RESEARCH ARTICLE

Smart Digital Stethoscope Using Artificial Intelligence, Machine Learning, and IoT

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Abstract

There is an increase in heart diseases at a very high rate in today's world, and therefore early detection becomes a necessity in the treatment of such cases. In this paper, we present a digital stethoscope with AI and ML that records heart sounds automatically. Phonocardiogram (PCG) signals are recorded by the system, and the recorded signals are then processed using filtering, normalization, and peak detection to obtain features including heart sounds S1 and S2. The extracted features are fed into the classification algorithm, which in this case is the Random Forest Classifier, and they are classified as either abnormal or normal heart conditions. IoT is implemented in the system to ensure storage of data. Experimental tests carried out have shown that the system can detect abnormalities such as irregular heart rates and murmurs.

Keywords: heart sound analysis, digital stethoscope, machine learning, signal processing, IoT, PCG.

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1 Introduction

Cardiac diseases remain a leading cause of mortality around the globe, and cardiac auscultation has historically served as the primary clinical tool for their early detection [1]. Early diagnosis is essential to reduce deaths and improve treatment results, motivating the development of automated phonocardiogram signal processing approaches for reliable heart sound classification [2]. Historically, physicians have employed a stethoscope to detect heart sounds and identify abnormalities. Unfortunately, this procedure relies heavily on the experience of the doctor and can be significantly influenced by ambient noise and observation time constraints [3, 4].

In an effort to address the challenges above, this article introduces a smart digital stethoscope system designed to record and analyze heart sounds with the aid of AI and ML algorithms. The device captures heart sounds in digital form and analyzes them to generate valuable insights.

The primary aim of this study is to create a cost-effective tool that facilitates early detection of heart abnormalities, particularly in rural and underserved communities with limited medical facilities.

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2 Related Work

Several studies have examined the analysis of heart sounds through signal processing and machine learning approaches. Logistic Regression together with HSMMs (Hidden Semi-Markov Models) have been proposed to be used for heart sound segmentation [3, 4]; however, their efficiency depends greatly on the level of noise. The broader landscape of digital signal processing techniques for phonocardiography, including filtering, segmentation, and feature extraction, has been comprehensively reviewed in the literature [5].

Open datasets of heart sounds allow training machine learning models for classification purposes [6]. SVM (Support Vector Machine) and ANN (Artificial Neural Network) algorithms are most commonly employed for detection of anomalies in heart sounds [7, 8].

Furthermore, recent studies have demonstrated applications of deep learning methods to achieve better results in classification [9, 10], including both conference-validated ensemble approaches and preliminary deep learning investigations available as preprints. Nevertheless, the majority of existing systems do not provide real-time analysis or Internet of Things connectivity capabilities. The presented research will help overcome these limitations by integrating all three approaches into one system.

3 Methodology

The proposed system comprises four primary modules: heart sound acquisition, signal processing, machine learning classification, and report generation via IoT integration.

3.1 Heart Sound Acquisition

Heart sounds are collected through a digital stethoscope or a microphone and digitized into signals referred to as phonocardiogram (PCG).

3.2 Signal Processing

Signal processing involves eliminating noise from the acquired signals by implementing band-pass filtering [11], followed by envelope-based methods to isolate the characteristic heart sound components [12]. The signals are normalized, and methods like envelope detection and peak detection are applied to isolate significant features like S1 and S2 heart sounds.

3.3 Feature Extraction and Classification

Critical features such as heart rate, rhythm regularity, and signal energy are extracted from the processed signals [13]. The extracted features are inputted into the Random Forest classifier algorithm to determine whether the heart condition is normal or abnormal.

3.4 IoT Integration and Report Generation

The classification result is presented in an understandable format and can be stored and transmitted remotely using IoT integration techniques.

4 Experiments

The system was evaluated using both pre-recorded heart sound samples from publicly available datasets and real-time recordings collected from volunteer participants under informed consent.

During analysis, the system evaluates parameters such as heart rate, rhythm regularity, detection of S1 and S2 sounds, and identification of heart murmurs. The system analyzes the input audio data and displays whether the heart condition is normal or not. The results are also presented together with the waveforms for better understanding.

4.1 Results

Figure 1 displays the login screen of the Smart Digital Stethoscope where registered users input their details to access the dashboard.

Figure 1. User Interface of the Smart Digital Stethoscope system showing the login screen.

Figure 2 displays the user registration screen where new users register to use the system. As shown in Figure 2, the system provides a clean interface for user authentication.

Figure 3 displays the dashboard screen that enables users to navigate the various system features including dataset analysis, uploading of heart sounds, and creation of reports. The dashboard shown in provides easy navigation to all system features.

Figure 2. User Login and Registration Page.

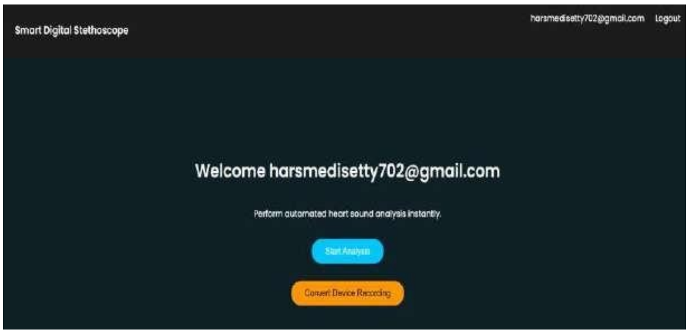


Figure 3. System Dashboard.

Figure 4 displays the interface from where the user can choose the dataset of the PCGs for heart sound analysis.

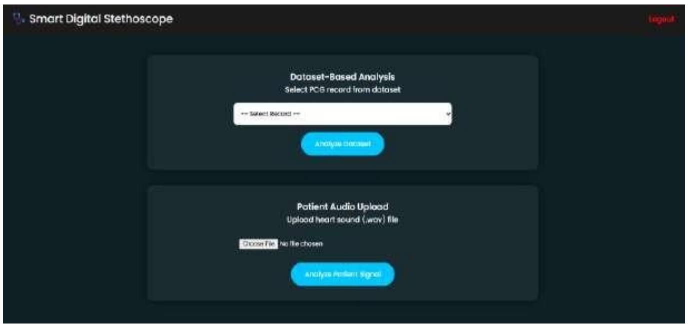


Figure 4. System Dashboard for Dataset Analysis and Heart Sound Upload.

Figure 5 displays the page where users can upload heart sounds converted into WAV files.

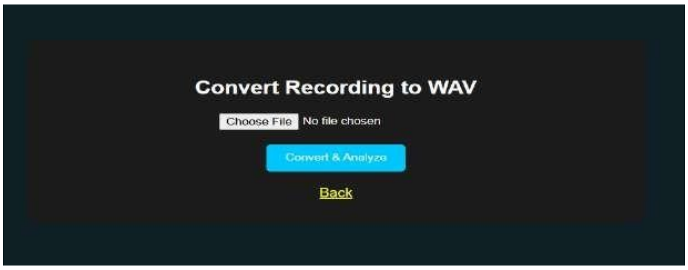
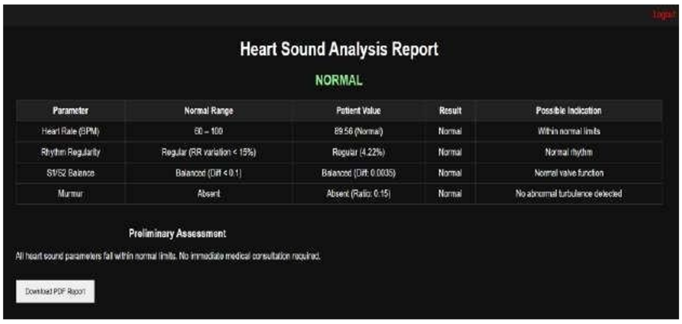
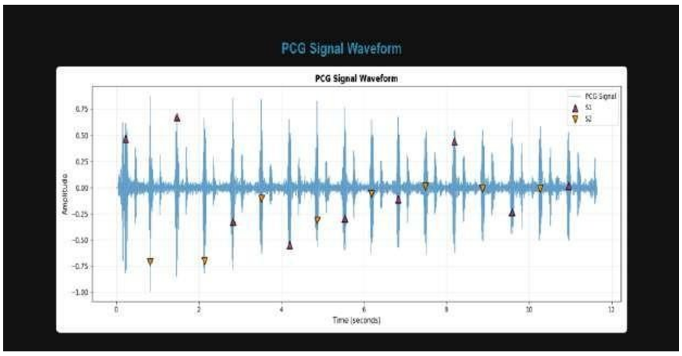


Figure 5. Heart Sound Upload Interface for WAV file submission and preliminary signal preview.

The complete analysis results are shown in Figure 6,



(a)



(b)

Figure 6. Phonocardiogram signal processing and derived diagnostic parameters. (a) Summary of heart rate, rhythm regularity, S1/S2 balance, and murmur status. (b) Corresponding PCG waveform with detected S1 (red) and S2 (blue) peaks.

displaying the comprehensive heart sound analysis including the PCG signal waveform with detected S1 and S2 peaks. The system workflow is illustrated through Figures 1- 6, demonstrating the complete user journey from login to heart sound analysis and report generation.

5 Conclusion

A smart digital stethoscope system using Artificial Intelligence and Machine Learning algorithms to detect early heart disease symptoms has been proposed in this paper. This system is able to process the heart sounds and classify whether it is a healthy heart or not. The incorporation of IoT has enabled remote data collection and easier transfer of medical information. The system is affordable and convenient to operate in rural areas. Deep learning models could be used to improve the accuracy in future research works.

Data Availability Statement

Data will be made available on request.

Funding

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Conflicts of Interest

The authors declare no conflicts of interest.

AI Use Statement

The authors declare that no generative AI was used in the preparation of this manuscript.

Ethical Approval and Consent to Participate

Real-time heart sound recordings were collected from volunteer participants under informed consent. As this constitutes minimal-risk research involving non-invasive acoustic recording only, formal institutional ethics review was waived in accordance with institutional guidelines.

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