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## **Heart Disease Prediction using Machine Learning**

#### Abdul Lathif, Abhishek Aravind Tawarkhed, Aryan Kumar, Deepak A

Department of Electronics and Communication Engineering, PES College of Engineering, Mandya, Karnataka, India

#### Shwetha S K

Assistant Professor, Department of Electronics and Communication Engineering, PES College of Engineering,

#### Mandya, Karnataka, India

**ABSTRACT**: This work presents the development of an automated system for ECG-based heart disease classification, leveraging Convolutional Neural Networks (CNNs) for accurate and efficient diagnosis. Heart disease remains a global concern, with early detection playing a critical role in improving patient outcomes. In this research, the EfficientNet-B0 CNN model is employed to classify ECG images into four distinct categories: Myocardial Infarction, History of MI, Abnormal Heartbeat, and Normal ECG. A structured dataset of labelled ECG images is used for training, ensuring robust generalization across diverse cardiac conditions.

The model undergoes fine-tuning using transfer learning, optimizing feature extraction from ECG patterns to enhance diagnostic reliability. A mobile and web-based ECG classification application is designed for user-friendly access, allowing individuals to upload ECG images and receive automated classification results. This approach provides an accessible tool for early detection and assists healthcare providers in making preliminary assessments efficiently. The study demonstrates that EfficientNet-B0, combined with structured preprocessing techniques and deep learning enhancements, achieves high accuracy in classifying cardiac abnormalities. The implementation of this system shows promise in bridging gaps in medical access, offering real-time AI-driven ECG analysis for both clinicians and individuals. While not a substitute for professional diagnosis, this technology enhances preliminary screening, helping users make informed decisions and seek timely medical intervention.

KEYWORDS: ECG Classification, Deep Learning, Web App, CNN, EfficientNet-B0, Heart Disease Prediction

#### I. INTRODUCTION

Heart disease continues to be one of the most pressing global health concerns, affecting individuals across all demographics and regions. According to the World Health Organization (WHO), cardiovascular diseases account for a significant portion of global mortality, with early diagnosis playing a crucial role in improving patient outcomes. Despite medical advancements, access to specialized cardiology expertise remains limited in many rural and underserved areas, leading to delayed detection and intervention.

The rise of artificial intelligence (AI) and machine learning (ML) has opened new avenues for the automated analysis of ECG patterns, offering promising solutions for early heart disease detection. Most individuals lack comprehensive knowledge of ECG abnormalities, leading to undiagnosed conditions and severe complications. Recognizing cardiac irregularities at an early stage is vital to preventing long-term health risks and ensuring timely medical intervention.

This study introduces a CNN-based EfficientNet-B0 deep learning model, designed to classify ECG images into four categories: Myocardial Infarction, History of MI, Abnormal Heartbeat, and Normal ECG. By leveraging transfer learning, this system enhances diagnostic accuracy while maintaining computational efficiency. The developed ECG classification application allows users to upload ECG images for automated classification, aiding both healthcare providers and individuals in identifying potential heart conditions.

If implemented, this AI-driven system can bridge gaps in medical accessibility, particularly in areas where specialized cardiac screenings are scarce. By providing real-time ECG analysis, the model ensures rapid and precise classification, supporting early detection and clinical decision-making. While not a replacement for professional diagnosis, the system serves as an assistive tool to improve patient awareness and facilitate timely medical consultation.





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#### **II. RELATED WORK**

The electrocardiogram (ECG) serves as a critical diagnostic tool for detecting cardiac conditions, providing valuable insights into heart activity through waveform analysis. Heart disease is a leading cause of mortality worldwide, and researchers have explored various machine learning and deep learning approaches to improve ECG classification and early disease detection [1]. Traditional rule-based methods for ECG analysis require expert cardiologists for accurate interpretation, making automated classification systems an essential advancement in healthcare diagnostics.

Many studies have proposed deep learning-based ECG classification models, integrating CNN architectures to enhance feature extraction from ECG signals. In this regard, T. Shanthi et al. [2] explored CNN-based models for classifying ECG patterns into normal and abnormal categories, demonstrating an accuracy improvement using transfer learning techniques. Similarly, Jessica S. Velasco et al. [3] examined the influence of pretrained models like ResNet in refining ECG classification performance across various datasets. Bandyopadhyay et al. [4] introduced a hybrid model combining deep learning (DL) with machine learning (ML), optimizing ECG feature extraction through fused architectures.

EfficientNet has emerged as a powerful CNN architecture for medical imaging, known for its optimized depth scaling and feature extraction efficiency. Studies by Kethana et al. [5] utilized EfficientNet for ECG analysis, achieving high accuracy in multi-class cardiac abnormality detection. Furthermore, Kshirsagar et al. [6] compared CNN-based ECG classification models with traditional algorithms like SVM and Random Forest, concluding that deep learning outperformed conventional methods. Hao Zhang and Liang Ma [7] provided an extensive evaluation of different ECG datasets, assessing model generalizability and real-world applicability in cardiac diagnostics.

Building upon this body of work, this study leverages CNN-based EfficientNet-B0 for ECG classification, ensuring an efficient, high-accuracy approach to multi-class heart disease identification. The developed ECG classification application bridges gaps in accessibility and real-time diagnosis, serving as an assistive tool for healthcare providers and individuals seeking early cardiac condition screening.

#### III. SYSTEM ARCHITECTURE FOR ECG-BASED HEART DISEASE PREDICTION

The architecture of the CNN-based ECG classification system is structured into three primary modules: Dataset Collection, Model Training, and Mobile Application Development. This modular design ensures efficient preprocessing, robust feature extraction, and real-time classification using EfficientNet-B0.

1. Dataset Collection

The foundation of the system is a structured dataset containing labelled ECG images, ensuring reliable training and validation.

- Sources: Public repositories or simulated ECG recordings representing multiple heart conditions.

- Classes: The dataset consists of ECG images categorized into Myocardial Infarction, History of MI, Abnormal Heartbeat, and Normal ECG.

- Objective: To train a CNN model for automated ECG classification, supporting early detection and clinical diagnostics.

#### 2. Model Training

The deep learning model is trained using EfficientNet-B0, leveraging CNN-based feature extraction for heart disease classification.

- Preprocessing Steps:
- ECG images are resized to 224×224 pixels, ensuring compatibility with EfficientNet-B0's architecture.
- Normalization is applied based on ImageNet's mean and standard deviation to enhance contrast.
- Images are converted into PyTorch tensors for deep learning processing.
- Dataset Splitting:
- 80% for training, 10% for validation, and 10% for testing, ensuring structured learning.

- Training Process:





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- EfficientNet-B0 is fine-tuned using transfer learning, modifying its classifier layer for four-class ECG classification.
- Cross Entropy Loss is used to optimize classification performance.
- Adam optimizer ensures stable convergence, assisted by a learning rate scheduler (StepLR).
- Output: A trained CNN-based ECG classifier, capable of detecting cardiac abnormalities with high accuracy.



Fig.1. Block Diagram

3. Mobile Application Development (ECG Diagnosis App)

The trained model is integrated into a web/mobile application, allowing users to upload ECG images for real-time classification.

- User Interface:
- Users can upload ECG images from mobile or desktop interfaces for automated analysis.
- The app provides instant classification results, supporting early diagnosis efforts.
- Deployment Considerations:
- Ensuring real-time inference with minimal latency for smooth user experience.
- Handling diverse ECG image formats, ensuring generalization across patient data.
- Scalability for wider clinical adoption, supporting healthcare professionals.
- Advantages:
- Facilitates preliminary heart disease screening using AI-powered ECG classification.

- Improves accessibility, assisting individuals in remote areas with limited cardiology expertise.

#### **IV. RESULTS**

Every image in the validation dataset has been processed iteratively to compute validation accuracy. This procedure continues until the training and validation datasets pass through the model's layers for a set number of epochs. At the end of each epoch, the model evaluates the validation dataset to assess the accuracy of its weights and optimize performance.

The CNN-based EfficientNet-B0 model has been trained in two phases to maximize predictive accuracy:

#### Phase 1: Initial Training of Custom Layers

During this phase, only the newly added dense layers of the classification head are trained, while the pretrained layers of EfficientNet-B0 remain frozen. This approach stabilizes feature extraction from ECG images, ensuring that the convolutional layers focus on learned spatial patterns.

- Training Loss and Accuracy for Phase 1 are depicted in Figure 4, illustrating the learning progression of the newly added layers.

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Phase 2: Fine-Tuning the Entire Model

Once the classification head learns to assign relevant features, the entire EfficientNet-B0 model is fine-tuned, allowing deeper feature extraction.

- A reduced learning rate prevents over-aggressive feature updates, ensuring smooth convergence.

- Training loss and accuracy metrics for Phase 2 are presented in Figure 5, showing further accuracy improvements after fine-tuning.

Skipping Phase 1 and immediately training the full CNN could result in random high-loss predictions, leading to overfitting. The structured two-phase approach mitigates this risk and ensures stable feature learning.

Model Performance and Optimization

- The dataset contained an imbalance, requiring up sampling techniques to balance class distributions.

- The model was trained for 15 epochs with a batch size of 32, ensuring sufficient iterations for feature learning.

- The final trained model achieved 97.8% accuracy on the test dataset, demonstrating its effectiveness in ECG classification.

- To enable mobile deployment, the model was quantized, reducing its size from 105MB to 26.6MB.

- Despite quantization, the accuracy remained at 94%, which is within an acceptable range for real-world application.

Validation	ion Report:				
Variation	ncpoi		neee11	£1	oursent
	precision		recall	TI-Score	support
	0	1.0000	1.0000	1.0000	57
	1	1.0000	1.0000	1.0000	36
	2	1.0000	0.9231	0.9600	39
	3	0.9474	1.0000	0.9730	54
accura	cv.			A 9839	186
accura	-y			0.0000	100
macro av	vg	0.9868	0.9808	0.9832	186
weighted av	√g	0.9847	0.9839	0.9838	186

Fig.2. Validation Report







ECG Diagnosis Application & User Interface

A key aspect of the developed ECG classification application is its user-friendly interface, allowing users to upload ECG images for automatic classification.

- Upon selecting an ECG image, the prediction button initiates classification, returning the detected heart condition.

- Confidence scores are displayed beneath the interactive controls, informing users about the model's certainty in its predictions.

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- Clicking the "Condition Details" button directs users to an additional interface, providing medical insights into each classified heart condition.



Fig.5. User Interface of web-application

#### **V. CONCLUSION**

Combining advanced deep learning techniques and optimizing image preprocessing enhances classification accuracy in ECG-based heart disease prediction. This study implemented EfficientNet-B0, leveraging transfer learning and structured preprocessing to accurately classify ECG images. By focusing on four key cardiac conditions, the model ensures effective screening and supports early intervention.

Heart disease remains a leading global health concern, yet many individuals lack immediate access to specialized cardiac diagnostics. AI-powered ECG classification systems provide an automated, efficient, and accessible solution, mitigating delays in early detection. The proposed CNN-based model demonstrates high accuracy, emphasizing its potential for real-world applications.

Furthermore, improvements in dataset diversity, augmentation strategies, and interpretability techniques can refine diagnostic precision. As AI continues to advance, integrating these solutions into healthcare workflows and mobile applications can revolutionize cardiac screening. Given the non-invasive nature of ECG analysis, this system enables real-time clinical assessments, ensuring informed medical decision-making with minimal effort.

#### VI. FUTURE SCOPE

Going forward, researchers can explore ECG classification algorithms across diverse datasets to further enhance the accuracy and reliability of heart disease detection. Future research could focus on refining the current EfficientNet-B0based ECG classification model, potentially establishing proxy standards for preliminary cardiac diagnostics. By improving automated screening efficiency, this approach may significantly reduce the time and costs associated with diagnosis and treatment.

This work holds great potential for supporting the healthcare sector, particularly in assisting cardiologists in early detection of myocardial infarction and arrhythmia risks. By enabling faster identification of cardiac abnormalities, healthcare providers can make more accurate and timely decisions that could improve patient outcomes.

Future studies could explore Big Data integration, applying ECG classification at scale to handle large volumes of medical imaging data efficiently. Additionally, researchers may improve model efficacy by leveraging cloud-based AI frameworks such as TensorFlow on Spark or AWS-based architectures to enable seamless real-time predictions.

Further advancements could also focus on enhancing model interpretability, implementing techniques like Grad-CAM visualization to provide deeper insights into the model's decision-making process. Another promising direction is self-learning AI, allowing the model to autonomously adapt, refine, and retrieve knowledge from prior classifications to improve diagnostic precision over time. This would significantly reduce the effort required for model optimization, making AI-based ECG screening more efficient and scalable.





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