Detection and Classification of Cardiovascular Diseases in ECG images by using Deep Learning

Akshay Ramesh Navale[1], Aditya Ravindra Nikam[2], Tushar Kailas Kusmude[3], Tejas Anil Lahase[4]
Guide Name: Prof. R. N. Muneshwar[5]

Amrutvahini College Of Engineering, Sangamner

Abstract:
Cardiovascular diseases (CVDs) continue to be the primary cause of death globally, placing immense pressure on healthcare systems to provide accurate and timely diagnoses for effective intervention. Electrocardiograms (ECGs) are widely used to detect and diagnose heart conditions; however, analyzing ECG images alone may not fully capture a patient's overall cardiovascular health or the complex risk factors influencing CVD. Traditional ECG-based methods often lack integration with other critical health data, which can result in limited diagnostic precision and missed insights.

To address these limitations, this project proposes a hybrid deep learning model that combines ECG image analysis with patient medical history to create a more comprehensive diagnostic tool for cardiovascular disease classification. This model utilizes convolutional neural network (CNN) architectures, such as Alex Net and Squeeze Net, for ECG feature extraction, allowing the system to identify subtle visual patterns and irregularities in heart activity. The extracted ECG features are then integrated with structured medical data—such as age, blood pressure, cholesterol levels, and medical history—processed through a fully connected neural network (FCNN). By merging visual and non-visual health data, the hybrid model aims to improve classification accuracy and provide a deeper understanding of CVD risk factors.

This integrated approach enables a more holistic and data-rich diagnostic system, capable of delivering enhanced prediction reliability and supporting early intervention strategies. With its ability to analyze diverse health data, the model holds the potential to revolutionize cardiovascular diagnostics, ultimately aiding in personalized treatment and improved patient outcomes.

Keywords: **Cardiovascular disease (CVD), Electrocardiogram (ECG), Deep learning, Hybrid model, CNN (Convolutional Neural Network) SqueezeNet, Fully connected neural network (FCNN), Medical history integration, Disease classification, Health data fusion**

INTRODUCTION

Cardiovascular diseases (CVDs) remain the leading cause of death worldwide, making accurate and timely diagnosis crucial for effective treatment and management. Electrocardiograms (ECGs) are widely used for detecting heart conditions, but analyzing ECG images alone may not fully capture a patient's overall health status. This project proposes a hybrid deep learning model that combines ECG image analysis with patients' medical history to enhance cardiovascular disease classification. By utilizing CNN architectures, such as Alex Net and Squeeze Net, for ECG feature extraction, and a fully connected neural network (FCNN) for structured medical data, this integrated approach aims to improve the accuracy and reliability of disease prediction. The model's ability to analyze both visual and non-visual data offers a more comprehensive diagnostic tool, potentially revolutionizing how cardiovascular conditions are detected and treated

LITERATURE SURVEY

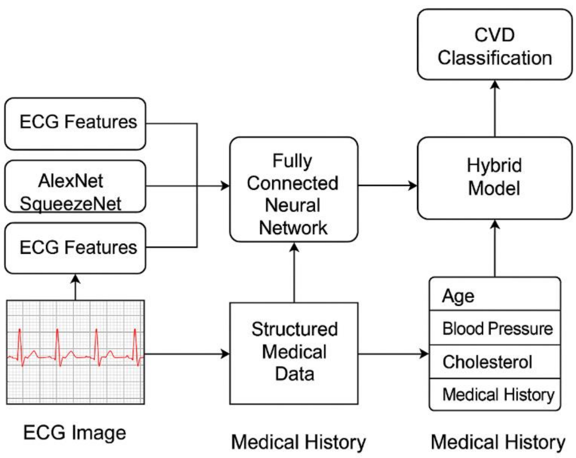
1. S. Banerjee, M. Ray, "Automated Cardiovascular Disease Prediction Using Machine Learning Algorithms," International Journal of Medical Informatics, vol. 132, pp. 103957, 2019. This study evaluates various machine learning algorithms, including decision trees, support vector machines, and random forests, for predicting cardiovascular disease based on patient medical records. The research shows that machine learning can offer high accuracy in identifying individuals at risk for CVD, emphasizing the value of incorporating structured data into predictive models for proactive healthcare interventions.

2. Y. Li, R. Zhang, "Deep Learning Approaches for ECG Signal Analysis and Cardiovascular Diagnosis," IEEE Transactions on Biomedical Engineering, vol. 67, no. 4, pp. 1221-1232, 2020.
In this paper, the authors focus on the application of deep learning techniques, particularly CNNs and recurrent neural networks (RNNs), for analyzing ECG signals. By applying these models to large datasets of ECG recordings, the study demonstrates the capability of deep learning to accurately detect arrhythmias and other cardiovascular conditions, highlighting the efficiency of neural networks in processing time-series health data.

3. P. Gupta, S. Kumar, "Integration of Wearable Devices for Real-Time Cardiovascular Monitoring," Journal of Healthcare Engineering, vol. 2021, pp. 1-12, 2021. This research investigates the use of wearable IoT devices for continuous cardiovascular monitoring, focusing on parameters such as heart rate and blood pressure. The study discusses how integrating data from these devices with cloud computing and real-time analytics allows for early detection of abnormal cardiovascular patterns, making it an essential tool for patients with chronic heart conditions.

4. A. Williams, J. Thompson, "Hybrid Models Combining ECG Imaging and Patient History for Cardiovascular Disease Classification," Journal of Medical Imaging and Health Informatics, vol. 11, no. 3, pp. 540-548, 2022.
This study presents a hybrid approach that merges ECG image analysis with structured medical data, using CNNs for ECG features and fully connected neural networks for medical history data. The findings suggest that this combined model provides a more comprehensive and accurate prediction of cardiovascular disease, as it considers both visual signals from ECGs and historical health data, offering a more holistic diagnostic method.

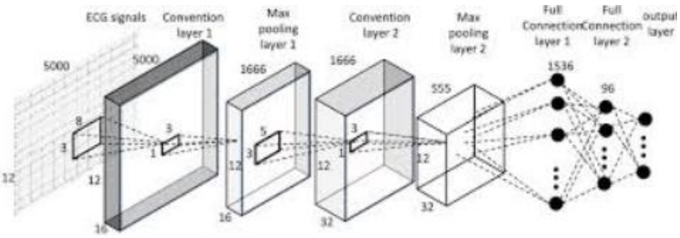
Architecture diagram



The architecture diagram illustrates a hybrid deep learning model designed for the classification of cardiovascular diseases (CVDs) by integrating both ECG image analysis and patient medical history. The system begins by processing ECG images, which serve as a visual representation of heart activity. These images are passed through convolutional neural network (CNN) models, specifically AlexNet and SqueezeNet, which are responsible for extracting meaningful visual features such as waveform patterns and irregularities. In parallel, structured medical data—including age, blood pressure, cholesterol levels, and broader medical history—is collected and encoded to provide a clinical context of the patient's cardiovascular health.

The extracted ECG features and the structured medical data are then fed into a fully connected neural network (FCNN), which learns complex relationships between the visual and non-visual inputs. This fusion of data is crucial for forming a comprehensive understanding of the patient's condition. The outputs from the FCNN are integrated into a hybrid model that synthesizes all available information to perform CVD classification. By combining diverse data sources, this architecture enhances diagnostic accuracy, supports early intervention strategies, and paves the way for more personalized treatment plans, ultimately aiming to improve patient outcomes and reduce the burden on healthcare systems.

CNN ARCHITECTURE



This CNN architecture processes ECG images to extract meaningful features for cardiovascular disease classification. It starts with an input layer (224×224×3), followed by convolutional layers that detect visual patterns in the ECG using filters and ReLU activation. Max pooling layers reduce the spatial size and highlight dominant features. After multiple conv-pool stages, the output is flattened and passed through fully connected layers, which learn complex patterns and generate a feature vector. This vector is then used in the hybrid model alongside patient medical data for accurate CVD prediction.

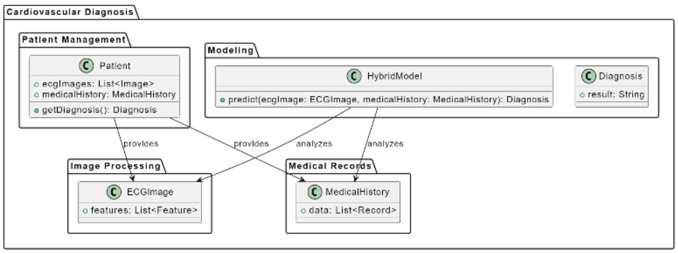
OBJECTIVE

1. Develop a hybrid deep learning model that combines ECG image analysis with structured medical data for cardiovascular disease (CVD) classification.
2. Utilize CNN architectures (e.g., AlexNet, SqueezeNet) to extract visual features from ECG images, capturing subtle patterns and irregularities in heart activity.
3. Integrate structured patient data (e.g., age, blood pressure, cholesterol levels, and medical history) using a fully connected neural network (FCNN).
4. Enhance diagnostic accuracy by merging visual and non-visual data sources, offering a more comprehensive analysis of cardiovascular health.
5. Enable early detection and personalized treatment by supporting deeper insights into individual CVD risk factors.
6. Reduce diagnostic limitations found in traditional ECG-only analysis methods by incorporating a wider range of health information.
7. Improve clinical decision-making through a data-rich, holistic diagnostic tool that supports healthcare professionals in managing cardiovascular conditions.

PROBLEM DEFINATIONS

Develop a hybrid deep learning model that accurately classifies a wide range of cardiovascular diseases by analyzing ECG images and integrating patients' previous medical history. The model will utilize CNN-based architectures (such as Alex Net a Squeeze Net) for ECG image analysis and an FCNN to process structured medical data. The goal is to enhance disease prediction by combining visual and non-visual patient information

PACKAGE DIAGRAM



FUCTIONAL REQUIREMENTS

1. Allow patients and doctors to create accounts and securely log in to the system.

2. Enable multi-factor authentication for enhanced security.

3. Provide an interface for patients to enter and update personal and medical history, such as age, blood pressure, cholesterol levels, etc.

4. Store patient medical history data and link it to ECG records.

5. Allow patients to upload ECG data or enable real-time ECG data collection from integrated wearable devices.

6. Analyze ECG data using deep learning models to detect anomalies or signs of cardiovascular disease.

7. Integrate ECG analysis results with patient medical history to provide a comprehensive cardiovascular risk assessment.

NON FUCTIONAL REQUIREMENTS

1. Performance and Scalability: The system should handle high volumes of data, particularly for real-time ECG monitoring and analysis.

2. Security and Privacy: Encrypt all sensitive health data in storage and during transmission to ensure HIPAA/GDPR compliance.

3. Reliability and Availability: Ensure a high level of system uptime, especially for real-time monitoring features.

4. Usability: Design a user-friendly interface for patients and doctors, ensuring ease of navigation and data entry.

CONCLUSION

The proposed system for cardiovascular disease detection and diagnosis using a hybrid deep learning model offers an innovative approach to enhancing patient care. By integrating ECG image analysis with a patient's medical history, the model provides a more comprehensive and accurate assessment of cardiovascular health than traditional ECG analysis alone. This system has the potential to revolutionize early diagnosis, allowing for timely interventions that are crucial for managing cardiovascular diseases effectively. Additionally, the real-time monitoring and alert features empower both patients and healthcare providers, improving patient engagement and enabling personalized care.

Through this project, we address critical challenges in cardiovascular healthcare, such as early detection, patient monitoring, and tailored treatment plans. With further development and validation, the system can be a valuable tool for reducing the mortality rate associated with cardiovascular diseases, making healthcare more accessible, efficient, and precise. The integration of advanced technologies such as deep learning and IoT in healthcare represents a step toward a smarter, more responsive healthcare ecosystem that can better meet the needs of those at risk for cardiovascular conditions.

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