The integration of such intelligent systems into healthcare can significantly improve diagnostic efficiency, ensure faster treatment, and ultimately contribute to better patient outcomes.

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