

Digital Signal Processing of ECG Signals for the Diagnosis of Heart Diseases

Ms. Poonam Bapu Kamble

E&TC Dept.

(JSPM's ICOER)

Abstract - Cardiovascular diseases (CVDs) are one of the leading causes of mortality worldwide, creating a growing demand for accurate and real-time cardiac monitoring systems. Electrocardiogram (ECG) signals are widely used to monitor the electrical activity of the heart and assist in the diagnosis of various cardiac abnormalities such as arrhythmias, myocardial infarction, and ischemic heart diseases. However, ECG signals are often affected by different types of noise including baseline wander, power line interference, motion artifacts, and muscle noise, which can reduce diagnostic accuracy. This project proposes an automated heart disease diagnosis system based on Digital Signal Processing (DSP) techniques for effective ECG signal analysis and interpretation. The system acquires real-time ECG data and applies preprocessing techniques such as digital filtering to remove noise and improve signal quality. The Pan-Tompkins algorithm is utilized for accurate detection of the QRS complex and extraction of important ECG parameters including PR interval, QT interval, ST segment, and R-R interval.

The proposed system further integrates machine learning techniques for automatic classification and detection of cardiac abnormalities. By analyzing extracted ECG features, the system can identify arrhythmias and other heart-related disorders with improved accuracy and reliability. The processed data and diagnostic results are displayed in real time, enabling continuous patient monitoring and assisting healthcare professionals in early diagnosis. In addition, the system supports IoT-based remote healthcare monitoring, allowing doctors to access patient information remotely for timely medical intervention. The developed solution is cost-effective, portable, and suitable for real-time applications, making it beneficial for hospitals, clinics, and home-based healthcare systems. Experimental analysis demonstrates that the combination of DSP techniques and intelligent classification methods significantly enhances ECG signal interpretation and reduces diagnostic errors, thereby improving overall patient care and treatment outcomes.

Key Words: ECG, DSP, Heart Disease Detection, QRS Complex, Arrhythmia, Pan-Tompkins Algorithm, Machine Learning, Biomedical Signal Processing, IOT Healthcare, Real-Time Monitoring.

1. INTRODUCTION

The Electrocardiogram (ECG) is one of the most important non-invasive diagnostic tools used to monitor and evaluate the electrical activity of the human heart. ECG signals provide valuable information regarding heart rhythm, heart rate, and various cardiac abnormalities, making them essential in the diagnosis of cardiovascular diseases. However, manual interpretation of ECG signals

by medical professionals can be subjective, time-consuming, and susceptible to human error, especially when the signals are contaminated by different types of noise such as baseline wander, muscle artifacts, motion artifacts, and power line interference. These unwanted disturbances can significantly affect the accuracy of diagnosis and may lead to incorrect interpretation of cardiac conditions. Therefore, the application of Digital Signal Processing (DSP) techniques has become increasingly important in biomedical engineering for enhancing ECG signal quality and enabling reliable automated diagnosis.

This project presents an embedded heart disease diagnostic system based on advanced Digital Signal Processing techniques for efficient ECG signal analysis. The proposed system acquires ECG signals in real time and applies preprocessing methods such as digital filtering to eliminate noise and improve signal clarity. Important features from the ECG waveform, including the QRS complex, PR interval, QT interval, ST segment, and R-R interval, are extracted using algorithms such as the Pan-Tompkins method. Both time-domain and frequency-domain analyses are performed to identify significant cardiac patterns and abnormalities. The processed data is analyzed using machine learning-based classification techniques integrated with embedded platforms such as ESP32 or Raspberry Pi to detect conditions including bradycardia, tachycardia, arrhythmia, and myocardial infarction. The system is capable of generating automated alerts and real-time monitoring outputs, which assist healthcare professionals in early diagnosis and timely treatment. Additionally, the proposed solution is portable, cost-effective, and suitable for remote healthcare applications through IoT integration, thereby reducing diagnostic effort and improving overall patient care and monitoring efficiency.

2. Body of Paper

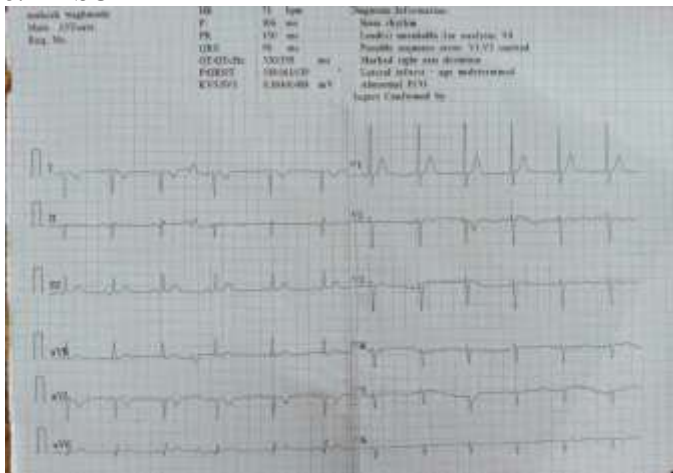
The body of the paper consists of numbered sections that present the main findings. These sections should be organized to best present the material.

It is often important to refer back (or forward) to specific sections. Such references are made by indicating the section number, for example, "In Sec. 2 we showed..." or "Section 2.1 contained a description...." If the word Section, Reference, Equation, or Figure starts a sentence, it is spelled out. When occurring in the middle of a sentence, these words are abbreviated Sec., Ref., Eq., and Fig.

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specially developed for biomedical and wearable healthcare applications. The module consists of an instrumentation amplifier, operational amplifiers, and filter circuits that help in amplifying and conditioning weak ECG signals obtained from the human body. The AD8232 module effectively removes noise and motion artifacts to provide accurate ECG waveform output. In this project, the sensor is used to acquire real-time ECG signals for Digital Signal Processing and heart disease diagnosis. It can be easily interfaced with microcontrollers such as Raspberry Pi, Arduino, and ESP32 for real-time cardiac monitoring applications.

3. RESULT



4. CONCLUSIONS

The proposed system for the Digital Signal Processing of ECG signals offers a highly reliable and automated solution for the diagnosis of heart diseases. By effectively implementing digital filters and feature extraction algorithms on an embedded platform, the system successfully cleans raw ECG data and identifies critical cardiac abnormalities in real-time. The integration of IoT capabilities allows for continuous remote patient monitoring, significantly reducing the burden on healthcare facilities and minimizing the risk of delayed treatment. While severe motion artifacts from patient movement remain a challenge requiring advanced adaptive filtering, the system demonstrates immense potential for modern telehealth. Future enhancements could include the deployment of deep learning models (such as CNNs) directly onto edge devices for even higher classification accuracy across a broader spectrum of cardiovascular diseases.

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