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# DEEP LEARNING-BASED LUNG NODULE CLASSIFICATION USING CT SCANS

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## ABSTRACT

Automated classification of pulmonary nodules has the potential to improve diagnostic consistency and support radiologists in distinguishing benign from malignant nodules on CT scans.

This study developed and evaluated an EfficientNetB0-based deep learning model for automated lung nodule classification using 130 LIDC-IDRI patient cases. One valid nodule per patient was selected using the first radiologist's reading, and nodules with malignancy scores of 1–2 and 4–5 were included.

The model achieved 81% accuracy, 88% sensitivity, and 87% F1-score at the patch level, while patient-level evaluation achieved 73% accuracy and 86% sensitivity. Grad-CAM visualization was used to improve model interpretability by identifying image regions influencing predictions.

Results suggest promising malignant detection and potential for clinical integration, especially in low-resource settings after further refinement.

## INTRODUCTION

- Lung cancer is the leading cause of cancer-related mortality worldwide, emphasizing the importance of early detection.
- Pulmonary nodules may represent an early manifestation of lung cancer and are commonly evaluated using CT imaging.
- However, accurate nodule classification remains challenging due to high radiologist workload, interpretation variability, and overlapping visual features between benign and malignant nodules.
- These limitations can contribute to inconsistent diagnoses and may delay clinical decision-making.
- Reliable automated classification approaches have the potential to improve diagnostic consistency, support clinical decision-making, and enhance clinical efficiency.
- Therefore, this study developed and evaluated a deep learning model for automated pulmonary nodule classification on CT scans.

## METHODS AND MATERIALS

- **Dataset:** 130 LIDC-IDRI (TCIA) patient CT scans with XML annotations from four radiologists; 70/15/15 patient-wise split.
- **Nodule Selection:** First radiologist's reading only; one valid nodule per patient was selected. Nodules with scores 1–2 (benign) and 4–5 (malignant) were included, while score 3 nodules were excluded.
- **Patch Extraction:** 128×128-sized patches were extracted around the center of each valid nodule (ROI).
- **Preprocessing:** RGB conversion, resizing (224×224), benign-class augmentation (horizontal flip, vertical flip, +10° rotation) and binary labeling (0=benign, 1=malignant).
- **Final count:** 948 patches total, 720 training, 130 validation, and 98 testing.
- **Model:** EfficientNetB0 (fixed feature extractor) + GAP + Dropout (0.2) + Sigmoid classifier (Figure 2).
- **Training:** Adam (LR=$1\times10^{-4}$), BCE loss, batch size 64, 65 epochs, seed=100.
- **Evaluation:** Performance assessed at patch and patient levels using standard classification metrics.

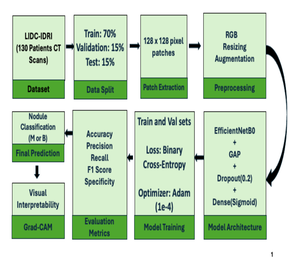


**Figure 1.** Study Workflow.

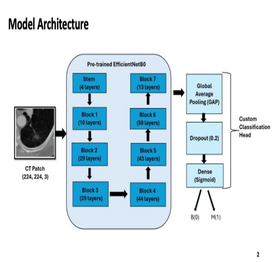


**Figure 2.** Model architecture.

## RESULTS

- The model achieved final training and validation accuracies of 86% and 80%, respectively.
- The trained model was evaluated on an independent test set comprising 98 CT patches from 15 patients.
- Patch-level evaluation achieved 81% accuracy and 88% sensitivity (Table 1; Figure 3).
- Patient-level evaluation using majority-vote aggregation achieved 73% accuracy and 86% sensitivity (Table 1;
- Figure 4).
- Grad-CAM visualizations showed strong attention on nodules in correct cases, while misclassifications had more diffused focus. Red indicated high attention, blue moderate, and black minimal (Figure 5).

**Table 1**. Performance metrics at the patch and patient levels.

| Metric | Patch | Patient |
|---|---|---|
| Accuracy | 81% | 73% |
| Precision | 87% | 67% |
| Recall (Sensitivity) | 88% | 86% |
| Specificity | 60% | 63% |
| F1-Score | 87% | 75% |

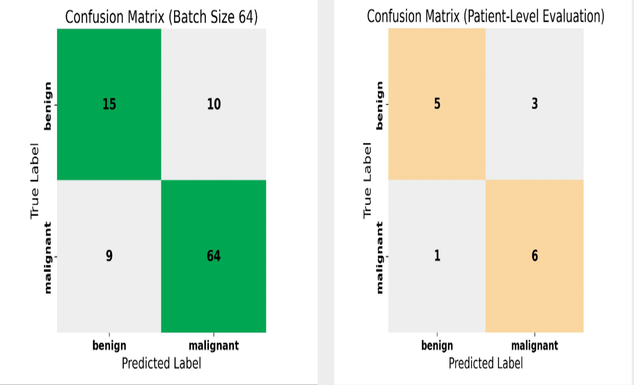


**Figure 3-4.** Patch-level and Patient level confusion matrices.

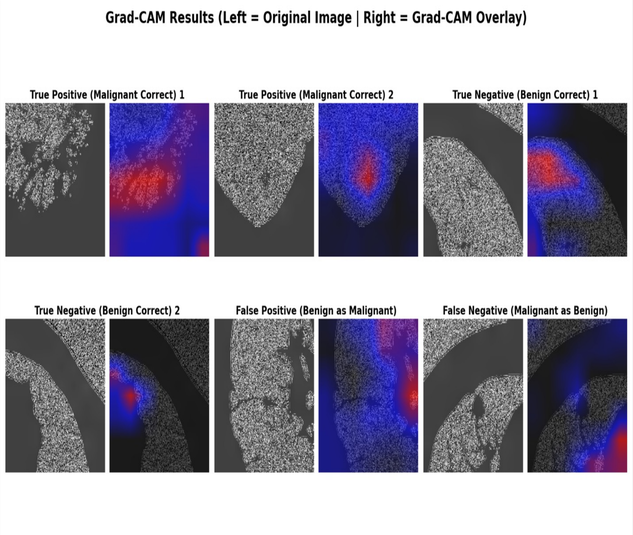


**Figure 5.** Grad-CAM overlays for six CT patches.

## DISCUSSION

- High sensitivity was maintained at both the patch level (88%) and patient level (86%), indicating effective identification of malignant nodules.
- The relatively small number of benign patches in our dataset, partially addressed through augmentation, may have contributed to the lower specificity.
- Patient-level evaluation showed a slight reduction in overall accuracy and F1-score compared with patch-level evaluation. This was expected because only 15 patients were included in the test set, where individual misclassifications had a larger impact on performance estimates.
- Despite the relatively small dataset, the model achieved performance comparable to several published studies, while Grad-CAM provided additional insight into the regions influencing model predictions.
- Future work should focus on including larger and more balanced datasets and further validating the model to support its development as a reliable AI-assisted tool for lung nodule classification.

## CONCLUSIONS

- An EfficientNetB0-based deep learning model was successfully developed for lung nodule classification on CT scans.
- The model demonstrated promising performance and maintained strong identification of malignant nodules.
- Grad-CAM improved interpretability by highlighting regions influencing model predictions.
- These findings support the potential of lightweight AI-assisted tools to aid lung nodule classification and assist radiologists in clinical practice.

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