

Chest X-Ray Disease Classification using ML

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ABSTRACT

This paper reviews recent advancements in deep learning-based medical image classification, emphasizing chest X-rays for COVID-19 and pneumonia detection. The objective is to analyze research trends and evaluate how evolving architectures enhance diagnostic performance. Ten key studies published between 2022 and 2025 were examined to identify a transition from conventional transfer learning models to hybrid and attention-driven networks. Early research focused on optimizing pre-trained architectures such as VGG-16 and ResNet50 through feature refinement and fine-tuning, whereas recent approaches incorporate conditional cascaded networks, attention capsule frameworks, and self-supervised learning to address challenges associated with limited medical datasets. The comparative analysis highlights that multi-stage and hybrid deep learning models consistently achieve superior accuracy and generalization. The review concludes that integrating multiple optimization and feature extraction strategies is critical for improving reliability and interpretability in automated radiographic diagnosis. These insights contribute to ongoing efforts toward developing efficient, data-adaptive AI systems for clinical applications.

Keywords: *Deep learning, Chest X-ray, COVID-19 detection, Pneumonia classification, Transfer learning, Hybrid networks, Attention mechanisms, Medical imaging.*

1. Introduction

Accurate and timely diagnosis of chest diseases, particularly pneumonia and COVID-19, remains a major challenge in modern healthcare. Chest X-rays remain among the most widely used diagnostic tools due to their accessibility, cost-effectiveness, and efficiency in clinical settings. However, manual interpretation of X-rays can be time-consuming and prone to human error, especially in regions with limited radiological expertise. In recent years, deep learning has emerged as a transformative approach for automating medical image analysis and enhancing diagnostic precision [1]. Early studies primarily focused on improving existing convolutional neural network (CNN) architectures through feature optimization and transfer learning. As research in this domain progressed, more sophisticated frameworks, such as attention-based and hybrid models, have been proposed to achieve greater robustness and adaptability [2, 3]. This paper provides a focused review of these developments, analyzing evolving trends in deep learning-based chest X-ray classification and highlighting promising directions for future research in automated disease detection.

2. Research Methodology

This study adopts a systematic review approach to analyze the evolution of deep learning models used for chest X-ray classification between 2022 and 2025. The methodology involves four key phases: selection of relevant research papers, extraction of model and dataset details, performance comparison, and synthesis of findings.

A total of ten peer-reviewed studies were selected from reputable journals and digital libraries based on relevance, publication year, and methodological significance. Each paper was examined for its architectural framework, dataset composition, evaluation metrics, and overall diagnostic performance. The selected works include a range of models such as VGG-16, ResNet50, DenseNet, CapsuleNet, and hybrid approaches integrating attention mechanisms, transfer learning, and self-supervised techniques [4].

Data from multiple benchmark datasets including NIH ChestX-ray14, Kaggle Pneumonia Detection, COVIDX, and Mendeley X-ray/CT were reviewed to ensure consistent comparison across studies. Accuracy, precision, recall, F1-score, and AUC were used as key evaluation metrics. This structured analysis enabled the identification of performance trends, innovations, and challenges in the progression from traditional CNNs to complex hybrid architectures. The methodology ensures replicability and provides a comprehensive framework for future comparative analyses in medical image classification.

3. Theory and Calculation

The theoretical foundation of this study is based on the principles of deep learning and convolutional neural networks (CNNs), which have become the cornerstone of modern medical image classification. CNNs operate by learning hierarchical feature representations from input images through convolutional and pooling operations. The convolution operation can be expressed mathematically as:

$$F(i, j) = \sum_m \sum_n I(i - m, j - n) K(m, n)$$

where I represents the input image, K is the convolution kernel, and $F(i, j)$ denotes the resulting feature map. This operation enables the extraction of local spatial patterns, which are crucial for identifying abnormalities in chest X-rays.

The activation function, typically the Rectified Linear Unit (ReLU), introduces non-linearity and can be defined as:

$$f(x) = \max(0, x)$$

This allows the network to model complex relationships in image data. The optimization process relies on minimizing a loss function, such as categorical cross-entropy, given by:

$$L = - \sum_i y_i \log(y_i)$$

where y_i is the true class label and $\hat{y}_i$ is the predicted probability.

In the context of this review, various studies have adapted these theoretical foundations with modifications—such as feature optimization [9], attention mechanisms [4], and transfer learning [5] to enhance accuracy and efficiency in detecting chest diseases. The comparative evaluation of these methods provides insights into how theoretical advancements are practically implemented in recent models.

4. Results and Discussion

The comparative review of ten studies published between 2022 and 2025 reveals significant advancements in deep learning-based chest X-ray disease classification. Early approaches utilizing pre-trained models such as VGG-16 and ResNet50 achieved strong performance through fine-tuning and feature optimization, reaching accuracies above 95% [8], [9]. As the field matured, hybrid and attention-based architectures demonstrated superior diagnostic precision and computational efficiency. For

instance, Makkapati and Rao’s attention capsule network [4] achieved 99.3% accuracy, while Shanthi and Mahalingam’s hybrid CapsuleNet–SENet model [10] reached 99% on large-scale datasets. Lightweight architectures such as EffiCOVID-Net [1] further proved that high accuracy can be maintained with reduced complexity, enabling practical deployment in limited-resource settings. Overall, a consistent trend was observed toward integrating attention mechanisms, self-supervised learning, and hybrid feature fusion to enhance model robustness and generalization. These developments mark a shift from conventional transfer learning to more adaptive, scalable frameworks capable of supporting real-time automated diagnosis in clinical environments.

Table 1. Comparison of Deep Learning Models for Chest X-Ray Classification

Study (Year)	Model / Technique	Dataset Used	No. of Images (%)	Accuracy (%)	Key Highlights
Kumar & Bhowmik (2025) [1]	EffiCOVID-Net (Multi-scale CNN)	COVID-19 Radiography, Curated CXR, DMix	21,000+	98.87 (3-class), 99.78 (2-class)	Lightweight and highly efficient architecture
Rajeshwari & Arunesh (2025) [2]	Deep CNN + InceptionV3 Ensemble	Kaggle Pneumonia Dataset	30,855	99.15	Ensemble learning improved pneumonia detection
Sharma et al. (2025) [3]	DenseNet-based CNN	NIH CXR, Kaggle	100,000	95.2	Multiclass lung disease classification
Makkapati & Rao (2024) [4]	Attention Bi-LSTM CapsuleNet	Kaggle COVID-Pneumonia CXR	6,432	99.3	High accuracy with low computational complexity
Rashed & Bahgat (2024) [5]	Conditional Cascaded Network (CCN)	Mendeley X-ray/CT, Kaggle	5,856–9,544	97.88	Transfer learning enhanced COVID-19 detection
Chehade et al. (2023) [6]	Radiomics + CycleGAN + XGBoost	ChestX-ray14 (NIH)	4,812	92.05	Image reconstruction boosted classification
Mondal (2023) [7]	Self-supervised BYOL + ResNet50	COVIDX, Kaggle	5,911 (train), 824 (test)	95.87	Effective on small datasets

Sharma & Guleria (2023) [8]	Improved VGG-16 + NN	Kaggle D1 & D2	5,856 & 6,432	92.15 / 95.4	Enhanced accuracy with modified CNN
Pramanik et al. (2022) [9]	ResNet50 + aAPSO + k-NN	Kermanny et al.	5,066	98.41	Feature optimization via PSO algorithm
Shanthi & Mahalingam (2025) [10]	CapsuleNet + SENet + Seagull Opt	COVIDX CXR-4	84,618	99.0	Hybrid model with superior robustness

5. Conclusions

This study reviewed recent progress in deep learning-based chest X-ray classification for detecting respiratory diseases such as COVID-19 and pneumonia. By analyzing ten key studies published between 2022 and 2025, the review identified a clear shift from conventional CNN architectures toward advanced hybrid and attention-driven networks. Early research optimized models like VGG-16 and ResNet50 using transfer learning and feature refinement, while later works introduced attention capsule networks, conditional cascaded networks, and self-supervised learning to achieve superior diagnostic accuracy and efficiency. These developments highlight how architectural innovation, rather than simple adaptation, has become central to improving medical image analysis. Despite notable gains, limitations persist due to restricted dataset diversity, interpretability challenges, and the need for clinical validation. Future work should emphasize explainable AI frameworks, multi-disease classification, and domain adaptation for real-world implementation. Overall, this review demonstrates that integrating deep learning with intelligent optimization strategies holds immense potential for creating faster, more accurate, and resource-efficient diagnostic systems capable of supporting healthcare delivery at scale.

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References

- [1]. Kumar, S., & Bhowmik, B. (2025). EffiCOVID-net: A highly efficient convolutional neural network for COVID-19 diagnosis using chest X-ray imaging. *Methods*.
- [2]. Rajeashwari, S., & Arunesh, K. (2024). Enhancing pneumonia diagnosis with ensemble-modified classifier and transfer learning in deep-CNN based classification of chest radiographs. *Biomedical Signal Processing and Control*, 93, 106130.
- [3]. Sharma, R., Venkatesh, K. A., Naikwade, I., Sharma, H., Sungheetha, A., & Ghatasala, G. P. (2025). Predicting Lung Diseases Using Machine Learning on X-ray Images. *Procedia Computer Science*, 259, 1432-1441..
- [4] Makkapati, S. S., & Rao, N. N. (2024). COVID-19 disease detection using attention based Bi-Directional capsule network model. *Biomedical Signal Processing and Control*, 96, 106636.

- [5] Rashed, A. E. E., & Bahgat, W. M. (2024). Conditional cascaded network (CCN) approach for diagnosis of COVID-19 in chest X-ray and CT images using transfer learning. *Biomedical Signal Processing and Control*, 87, 105563.
- [6] Chehade, A. H., Abdallah, N., Marion, J. M., Hatt, M., Oueidat, M., & Chauvet, P. (2025). Reconstruction-based approach for chest X-ray image segmentation and enhanced multi-label chest disease classification. *Artificial Intelligence in Medicine*, 103135.
- [7] Mondal, A. K. (2022). COVID-19 prognosis using limited chest X-ray images. *Applied Soft Computing*, 122, 108867.
- [8] Sharma, S., & Guleria, K. (2023). A deep learning based model for the detection of pneumonia from chest X-ray images using VGG-16 and neural networks. *Procedia Computer Science*, 218, 357-366.
- [9] Pramanik, R., Sarkar, S., & Sarkar, R. (2022). An adaptive and altruistic PSO-based deep feature selection method for Pneumonia detection from Chest X-rays. *Applied Soft Computing*, 128, 109464.
- [10] Shanthi, S., & Mahalingam, M. (2025). Advanced chest X-ray image classification for early detection and treatment monitoring of respiratory conditions. *Biomedical Signal Processing and Control*, 110, 107990.