Explainable AI for Chest Disease Diagnosis: A Grad-CAM Enhanced EfficientNetV2S Approach

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Introduction

- This project focuses on classifying chest diseases like Pneumonia–Viral and Bacterial, Emphysema, COVID-19, pose serious health risks and need early, accurate diagnosis.
- Chest X-rays are widely used due to their affordability and accessibility, but manual Interpretation is prone to errors and variability.
- The model was trained on a balanced chest X-ray dataset created using images from Kaggle.
- Traditional CNNs often miss subtle features, and this project uses EfficientNetV2S with Grad-CAM for accuracy and interpretability.

Materials and Methods

- Image Preprocessing: CLAHE is used to enhance local contrast in chest X-rays, improving the visibility of subtle disease features.
- Feature Extraction: EfficientNetV2S, a pretrained lightweight CNN, extracts deep hierarchical features from enhanced images using transfer learning.
- Classification: A custom dense neural network classifies X-rays into Pneumonia, COVID-19.
- Explainability: Grad-CAM generates visual heatmaps highlighting the lung regions influencing the model's decision, supporting clinical trust.

Materials and Methods

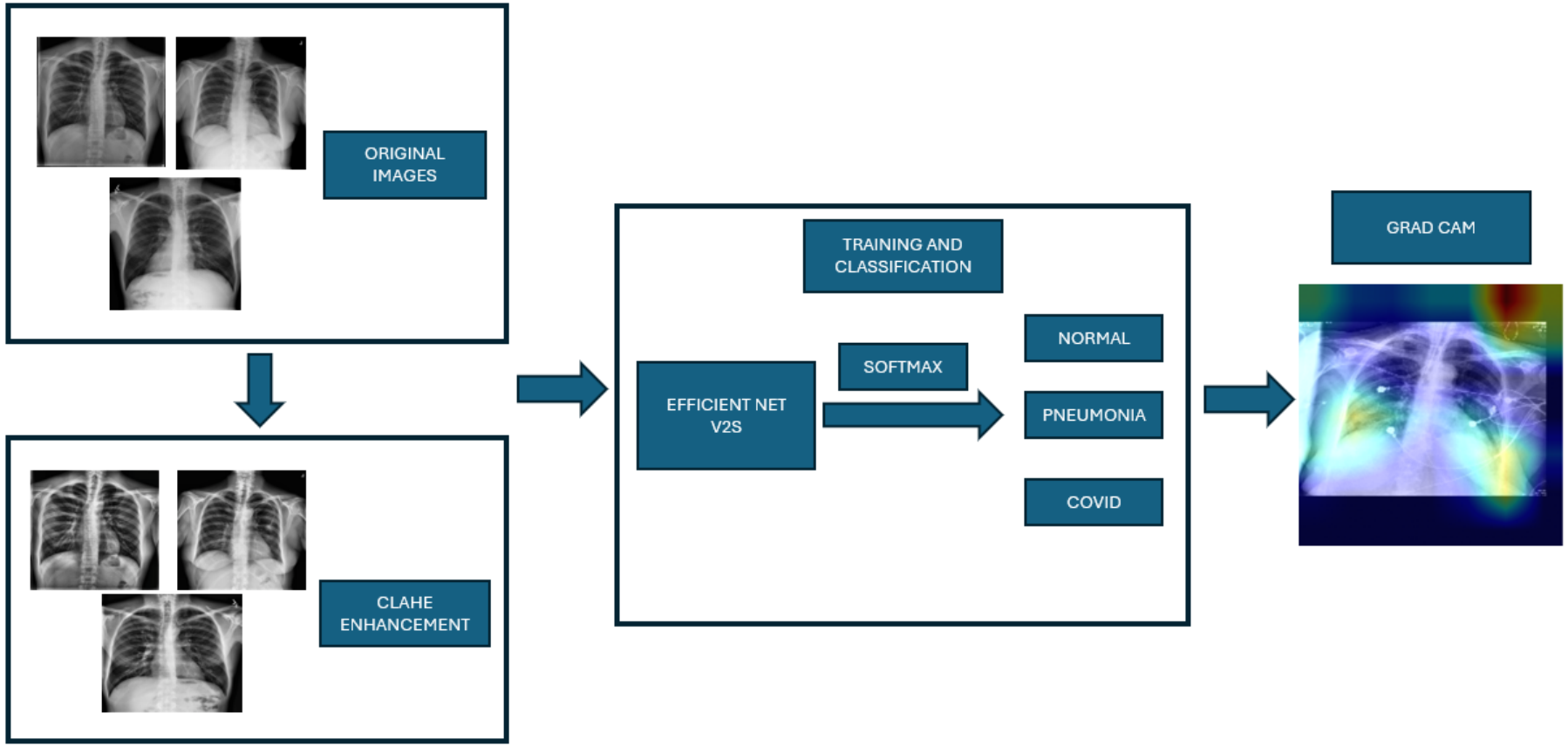


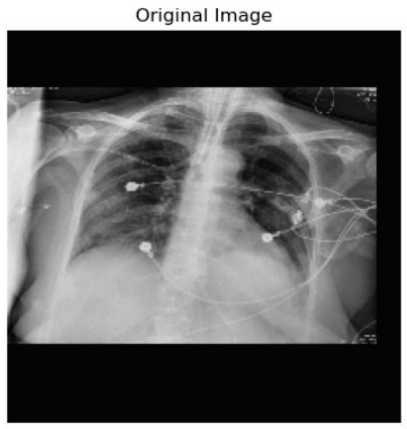
Image Enhancement & Explainability

CLAHE – Contrast Enhancement

- Enhances local contrast in X-ray images using adaptive histogram equalization.
- Reveals fine lung details like opacities and infiltrates.
- Preserves features while suppressing noise and avoiding over-enhancement.

Grad-CAM – Model Interpretability

- Generates heatmaps showing which regions influenced the model's prediction.
- Builds clinical trust by visually confirming disease focus areas.
- Useful for error analysis and validating correct decision paths.

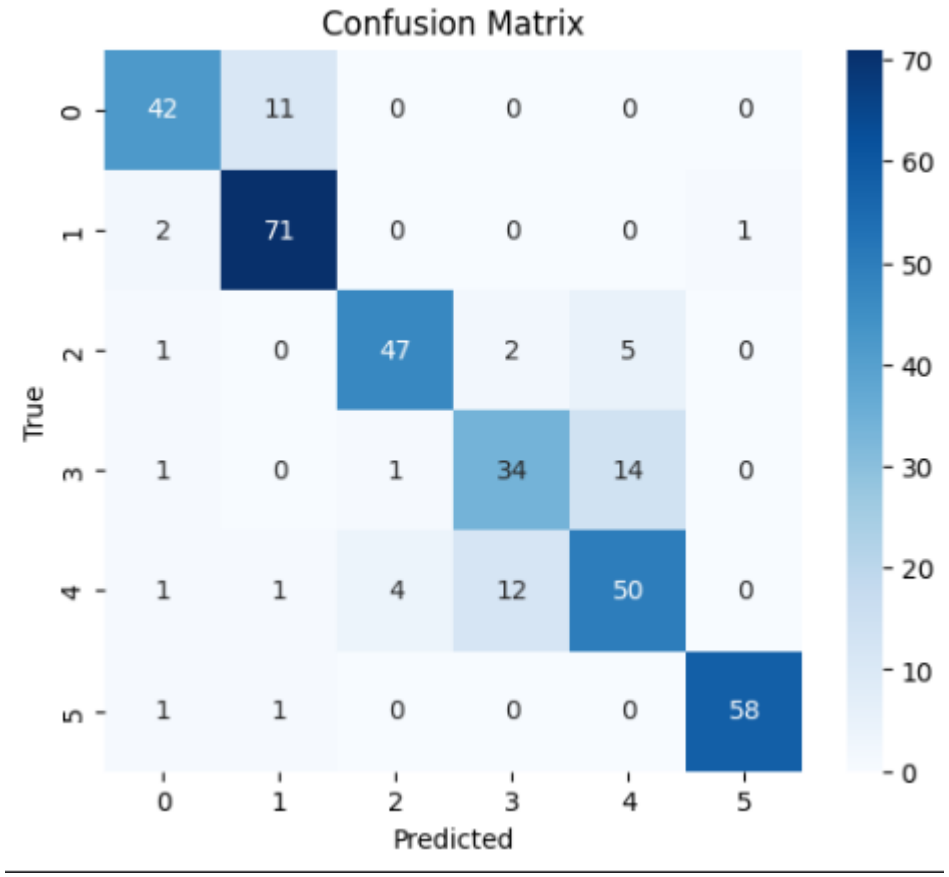


EfficientNetV2S Over Traditional CNN

- Compound scaling - Unlike traditional CNNs that scale depth, width, or resolution separately, EfficientNetV2S uses compound scaling.
- Detects subtle features more effectively with fewer parameters to achieve better generalization.
- It is optimized for speed, making it practical for real-time clinical environments where quick decisions matter
- Lightweight and effective for transfer learning on medical data.

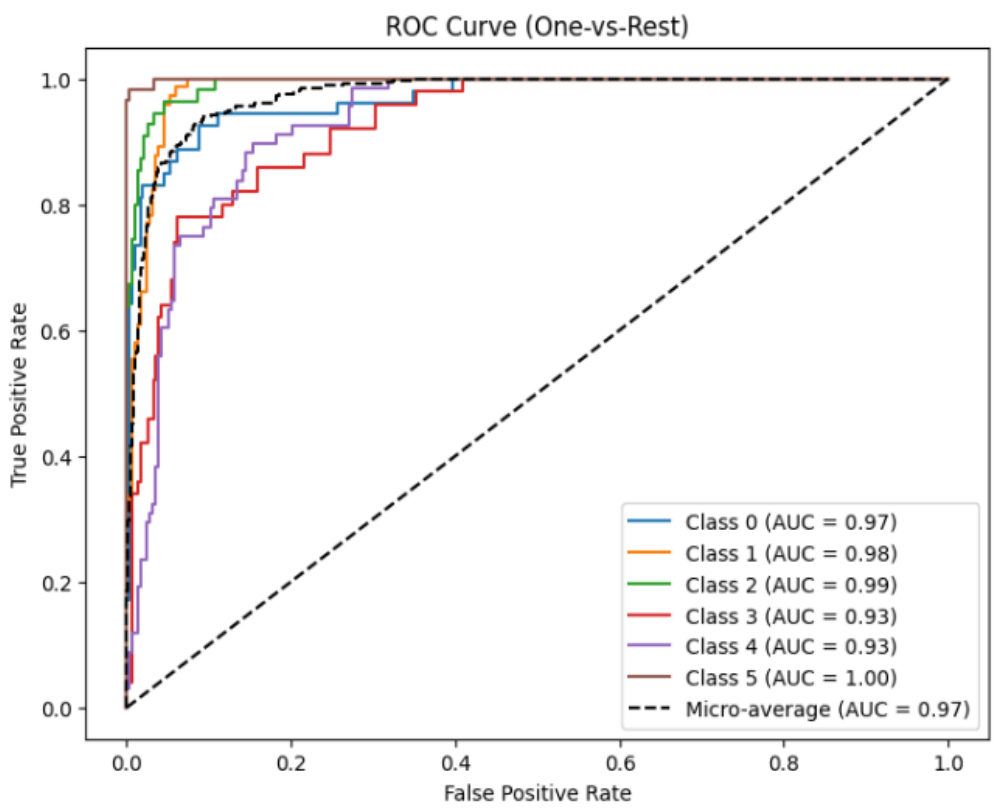
Results and Plots

- The model achieved 95.68% validation accuracy, correctly predicting most chest X-ray cases across all three classes.
- Some pneumonia cases (28) were predicted as normal, and a few normal cases (18) as pneumonia.
- COVID-19 Detection is Highly Reliable: 455 out of 463 COVID-19 images were correctly classified.
- The strong diagonal pattern in the confusion matrix shows the model is consistently accurate in identifying actual conditions.



Results and Plots

- The model shows excellent class separation with AUC scores of 0.98 (Pneumonia), 0.99 (Normal), and 1.00 (COVID-19), indicating robust diagnostic performance.
- All ROC curves are close to the top-left corner, showing high sensitivity and low false positives.
- High precision and recall values across all three classes, with F1-scores ranging from 0.94 to 0.98, indicating balanced and reliable predictions.
- The model performs especially well for COVID-19, achieving 0.99 precision and 0.98 recall.



Conclusion

- This work presents a reliable and explainable deep learning system for classifying chest X-rays into COVID-19, Pneumonia, and Normal using CLAHE, EfficientNetV2S, and Grad-CAM.
- The model achieved high accuracy (95.68%) and AUC (0.9884), proving its effectiveness in real-world diagnosis.
- Grad-CAM visualizations enhance trust by showing disease-relevant regions.
- The system offers a strong foundation for AI-assisted medical diagnosis.