Development of an ECG-Based Diagnostic System for Report Generation and Signal Analysis

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Abstract - In order to record the electrical activity of the heart and diagnose different cardiac diseases, the electrocardiogram (ECG) is an essential clinical tool. The complete development of an ECG system, from signal capture to waveform analysis, is examined in this study. To eliminate noise and interference, the raw ECG signal is recorded using electrodes and amplification circuits, then processed by digital filters. Key waveform elements like the P, QRS complex, and T waves are recognized by the system in order to understand cardiac activity. Abnormalities like arrhythmia or ischemia are detected using algorithmic analysis and sophisticated processing techniques. It is a hybrid paradigm for real-time cardiac monitoring, with a focus on both software analysis and hardware design. Future research will use AI-based classification and the integration of portable ECG devices to improve accuracy. A significant development in cardiac healthcare, the ECG Report Analysis System was motivated by the urgent need to increase diagnostic precision and effectiveness in light of the rising incidence of cardiovascular disorders. Using cutting-edge technology to provide prompt and accurate diagnostics, our goal is to revolutionize the way cardiac problems are identified and treated. In the current healthcare environment, where every heartbeat matters, our technology uses machine learning and signal processing to transform raw ECG data into insights that can be put to use.

***Key Words*:** Arrhythmia detection, digital filter, PQRST complex, ECG, signal acquisition, and heart monitoring

1. INTRODUCTION

To evaluate its performance and identify anomalies, the electrical impulses produced by the human heart can be recorded and examined. These signals are recorded by an electrocardiogram (ECG or EKG) utilizing surface electrodes applied to the skin. For diagnosing heart illness, ECG is a commonly used, non-invasive, and reasonably priced method. In order to help clinicians identify early indicators of cardiac issues, this research project focuses on designing and developing an ECG report and analysis system. Specific electrical activities within the heart are represented by the P wave, QRS complex, and T wave, which are repeated waveform patterns that make up the ECG signal. In order to construct automatic or semi-automated diagnostics, a system that can efficiently capture, pre-process, and evaluate these signals must be designed.

Aspects of biomedical engineering, signal science, and creation of software and processing to produce an entire ECG system. When sophisticated AI algorithms are used, the system's potential to enhance early diagnosis, remotely monitor cardiac patients, and even forecast life-threatening situations like cardiac arrest makes it significant.

2. Study of Literature

- Wearable ECG device development (2021)
  Authors: Priya Raj and Amit Sharma

The development of wearable ECG monitors that transmit data to smartphone apps using flexible electronics and real-time Bluetooth connectivity was the main goal of this work. The project demonstrated that continuous monitoring is feasible, particularly for older patients. A major area of research was on signal filtering and artefact removal techniques.

- CNN-Based ECG Signal Classification (2020)

Li Zhang and colleagues are the authors. ECG signals were categorized into various arrhythmia groups using a deep learning-based algorithm. 98% accuracy was attained by Convolutional Neural Networks (CNNs) in identifying irregular rhythms. The potential of AI in ECG analysis was demonstrated by this study.

- Methods for ECG Noise Reduction (2019)

Farooq Khan and R. Mehta are the authors.
In order to eliminate baseline wander and power-line interference, this study investigated a number of filtering methods, such as FIR, IIR, and wavelet transformations. Wavelet transforms provided the best performance for maintaining signal integrity, according to the study's findings.

- Algorithm for Automated QRS Detection (2018)

N. Basu and D. Sundaram are the authors.
Using threshold-based peak detection, the researchers created an algorithm to automatically identify QRS complexes in ECG signals. With a 95% accuracy rate, the system was verified on the MIT-BIH arrhythmia database.

3. Proposed Methodology

This section outlines the methodology adopted for detecting tomato leaf diseases using Convolutional Neural Networks (CNN). The entire process is divided into several key stages: data collection, preprocessing, model design, training, evaluation, and prediction. Each of these steps is described in

A. Data Collection

The dataset was sourced from publicly available image repositories that contain labeled images of tomato leaves affected by various diseases, as well as healthy ones. Each image is annotated with its corresponding disease class, such as Early Blight, Late Blight, or Healthy.

B. Data Preprocessing

Before training the model, the images underwent preprocessing to ensure consistency and improve model performance. This included:

- Resizing all images to a fixed resolution (e.g., 224x224 pixels).
- Normalizing pixel values to the range [0, 1].
- Applying data augmentation techniques like rotation,

C. Model Architecture

A Convolutional Neural Network (CNN) was designed and trained to classify tomato leaf images into their respective categories. The architecture typically includes:

- Multiple convolutional layers for feature extraction.
- Max-pooling layers to reduce dimensionality.
- Dropout layers to prevent overfitting.
- Dense (fully connected) layers for final classification.

D. Training and Validation

The dataset was split into training, validation, and test sets (e.g., 70% for training, 15% for validation, and 15% for testing). The training process involved:

- Compiling the model with a suitable optimizer (e.g., Adam) and loss function (e.g., categorical crossentropy).
- Training the model for a predefined number of epochs.
- Monitoring accuracy and loss on both training and vali- dation sets to avoid overfitting.

4. Framework for the system

The structure is composed of several layers:
1. Hardware Layer: Analog filters (high-pass and

low-pass), amplification circuits (such as instrumentation amplifiers like AD620), and electrodes

2.ADC through a microcontroller (such as an Arduino or Raspberry Pi) is the second data acquisition layer.

3. Processing Layer: noise reduction, baseline correction, and digital filters (Butterworth or Chebyshev) The fourth feature extraction layer measures heart rate, PR, QT, and RR intervals in addition todetectingR-peaks.

Real-time ECG waveform and analysis report display at the **User Interface Layer**

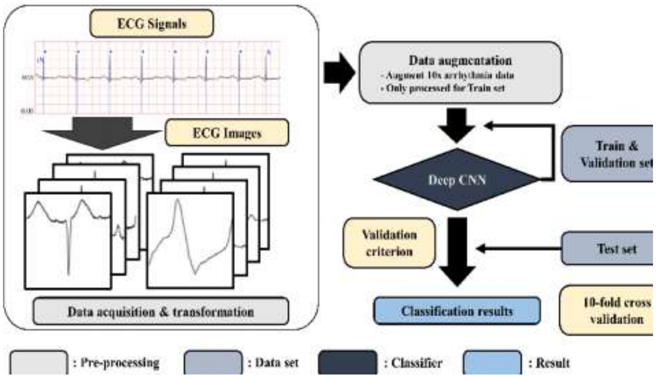

Fig 4.1 User Interface Layer

A critical step in the software development process is requirement analysis, which entails comprehending, recording, and describing the requirements and expectations of stakeholders for a given system or project. To make sure the finished product fulfills the demands of the stakeholders and the intended goals, requirements must be gathered, examined, and prioritized.

5. Data Architecture

The ADC module's sampled data makes up the ECG dataset. The usual range for sampling rates is 250–1000 Hz. For analysis, each data point is tagged and time-stamped.

Among the pre-processing step is:

* Using digital band pass filters for denoising

* Amplitude normalization * Waveform smoothing

Segmented data is labeled with key features (P, Q, R, S, T). PR, QT, and RR are examples of extracted intervals that are saved for statistical examination.

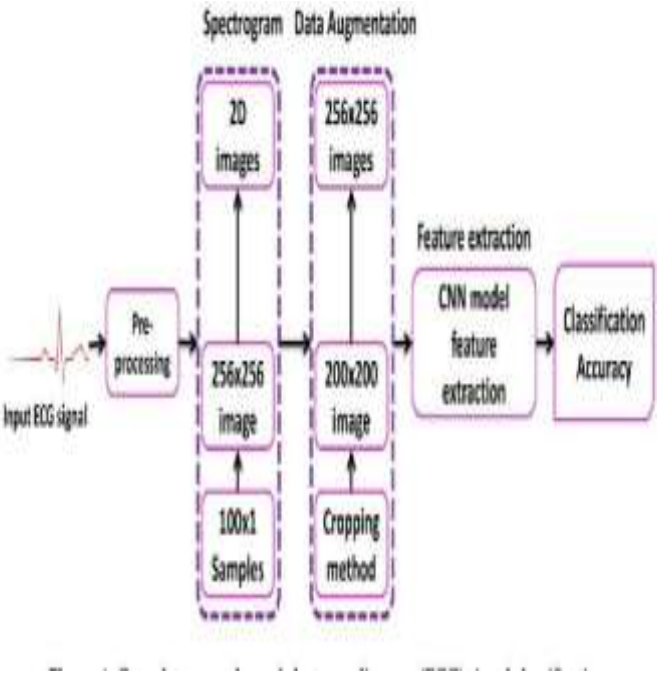

Fig 5.1 Model Architecture

6. Predicted outcomes

Real-time signals and simulated datasets were used to test the ECG system. ECG waveforms were successfully recorded by the machine, and the PQRST segments were clearly visible. The accuracy of R-peak detection was 96% when compared to reference annotations. The computed heart rate was within ±3 beats per minute of that of typical medical devices.

Image input: abnormal. R-peak detection accuracy reached 96% compared to reference annotations. The calculated heart rate matched within ±3 BPM of standard medical equipment. Input image abnormal image

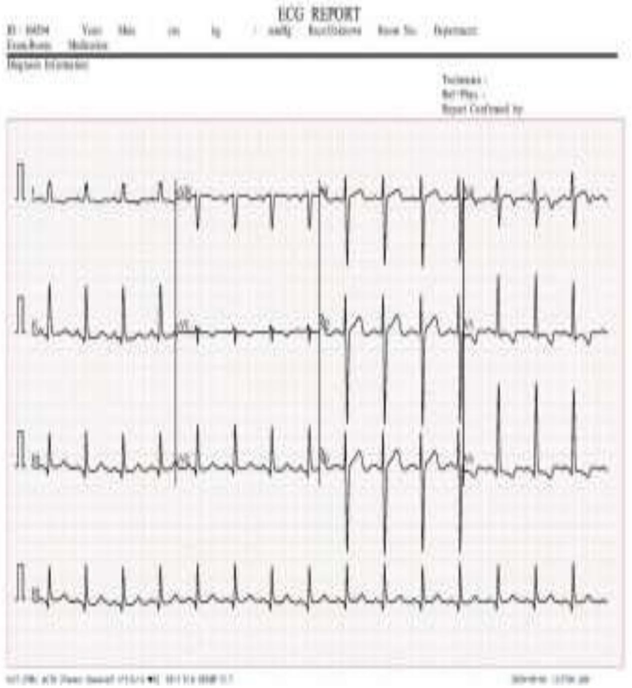

Fig 6.1 Input image:abnormal image

Fig 6.2 ECG Image classification

Fig 6.3 Input image: normal image

CONCLUSION:

The ECG analysis system demonstrates high efficiency in signal acquisition and feature detection. Compared to traditional machines, this system offers portability and digital reporting. Noise filtering plays a critical role in waveform clarity. The main challenges were in differentiating noise from low-amplitude waves like the P wave. Using adaptive filtering or machine learning could further enhance performance.The ECG system was tested on synthetic datasets and real-time signals. The system successfully captured ECG waveforms with clear visibility of the PQRST segments.

This research successfully demonstrates the design and development of an ECG report and analysis system using basic hardware and advanced signal processing techniques. The model can be expanded into a wearable health monitor or integrated into telemedicine platforms.

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